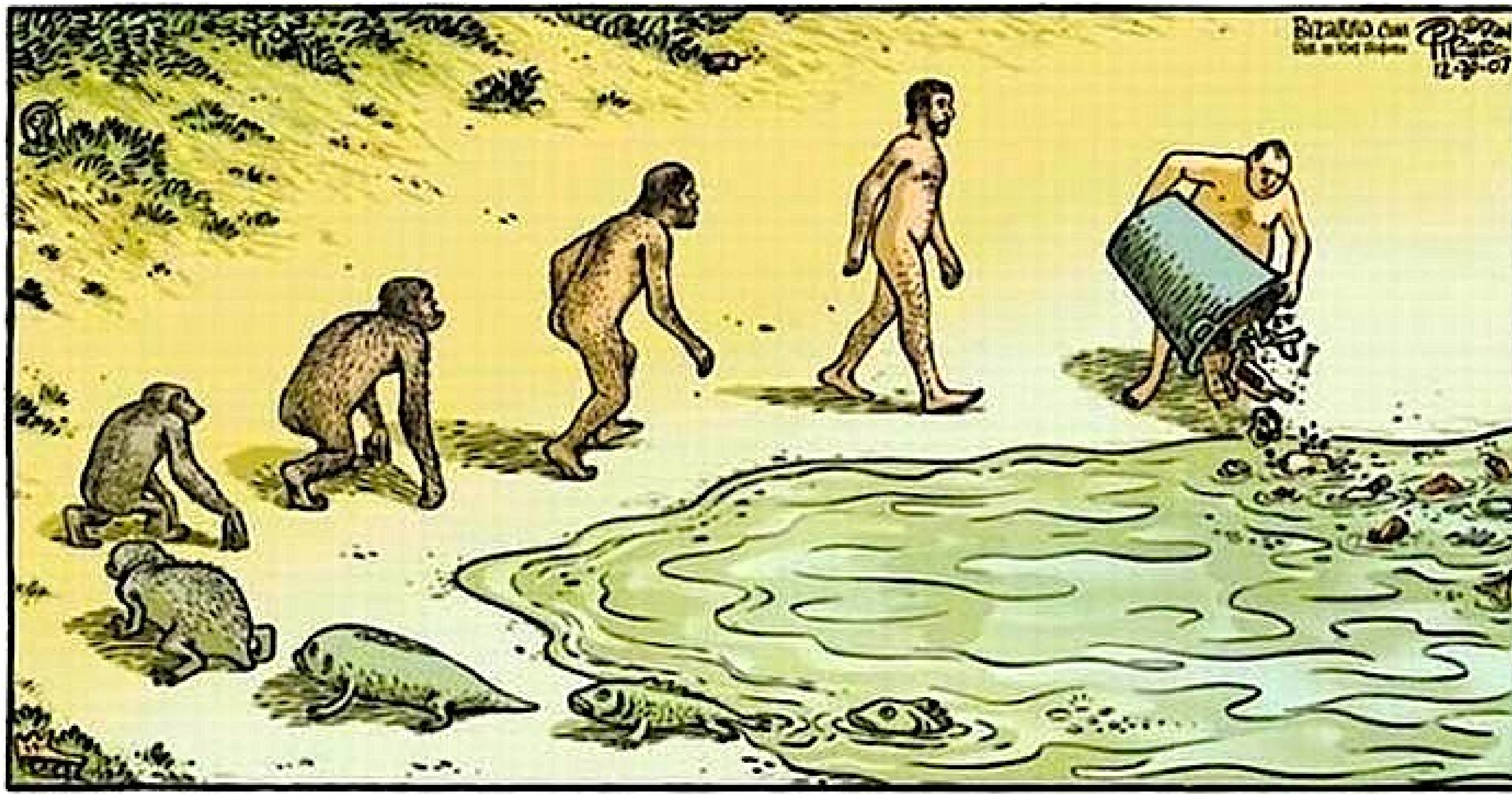
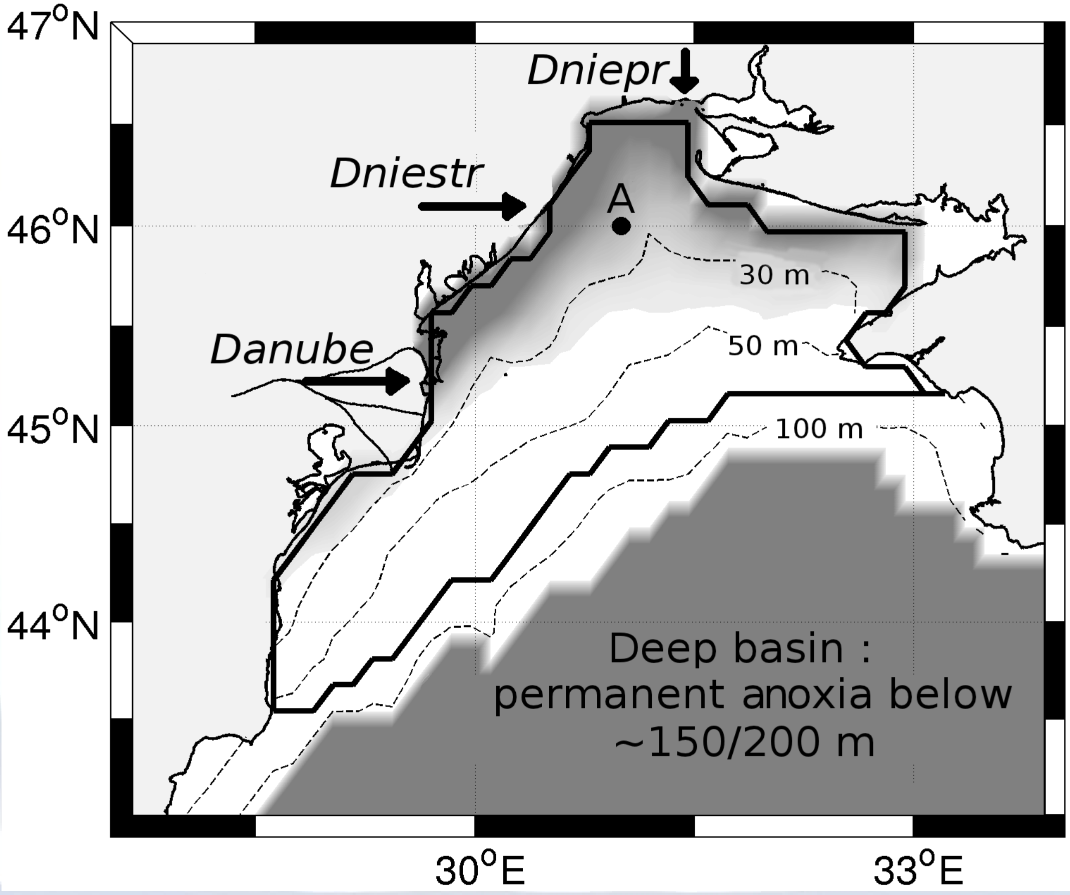


<u>Arthur Capet</u>, Jean-Marie Beckers, Marilaure Grégoire

Seasonal **hypoxia** in the Black Sea north-western Shelf.

Is there any recovery after eutrophication ?



PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

GHER
GeoHydrodynamics and Environment Research

Université de Liège

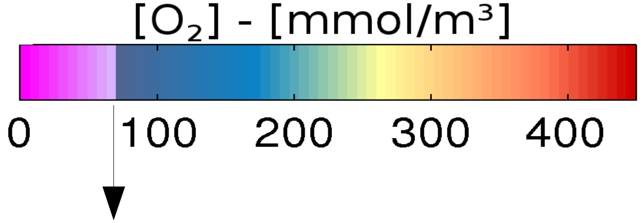
MARE
INTERFACULTARY CENTER FOR MARINE RESEARCH - LIEGE UNIVERSITY

SESAME
Southern European Seas: Assessing and Modelling Ecosystem changes

FNRS

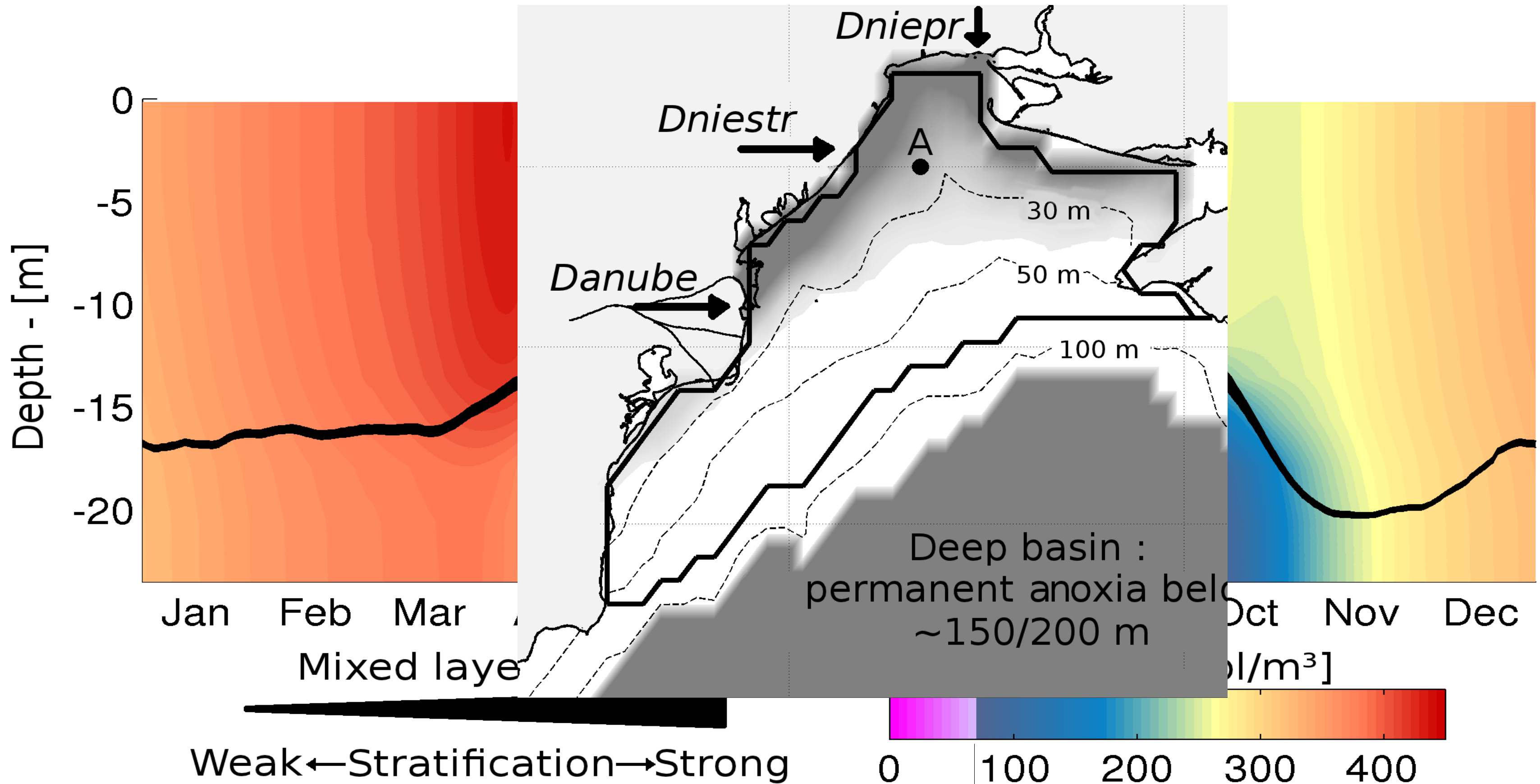
Seasonal Hypoxia in the Black Sea

Seasonal Hypoxia



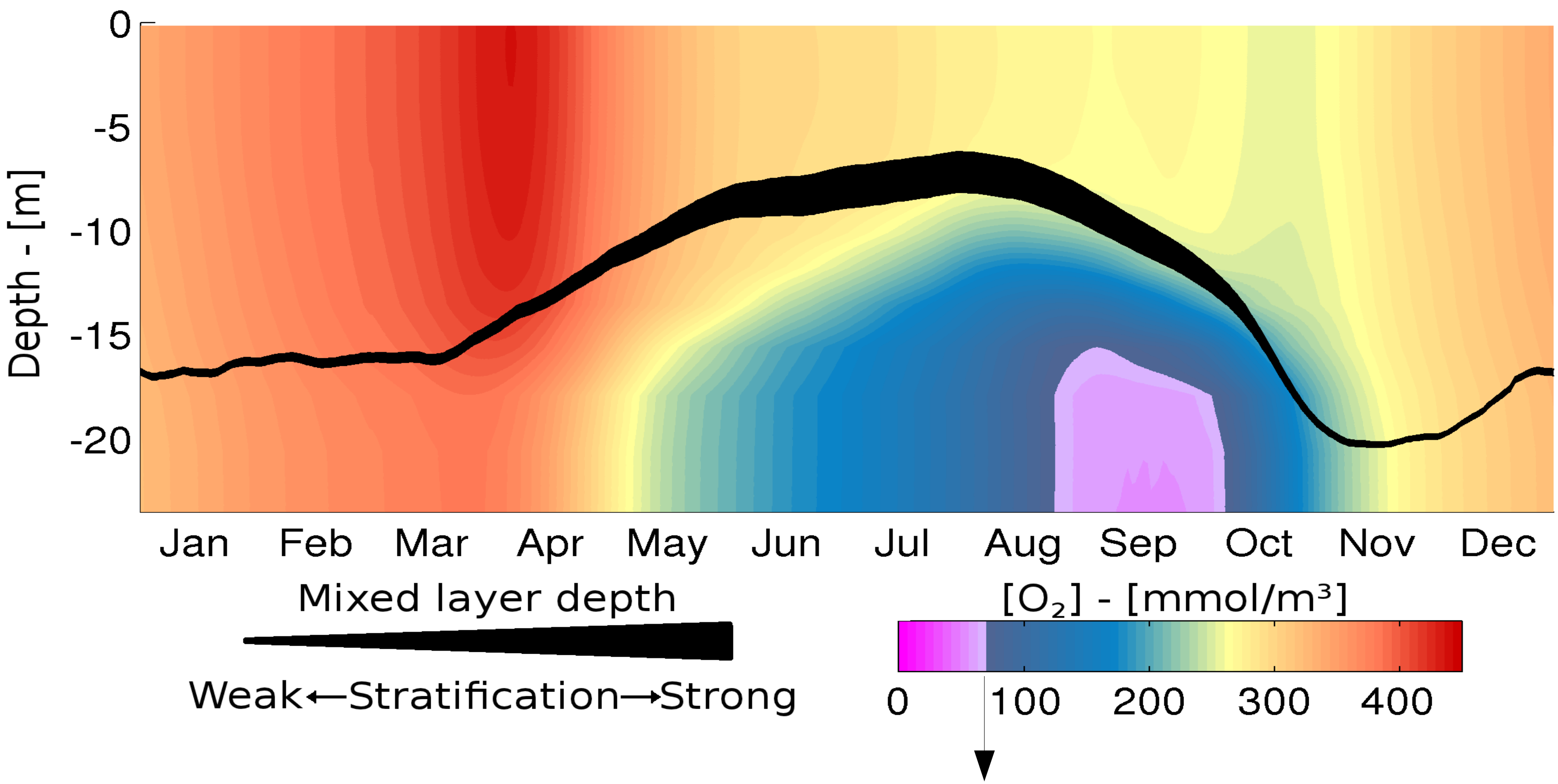
Hypoxic thresold : [O_2] < **62 mmol/m³ (2 mg/l)**

Seasonal Hypoxia



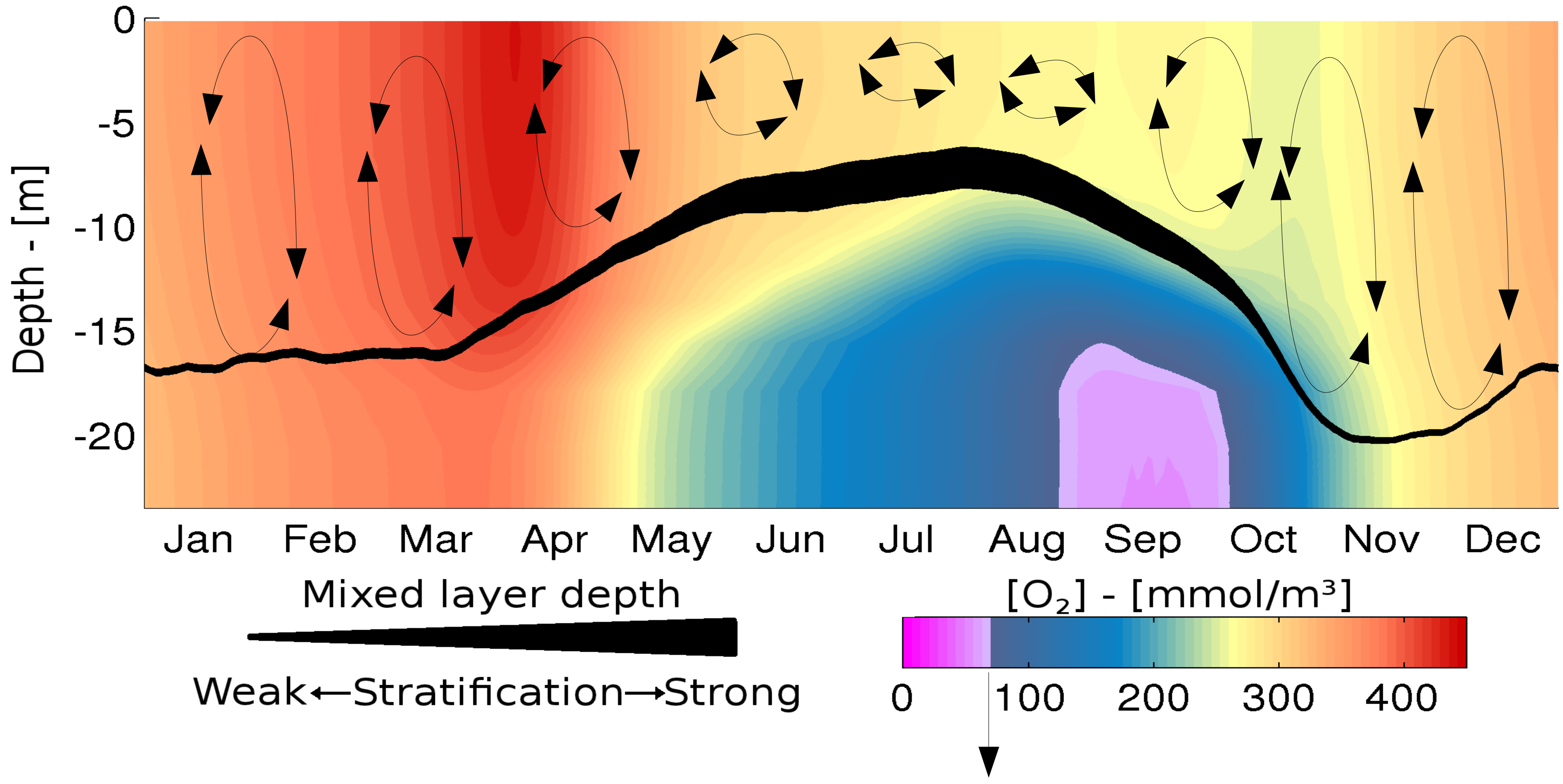
Hypoxic thresold : $[O_2]$ < **62 mmol/m³ (2 mg/l)**

Seasonal Hypoxia



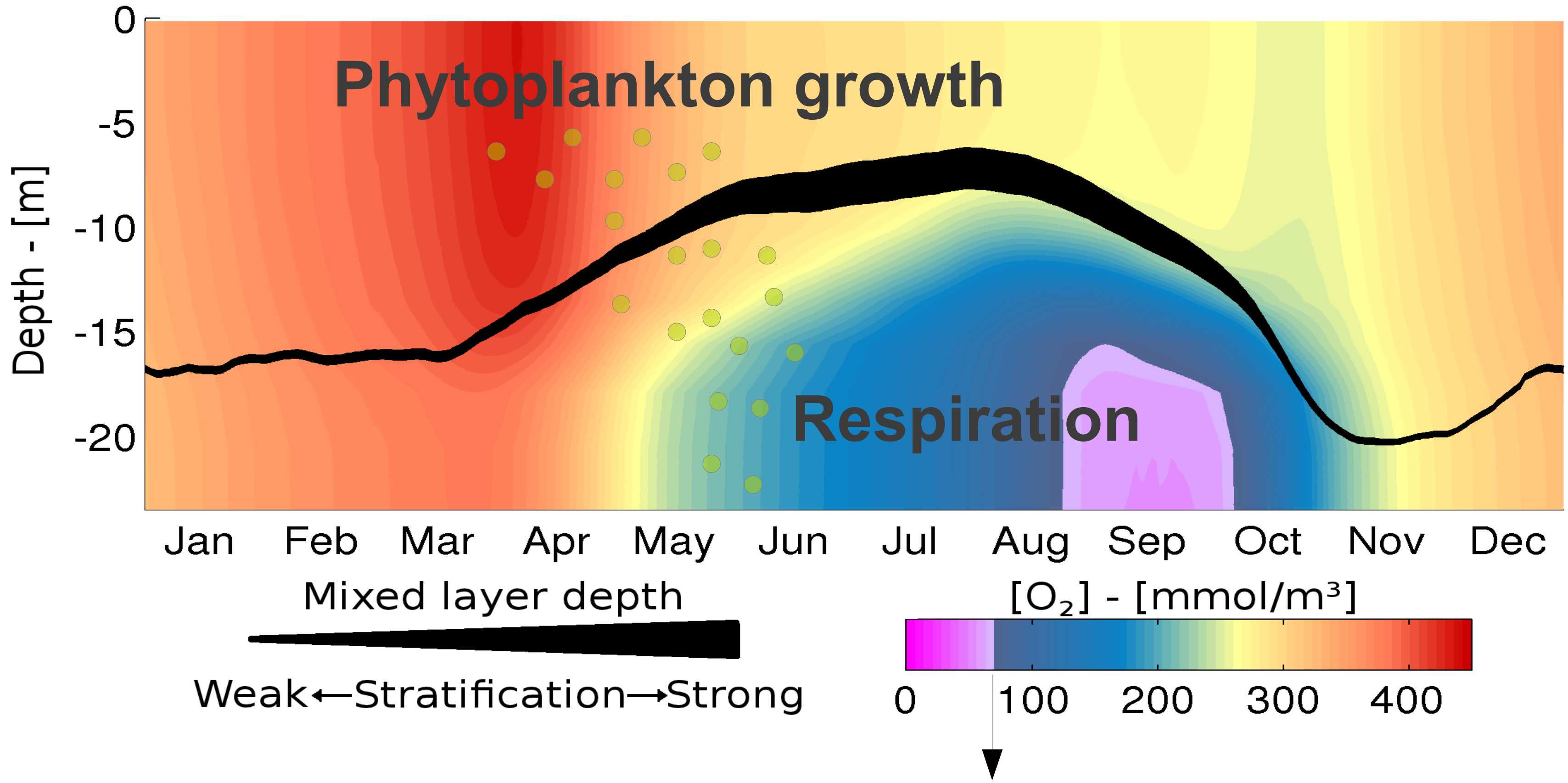
Hypoxic thresold : $[O_2]$ < **62 mmol/m³ (2 mg/l)**

Seasonal Hypoxia



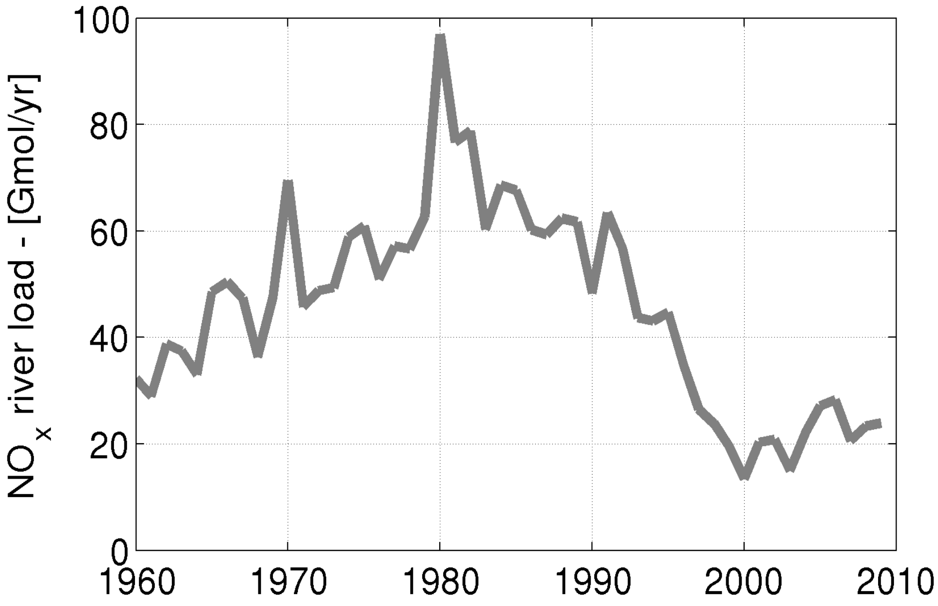
Hypoxic thresold : $[O_2]$ < **62 mmol/m³ (2 mg/l)**

Seasonal Hypoxia



Hypoxic thresold : $[O_2]$ < **62 mmol/m³ (2 mg/l)**

Seasonal Hypoxia in the BS-NWS



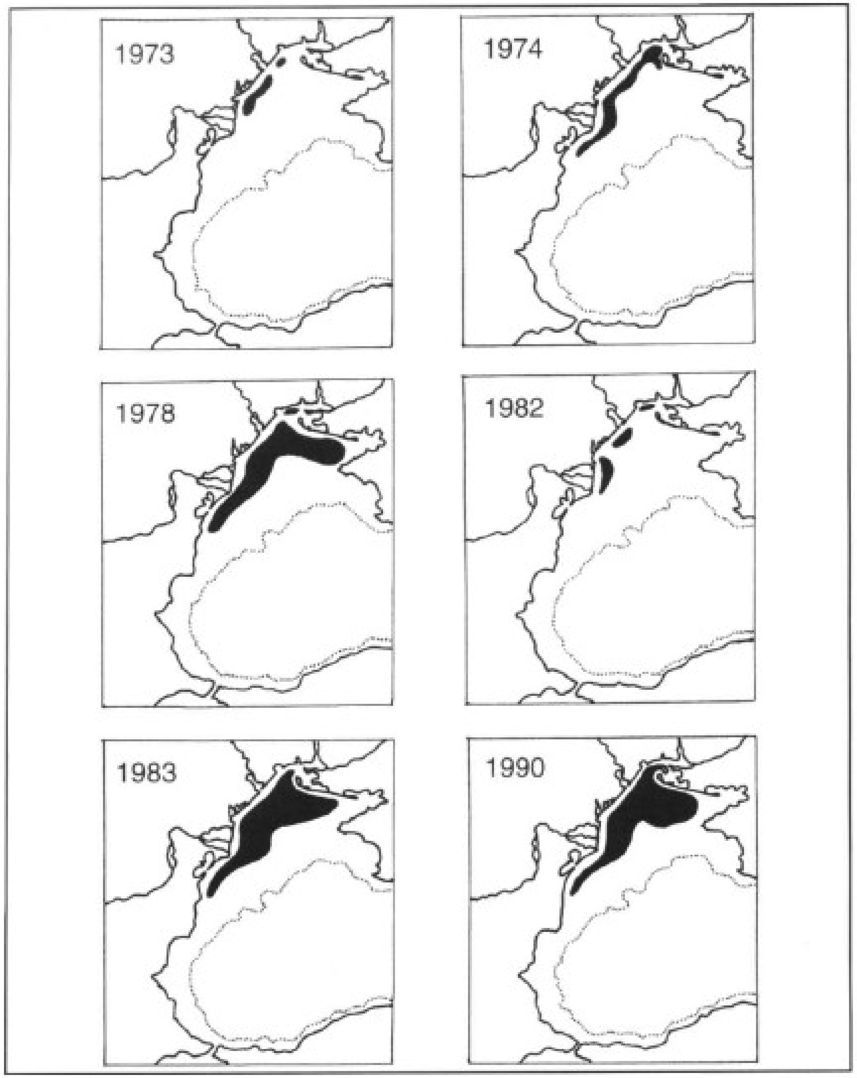
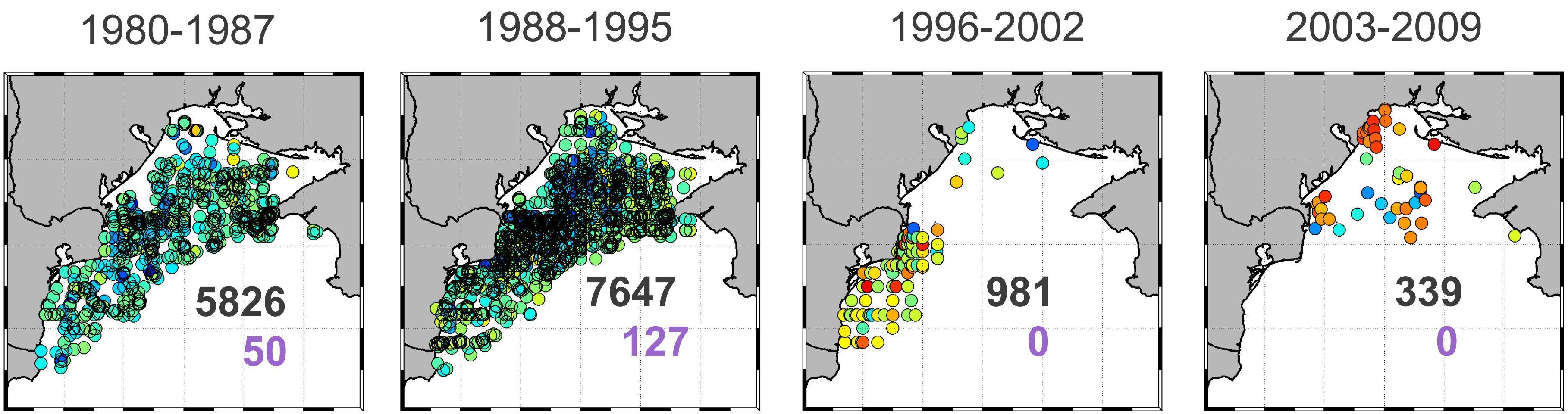


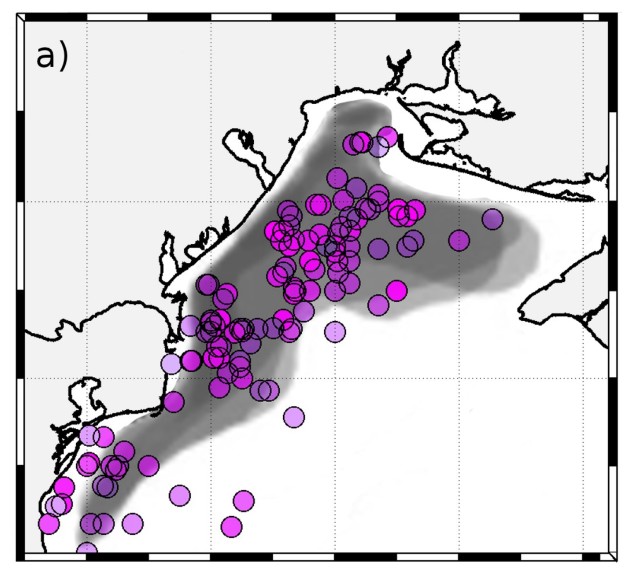
Fig 15. Expansion of seasonal hypoxic and anoxic zones on the north-western shelf (from Zaitsev, 1992(a)).

Recovery ?



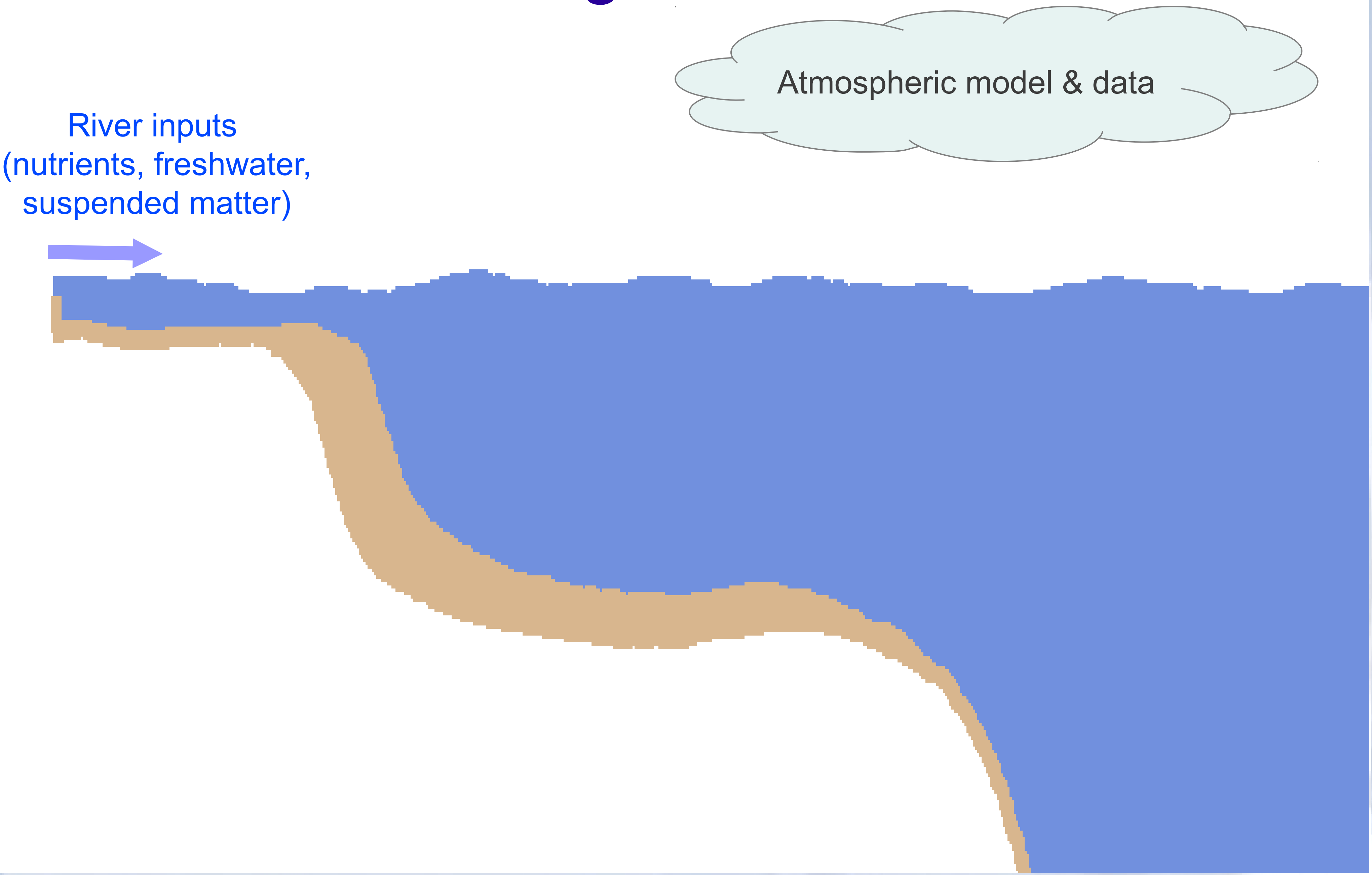
Oxygen records
(World ocean atlas, Seadatanet, Black Sea Comission data)

Hypoxic records
(<62 mmol O/m³)

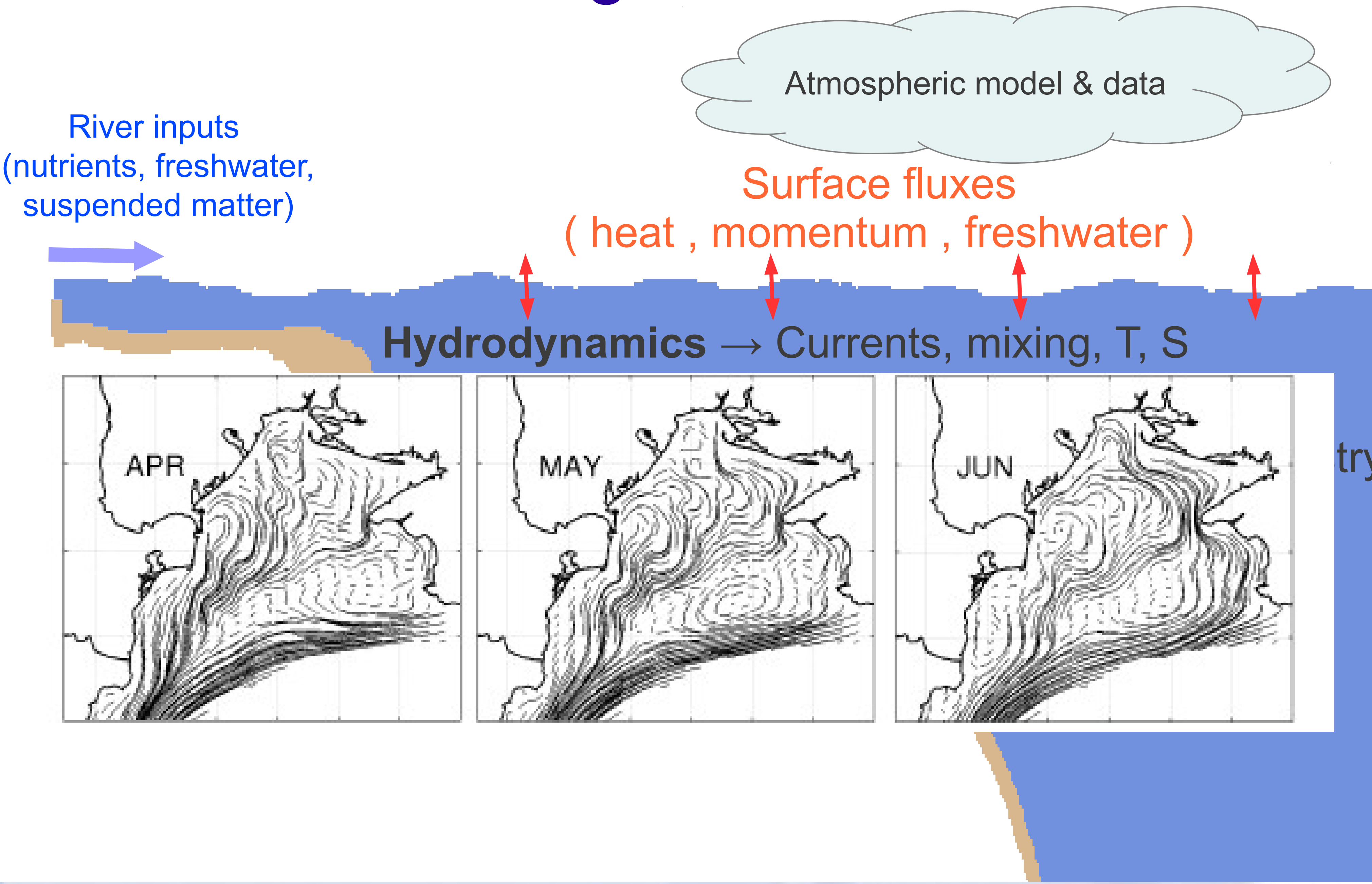


Studying Hypoxia with a 3D model

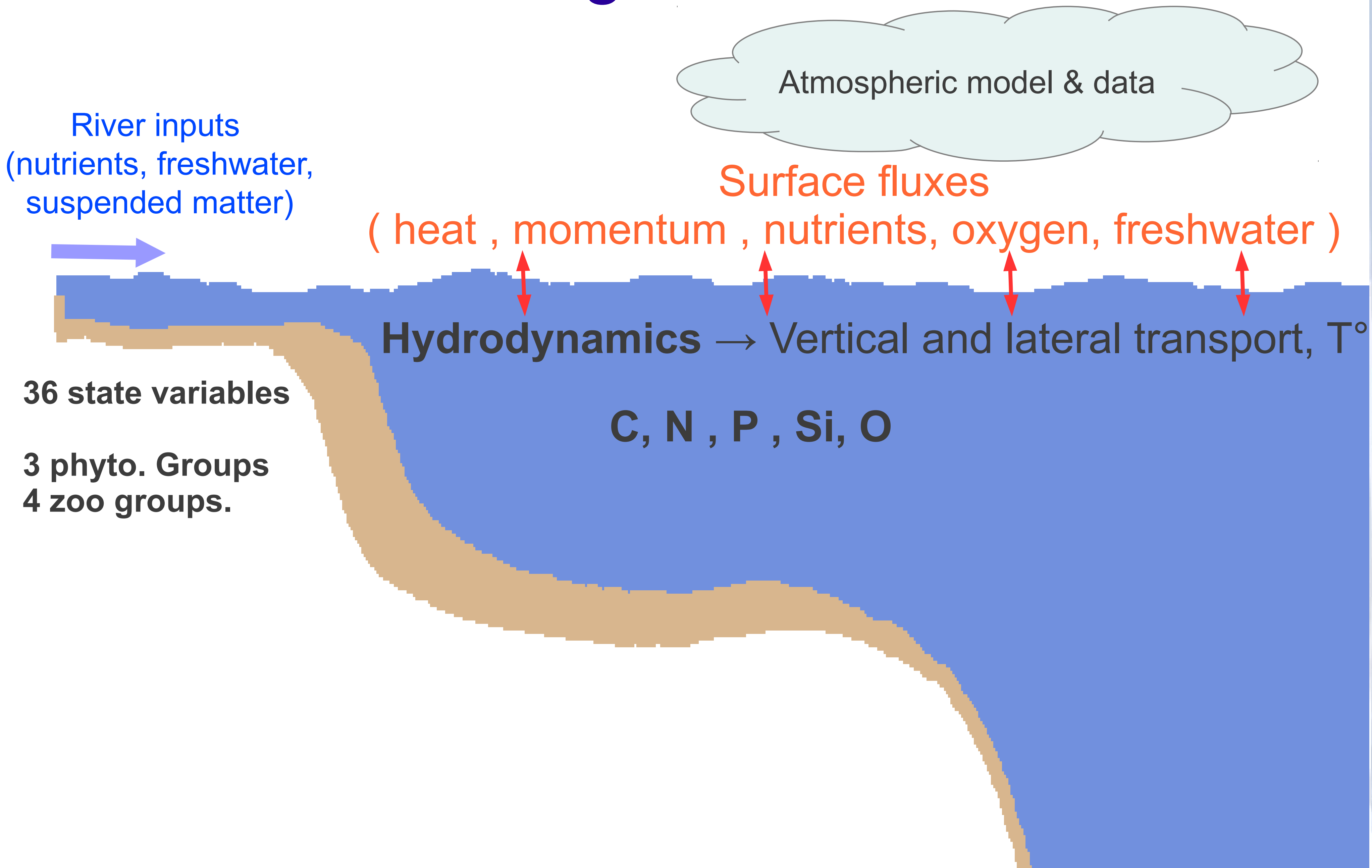
GHER 3D biogeochemical model



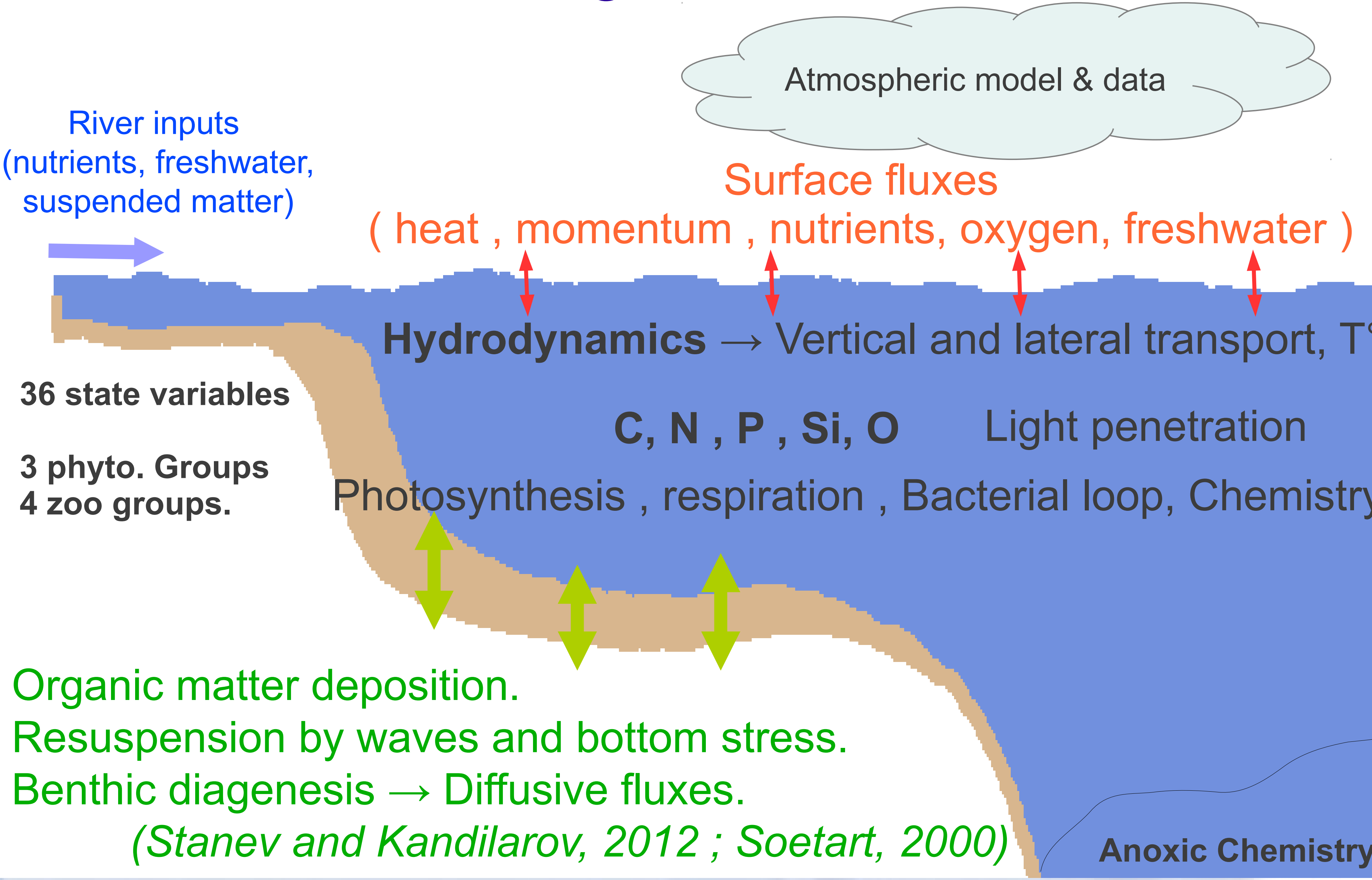
GHER 3D biogeochemical model



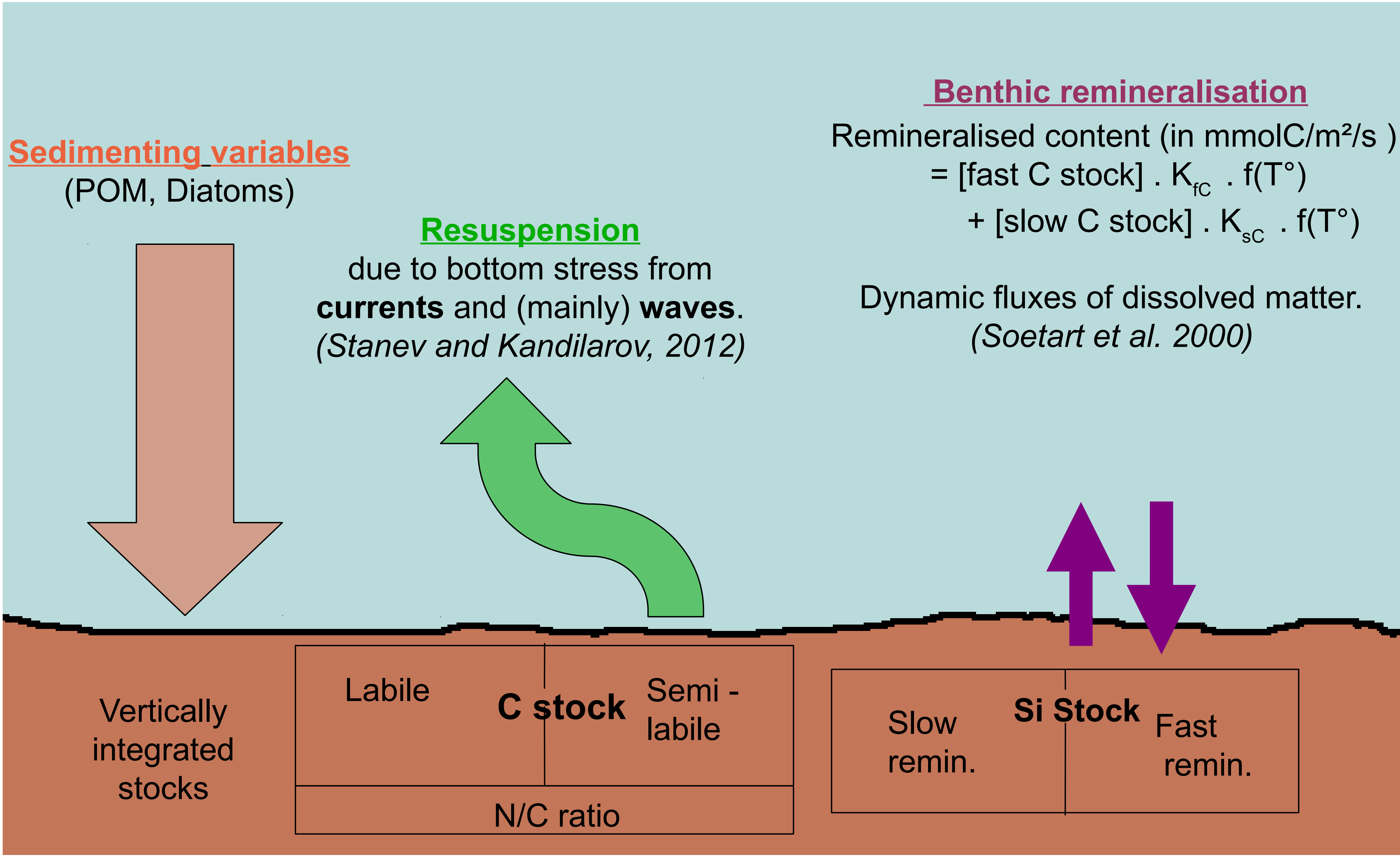
GHER 3D biogeochemical model



GHER 3D biogeochemical model



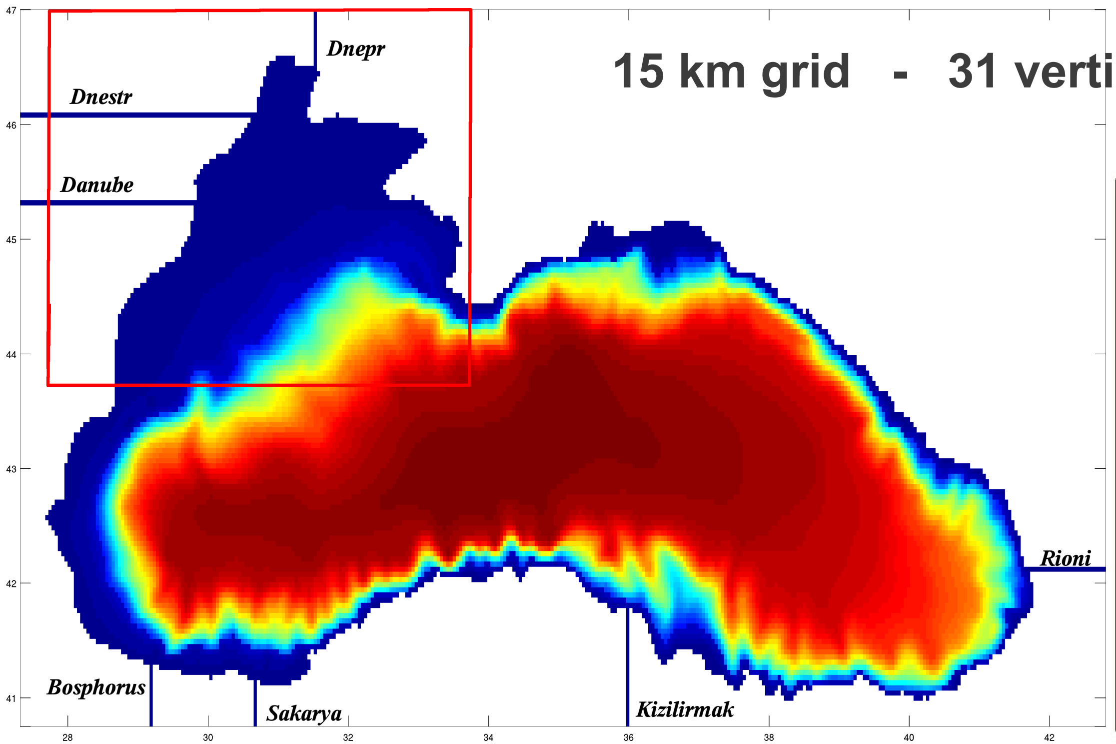
Benthic Model



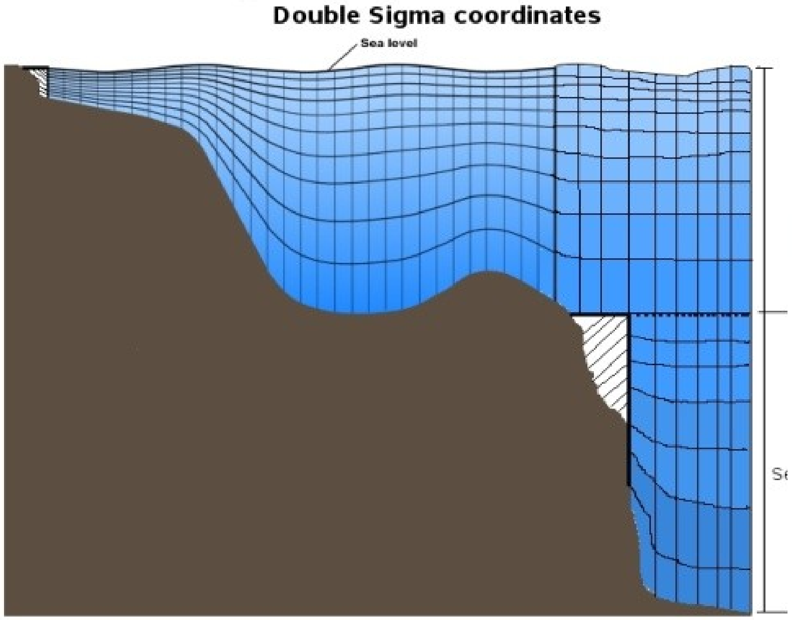
Model Experiment : 1980 – 2009

Realistic forcings

- Atmospheric : ERAinterim (*ECMWF*)
- River inputs : Ludwig et al. , 2009

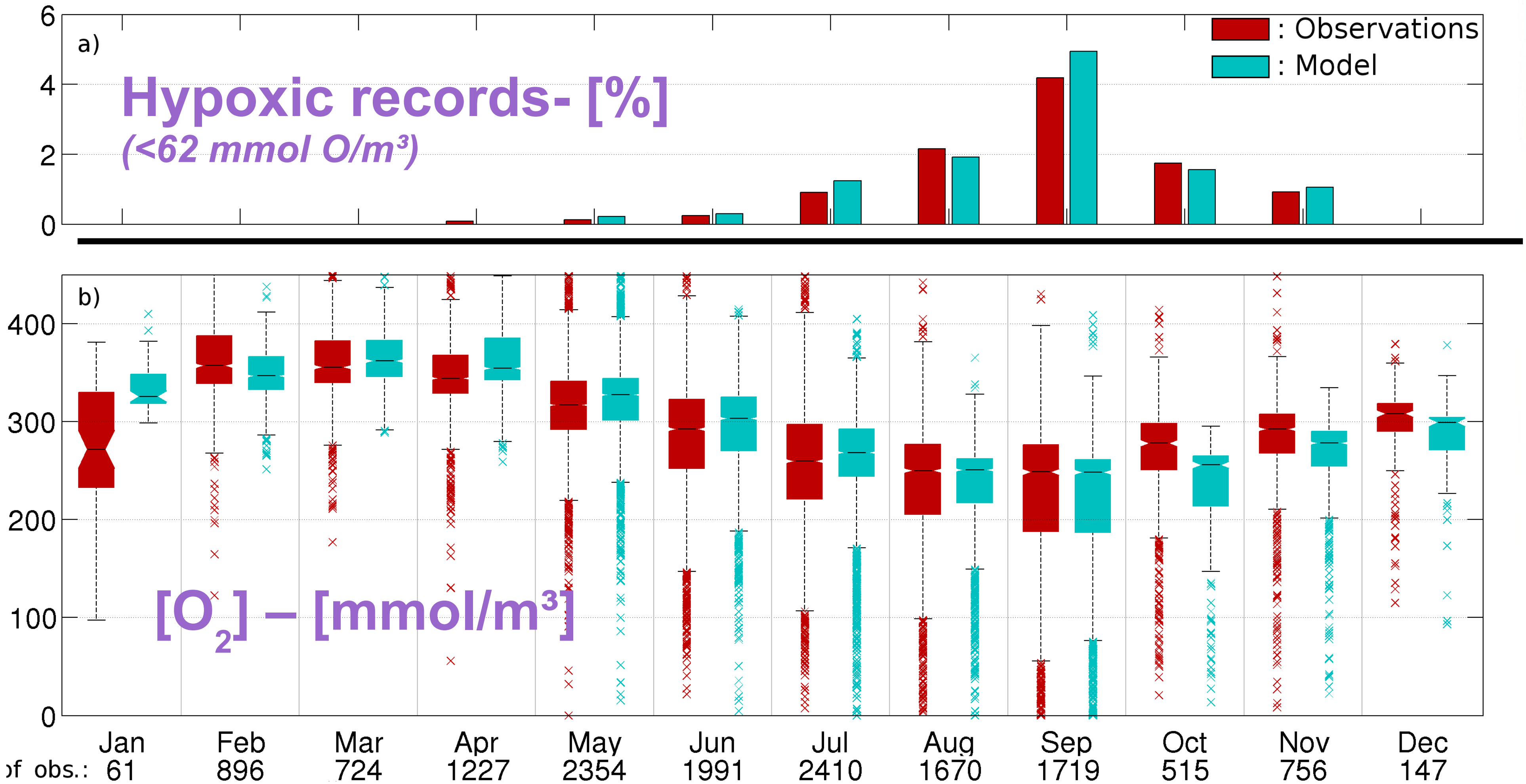


15 km grid - 31 vertical levels

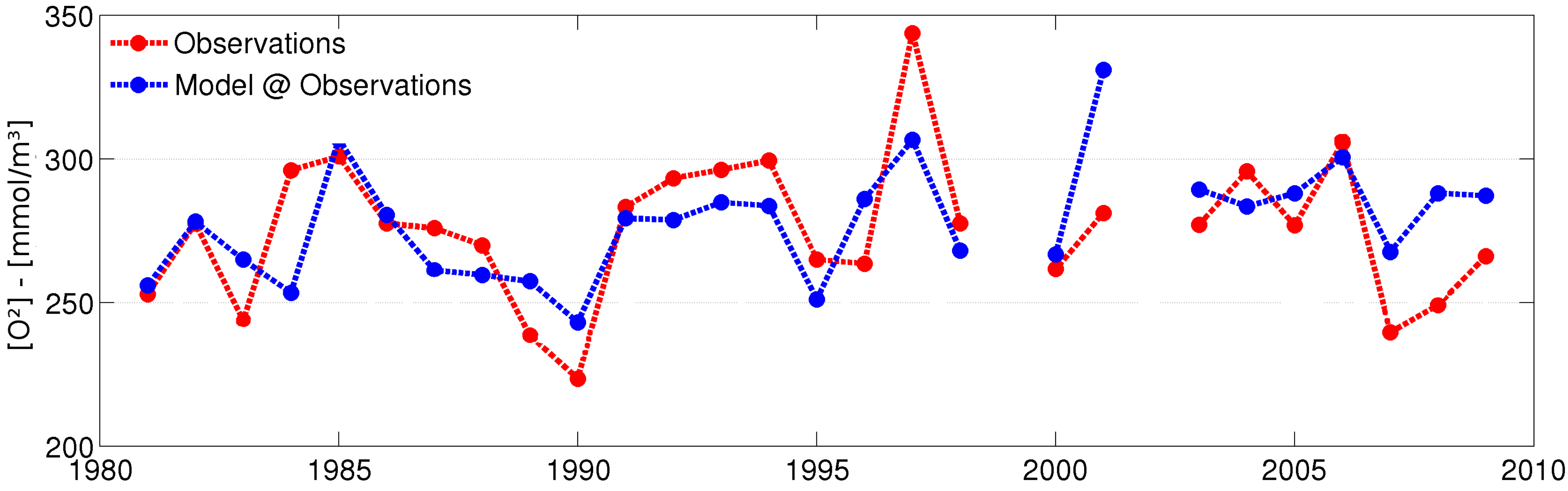


Model Validation : Point-to-point

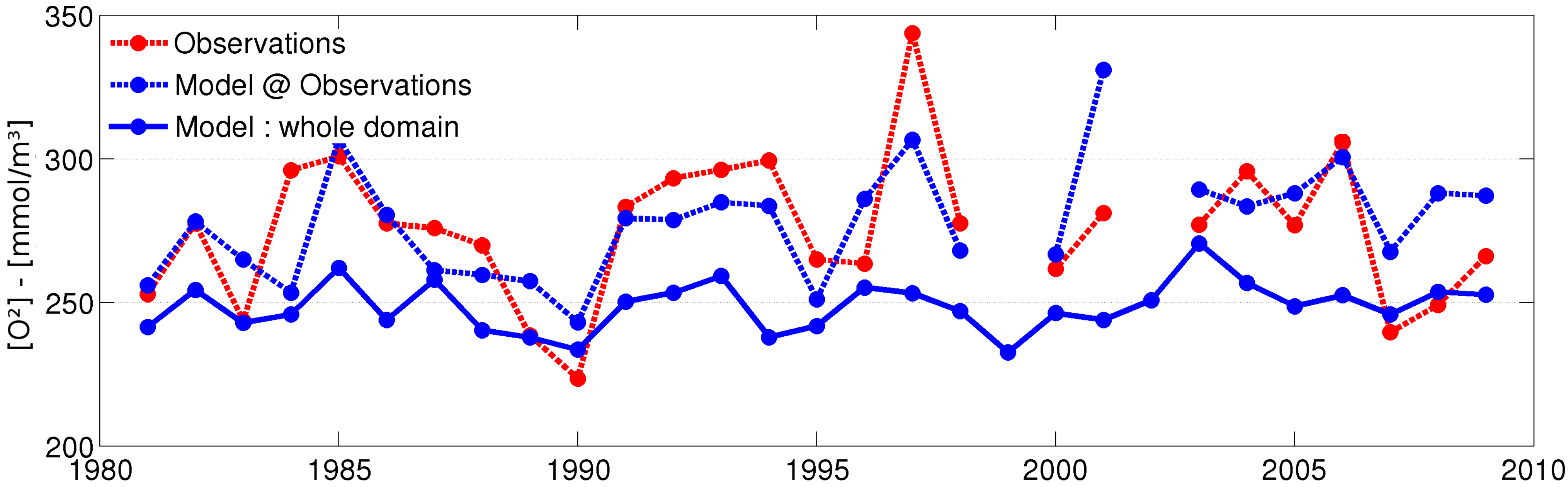
Merged by months → validation of the seasonal cycle

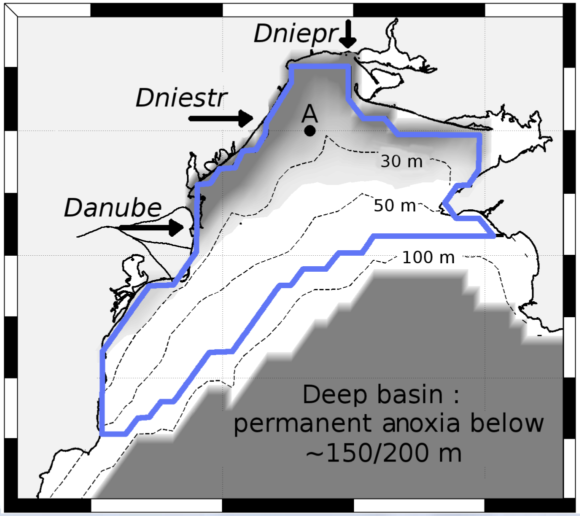


Interannual variability

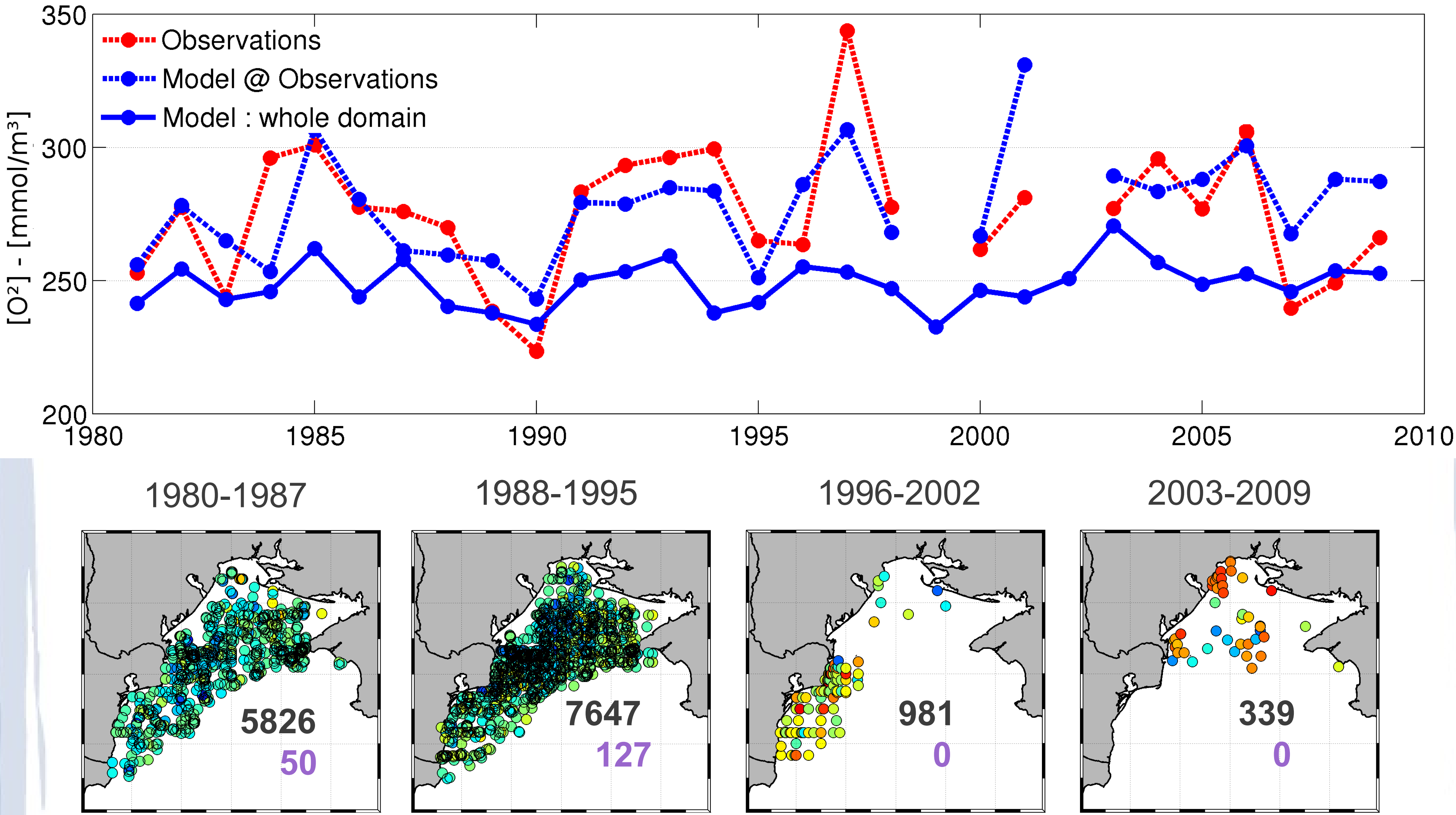


Interannual



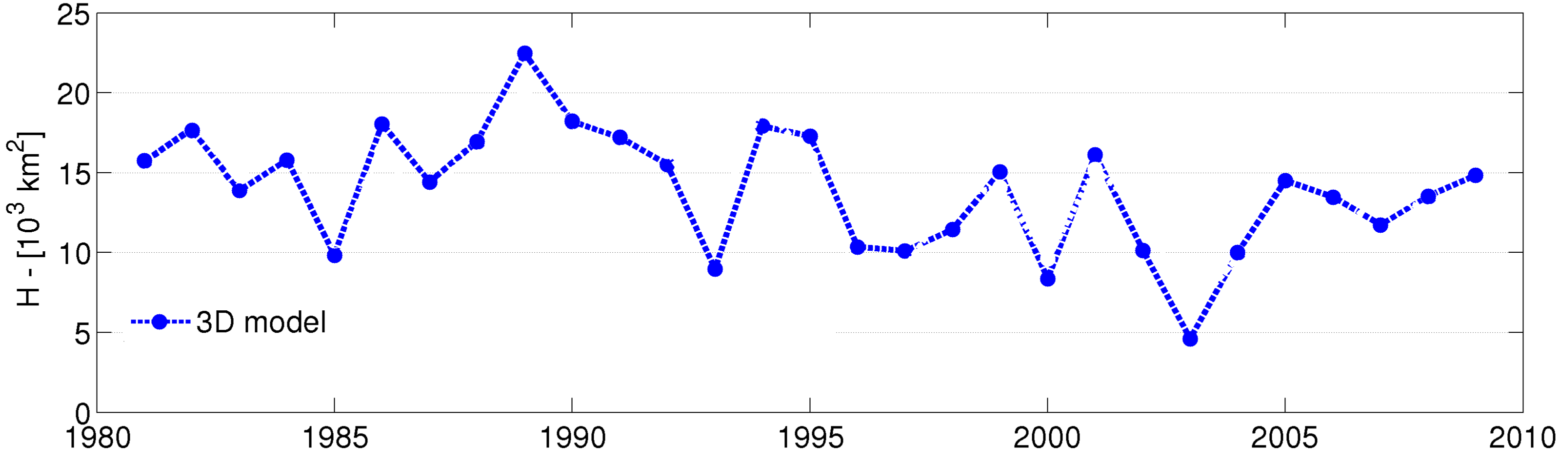


Interannual

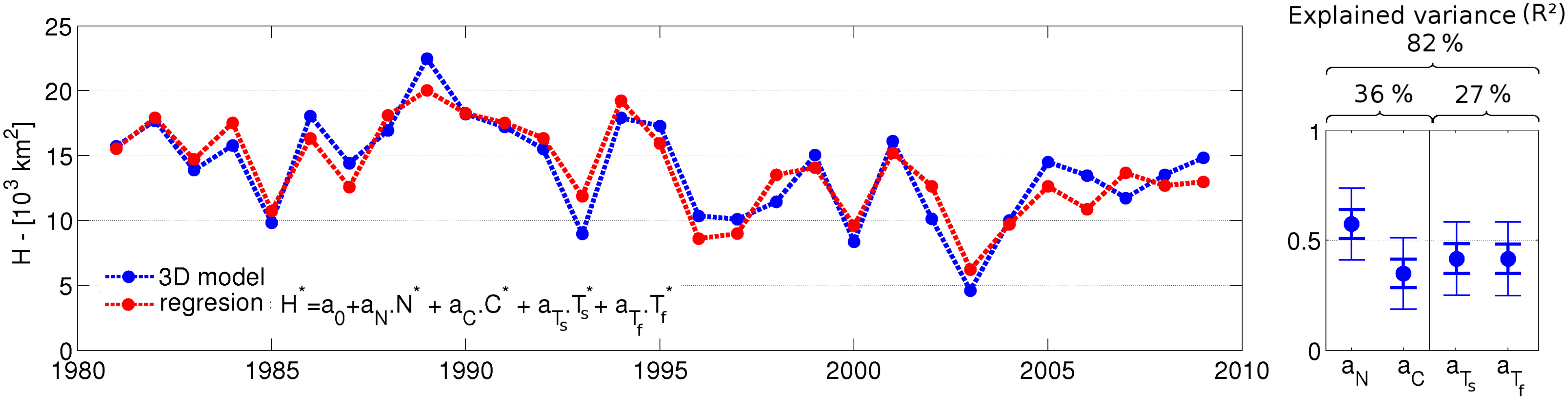


Drivers of interannual variability

Interannual variability of Hypoxia



Interannual variability of Hypoxia



<u>**Eutrophication**</u>

N : riverine Nitrogen load

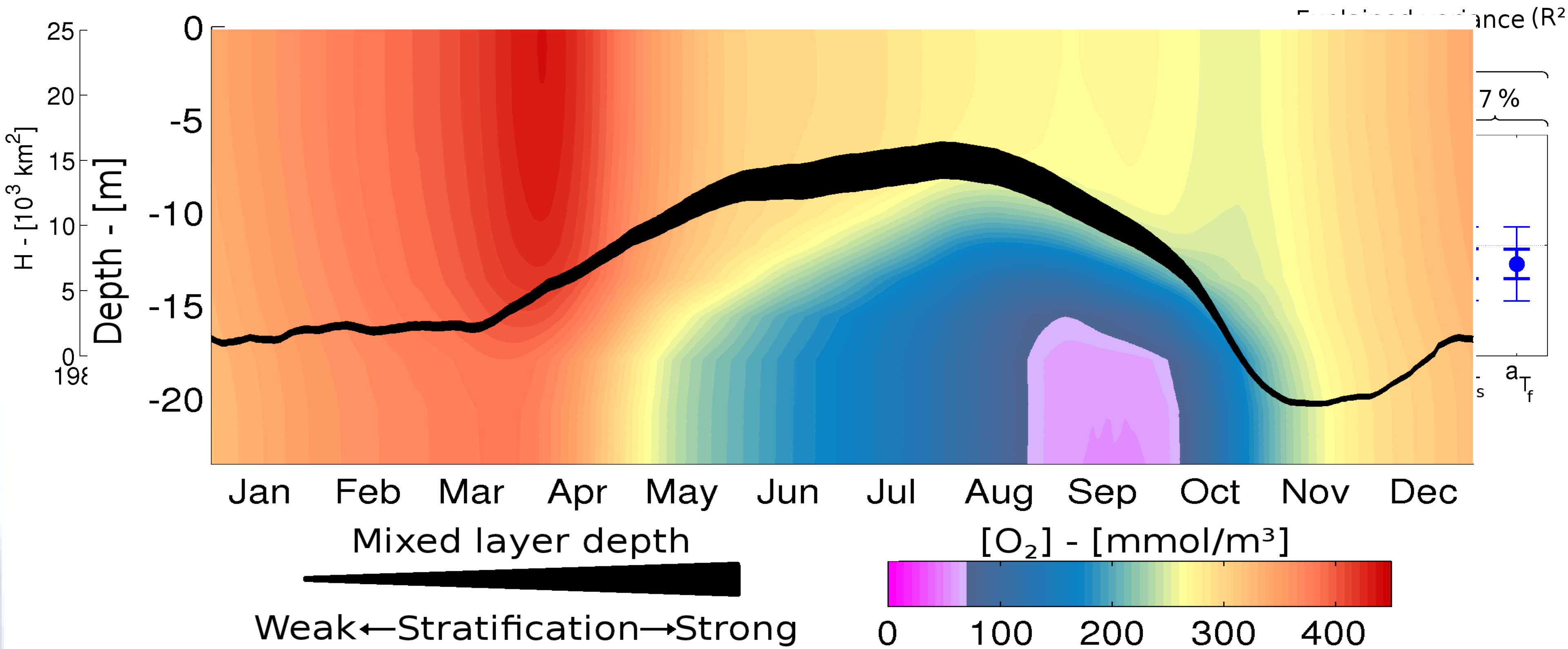
C : Accumulation of organic matter in the sediments

<u>**Climatic**</u>

Ts : Sea surface temperature in early spring

Tf : Sea surface temperature in late summer

Interannual variability of Hypoxia

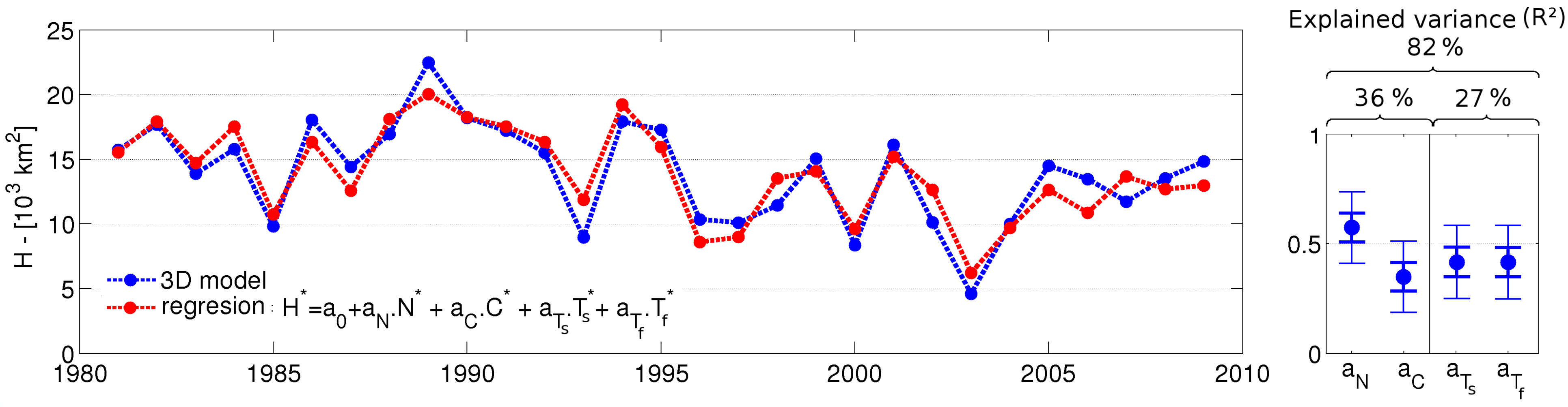


Climatic

Ts : Sea surface temperature in early spring

Tf : Sea surface temperature in late summer

Interannual variability of Hypoxia



Eutrophication

N : riverine Nitrogen load

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Climatic

Ts : Sea surface temperature in early spring

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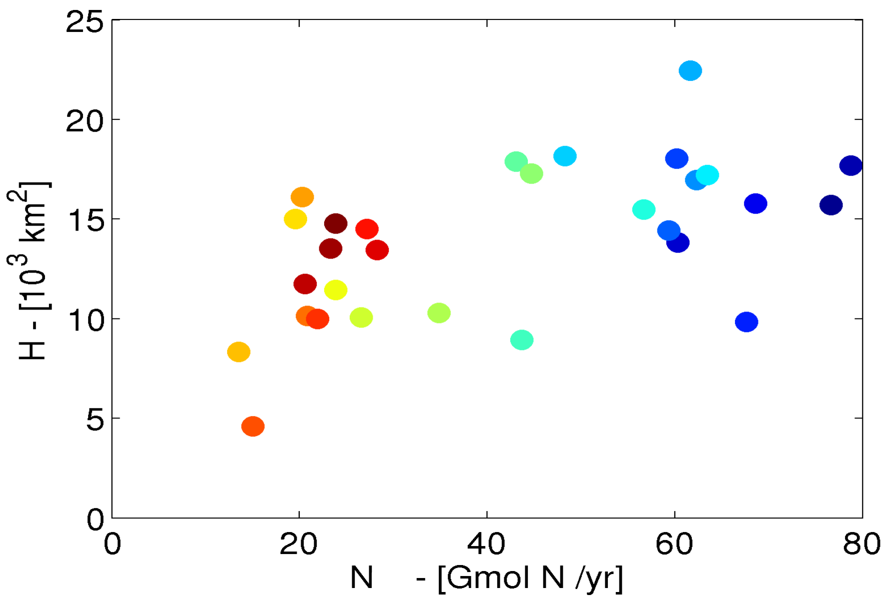
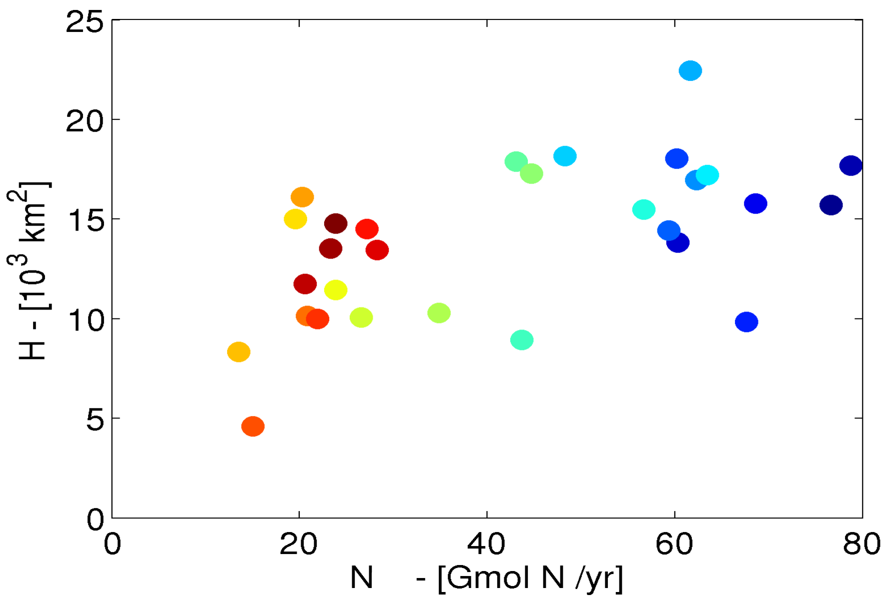
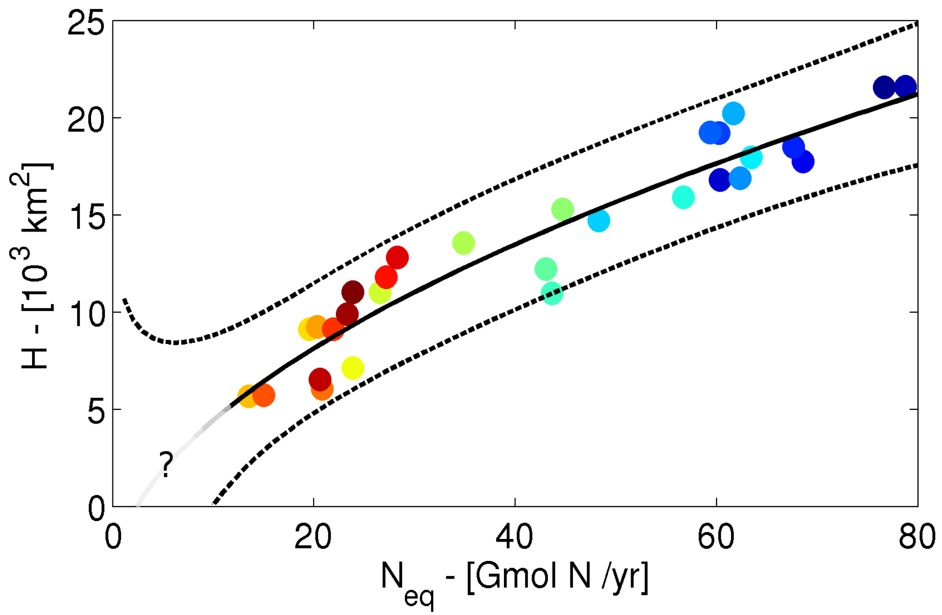
Hypoxia as a function of N



Includes the year specific influences of climatic and sediments drivers

Hypoxia as a function of N





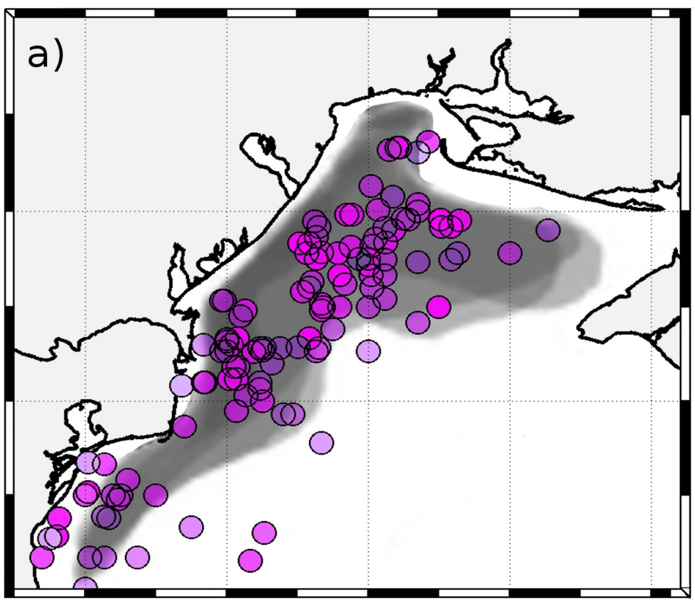
Includes the year specific influences of climatic and sediments drivers → Average climatic conditions and equilibrated sediments content

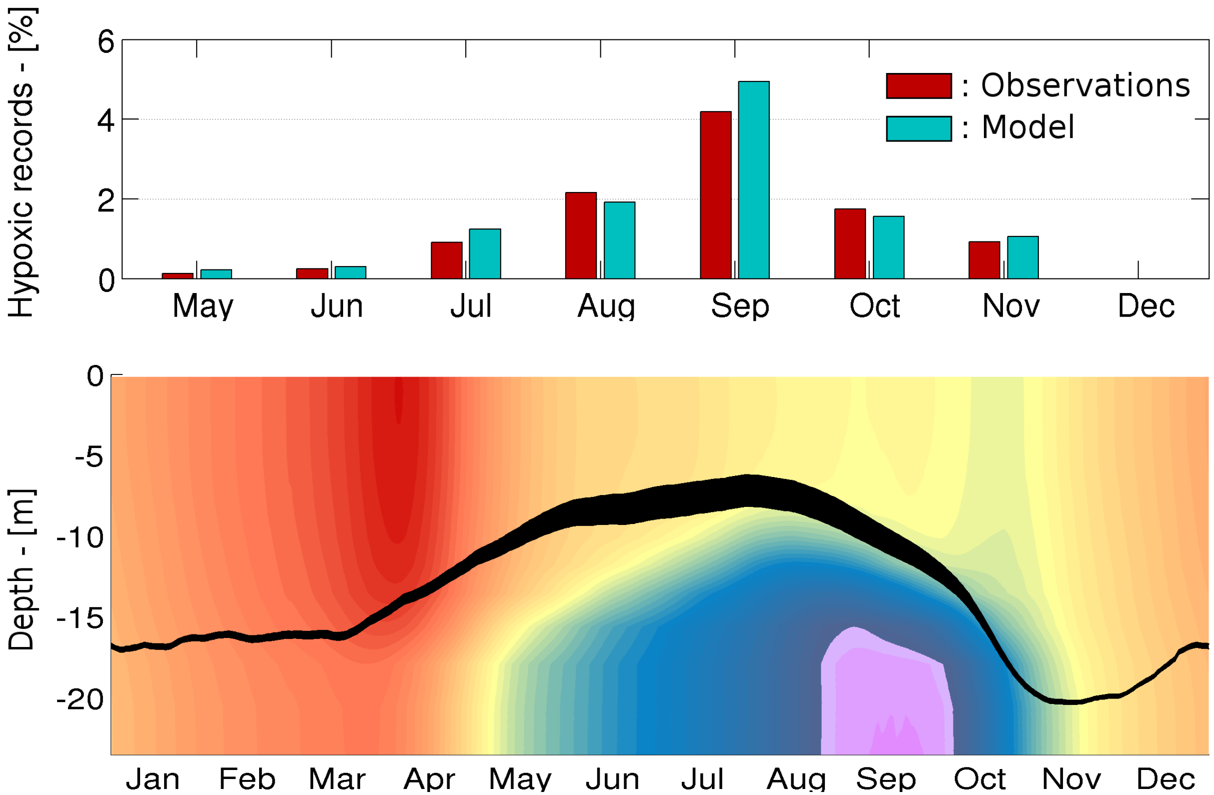
Take-home Messages (3)

Take-home Messages (1/3)

Hypoxia is still ongoing in the Black Sea NWS

Monitoring should be focused on the area, months and depth of known hypoxia occurence





Take-home Messages (2/3)

Hypoxia is intensified by year-to-year accumulation of organic matter in the sediments

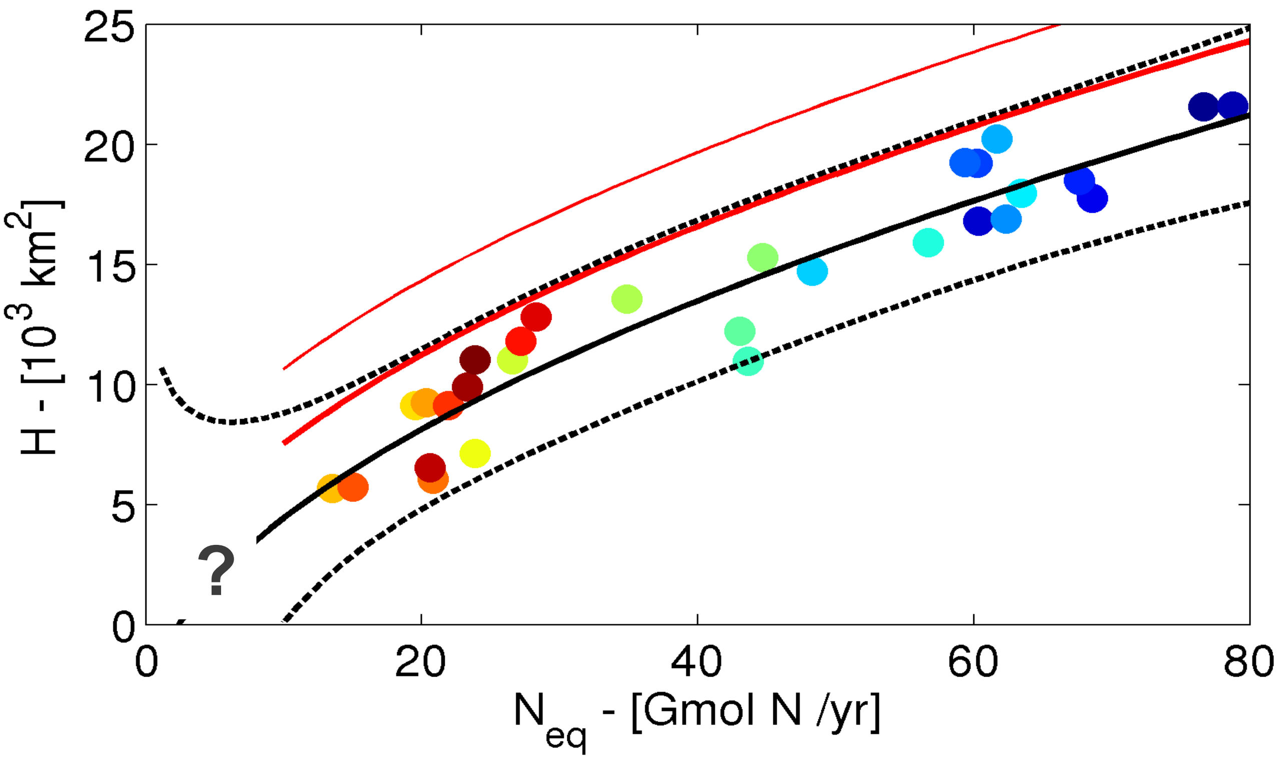
Systems with decreasing N → inertia in the recovery process.

Systems with increasing N → increase of the H/N ratio. *(Turner, 2008)*

.

Take-home Messages (3/3)

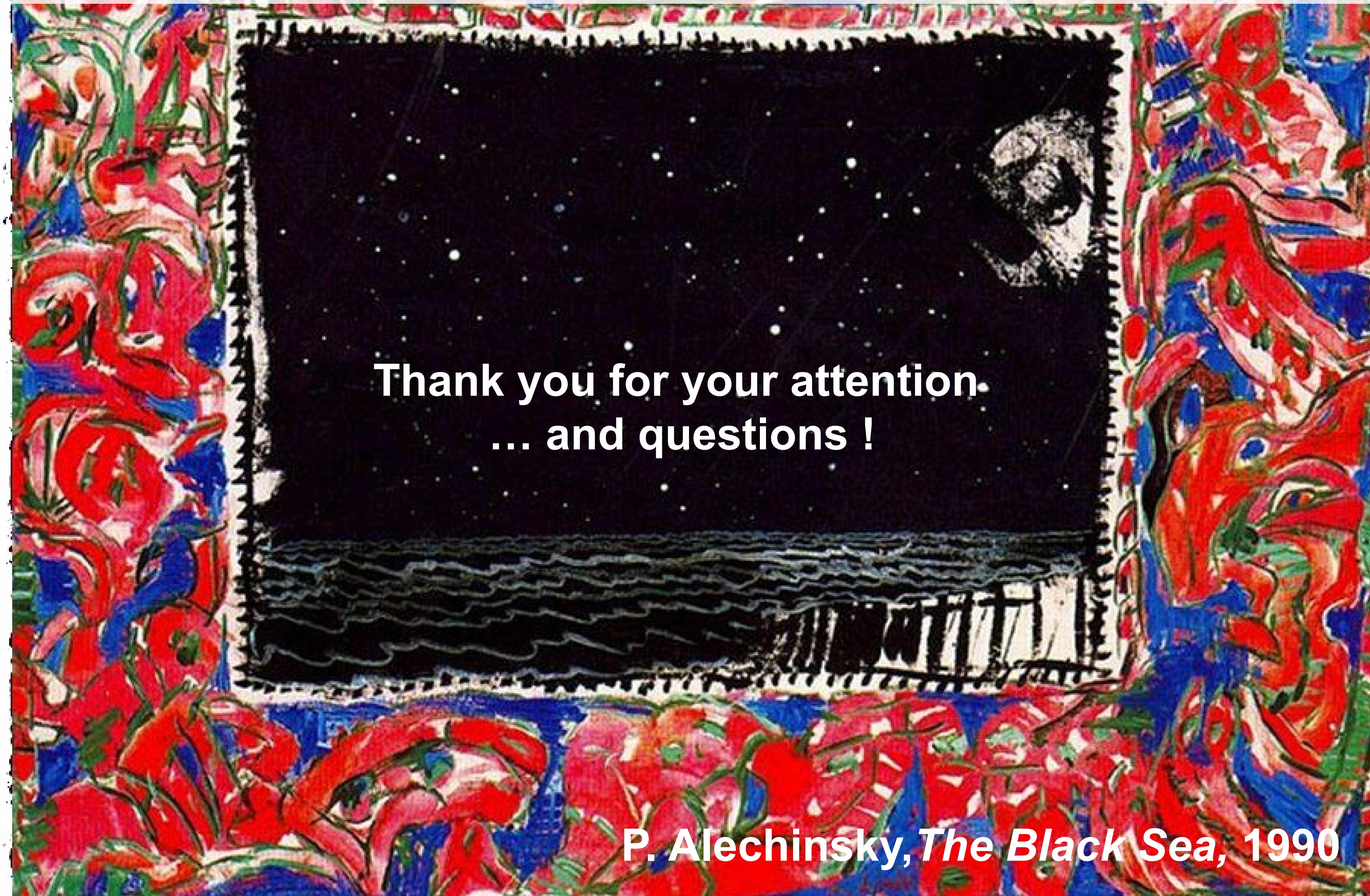
Climate impacts almost as much as eutrophication.



Nutrient reduction policies should account for realistic climatic scenarios

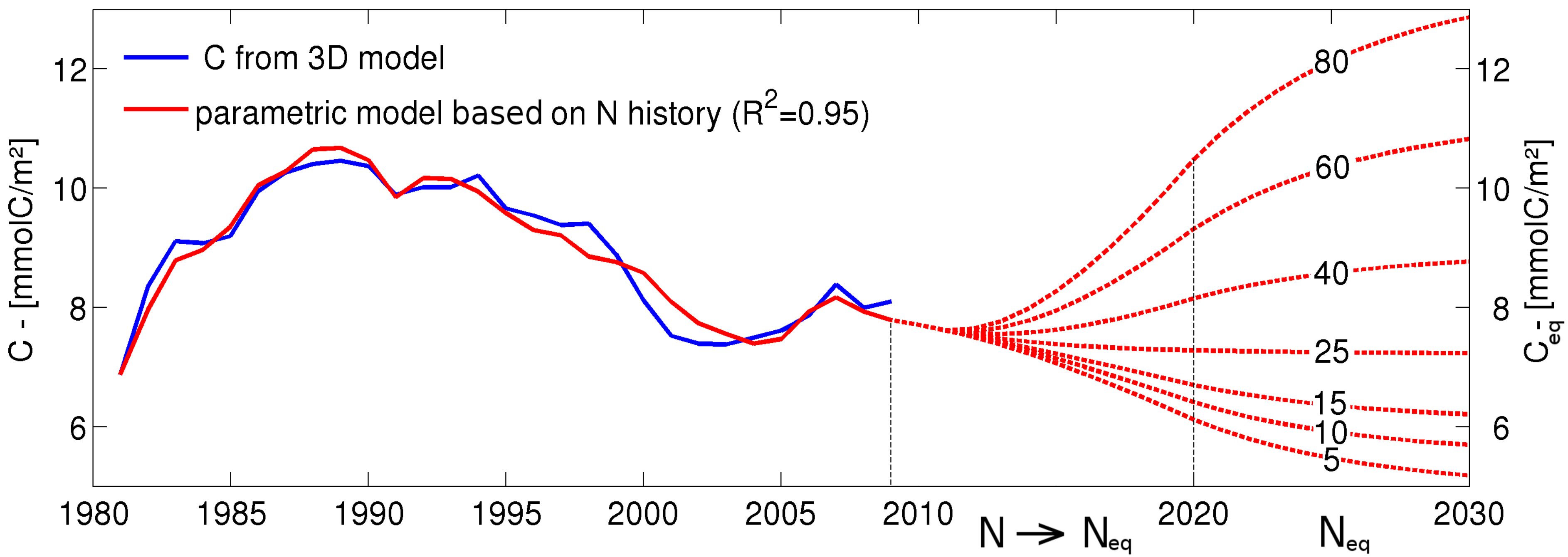
Capet, A., Beckers, J.-M., and Grégoire, M.: *Biogeosciences Discuss.*, *2012*,

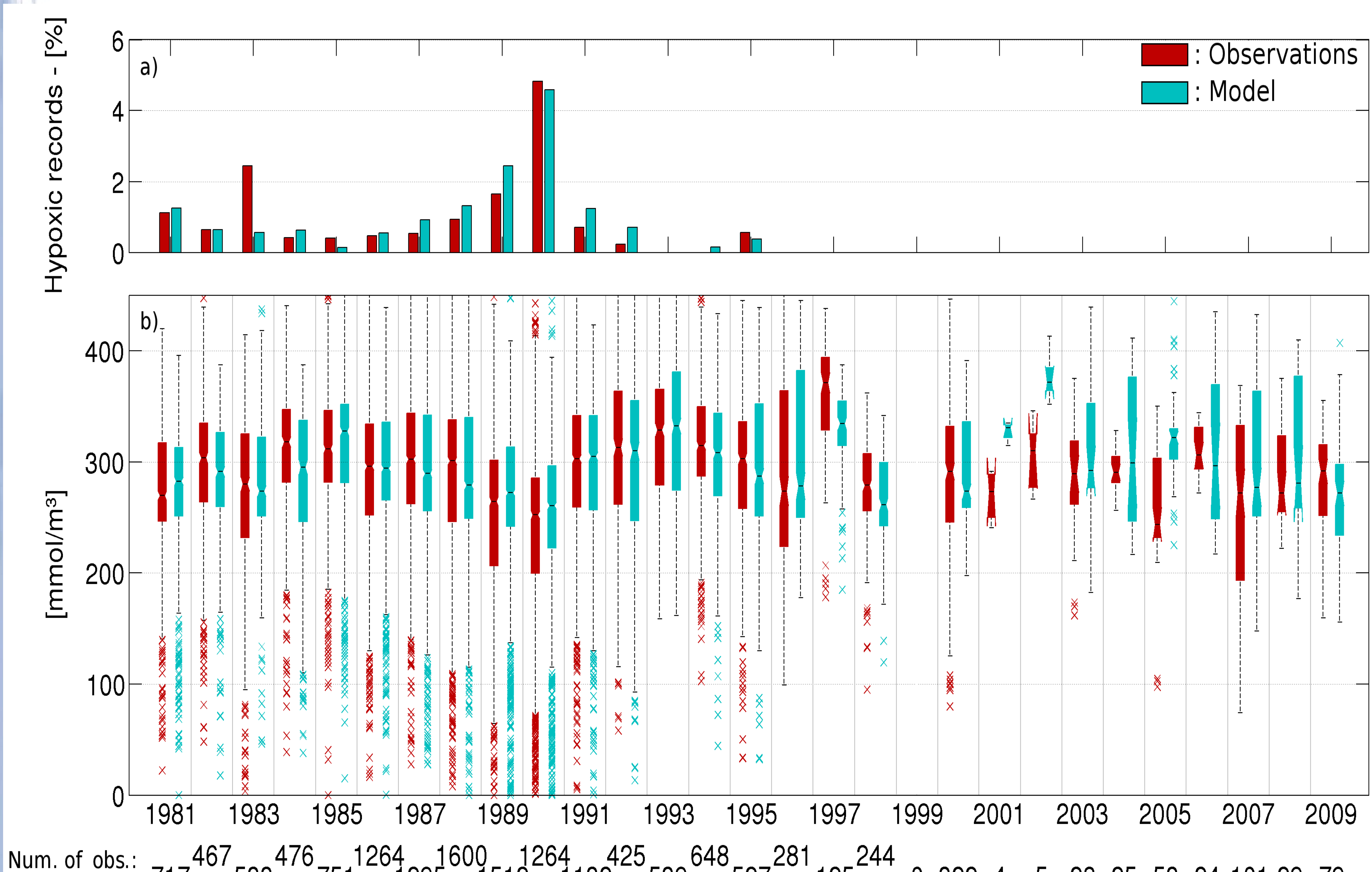
Seasonal hypoxia in eutrophic stratified coastal shelves: mechanisms, sensibilities and interannual variability from the North-Western Black Sea case,



P. Alechinsky, ***The Black Sea,*** **1990**

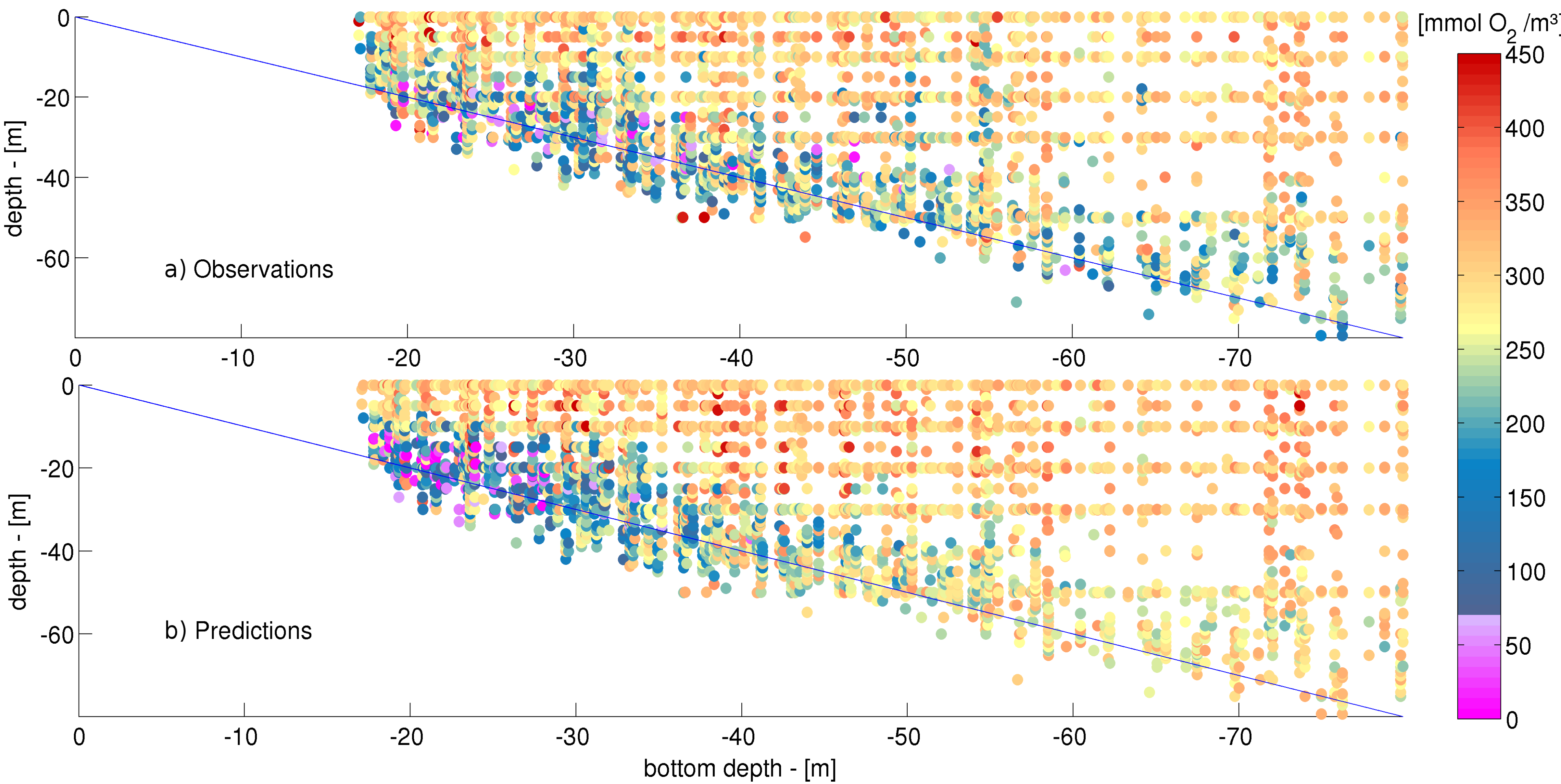
Organic matter accumulates in the sediments





Hypoxic records - [%]
a)
: Observations
: Model
b)
[mmol/m³]
0
2
4
6
100
200
300
400
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Num. of obs.:
717 467 533 476 751 1264 1295 1600 1512 1264 1132 425 539 648 527 281 125 244 0 322 4 5 28 25 53 24 101 29 79

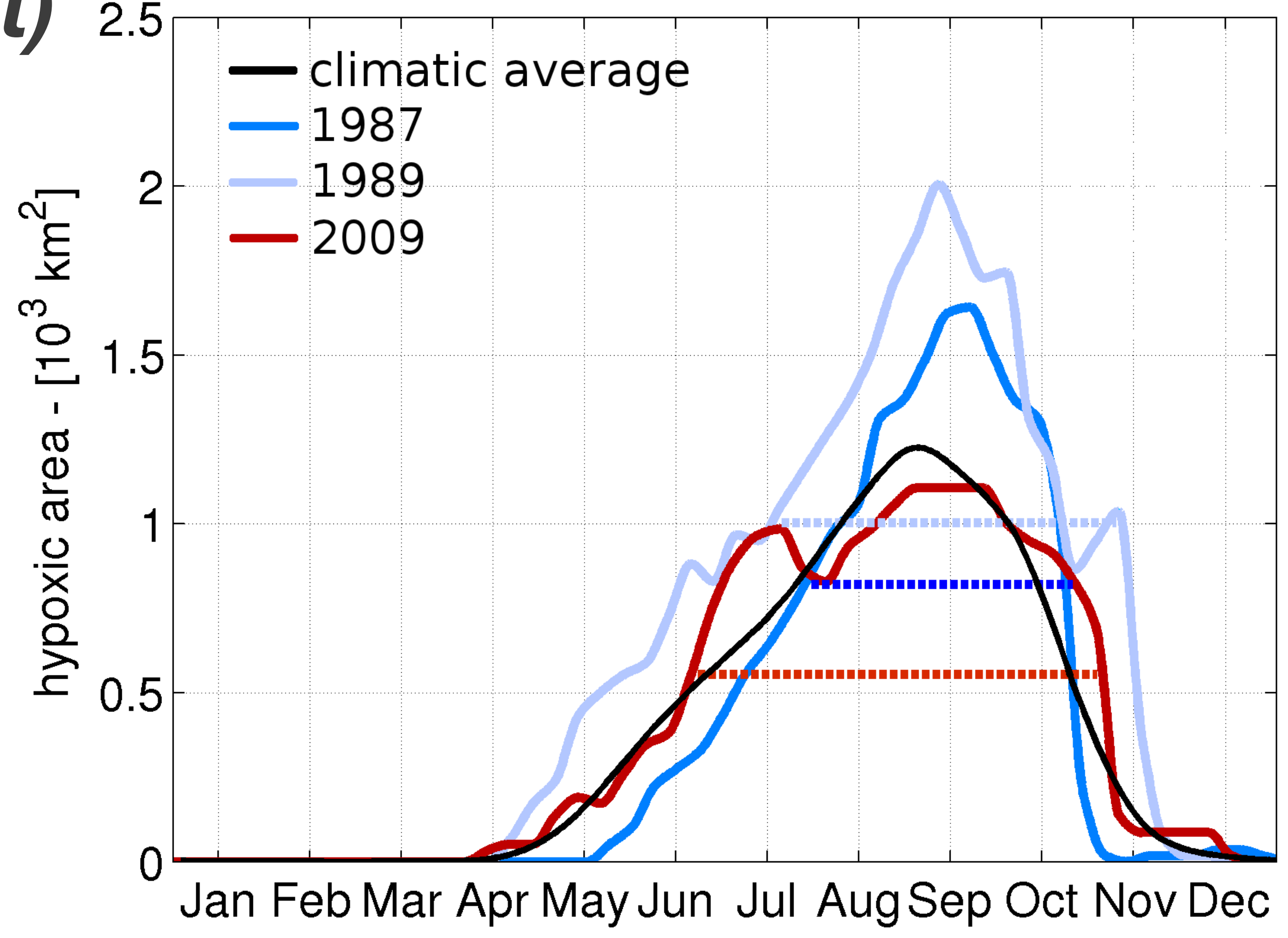
Model Validation : Point-to-point



$$D = \frac{1}{\max A(t)} \int_{year} A(t)dt,$$

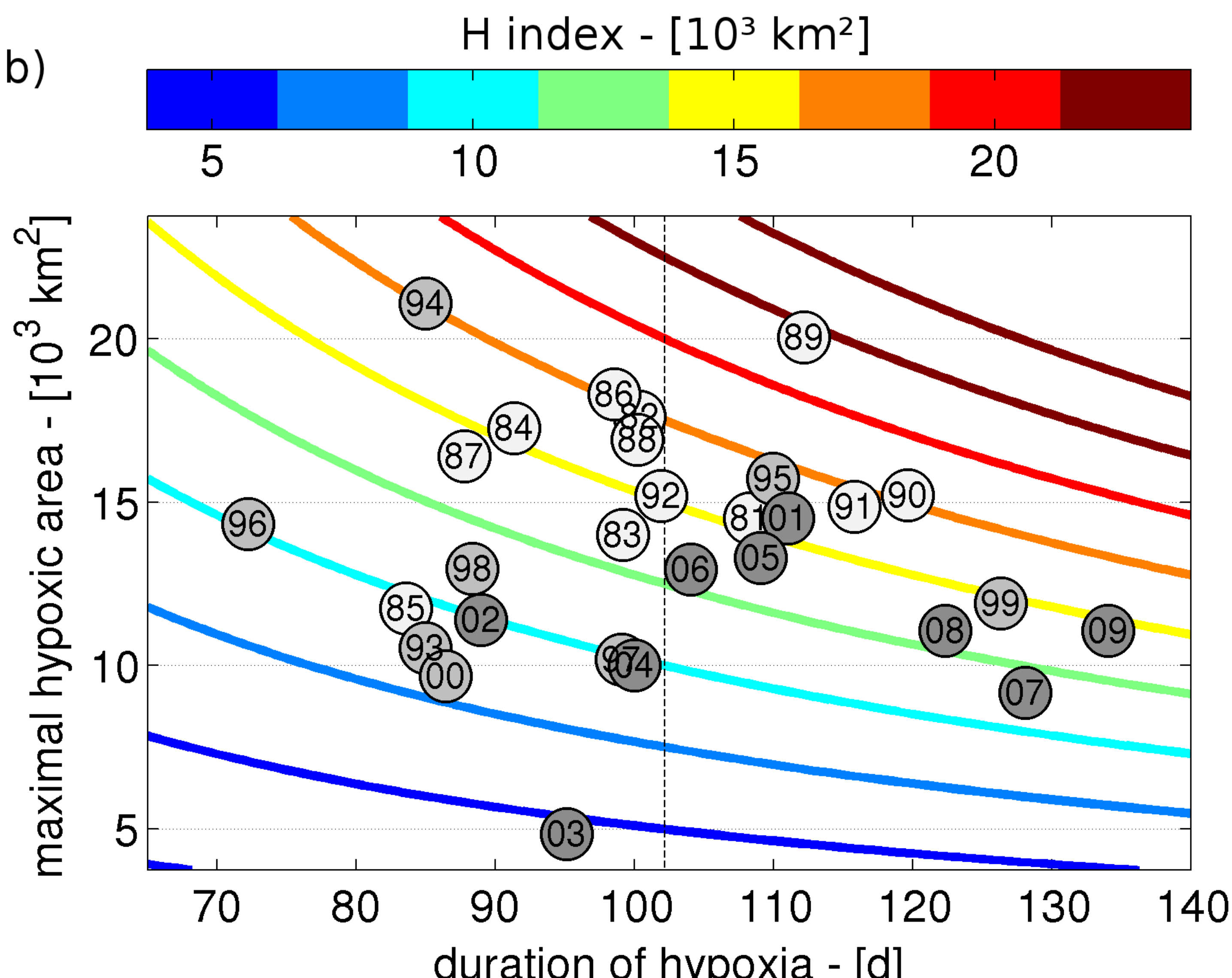
$$H = \frac{1}{\overline{D}} \int_{year} A(t)dt,$$

A(t)

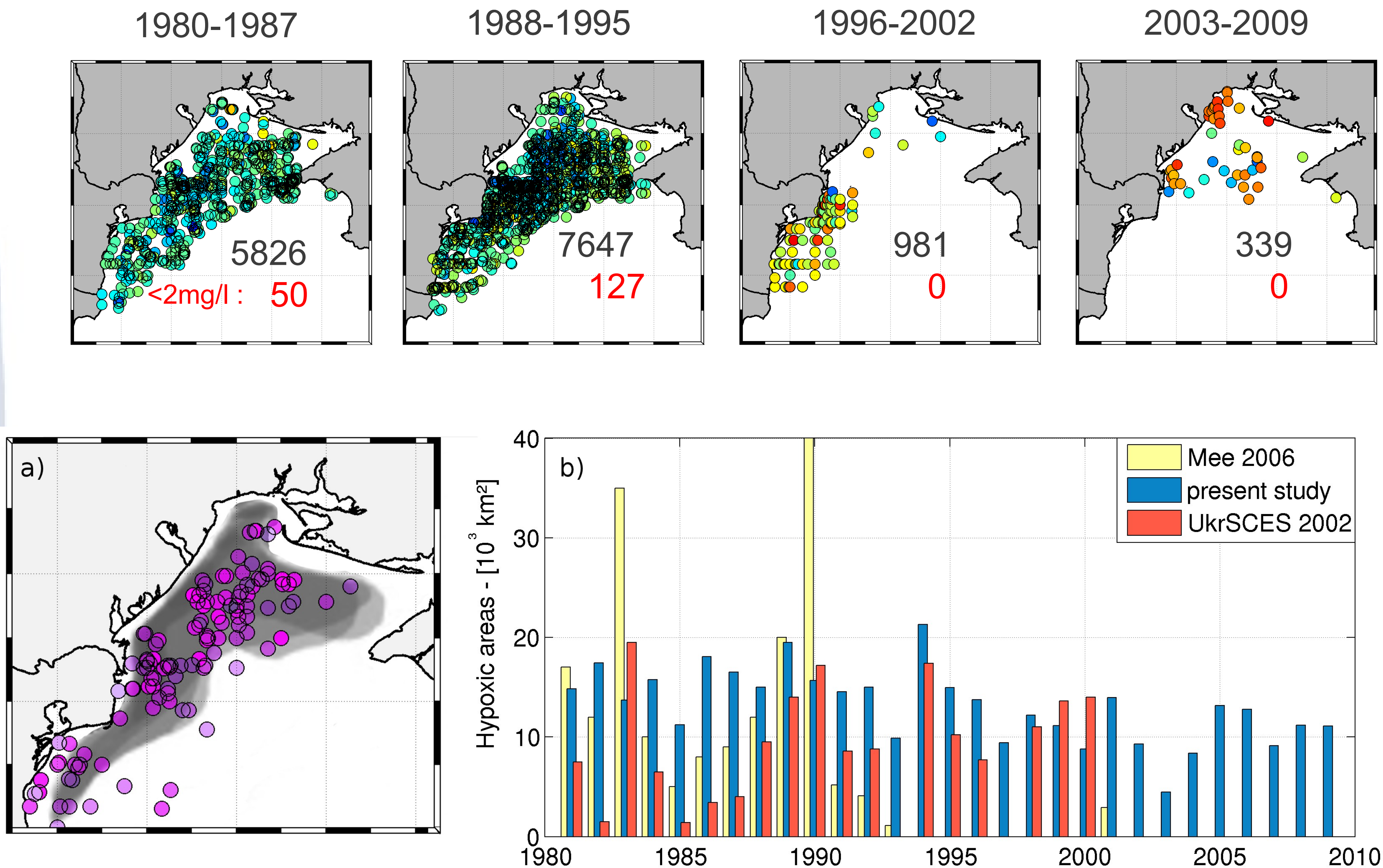


$$D = \frac{1}{\max A(t)} \int_{year} A(t)dt,$$

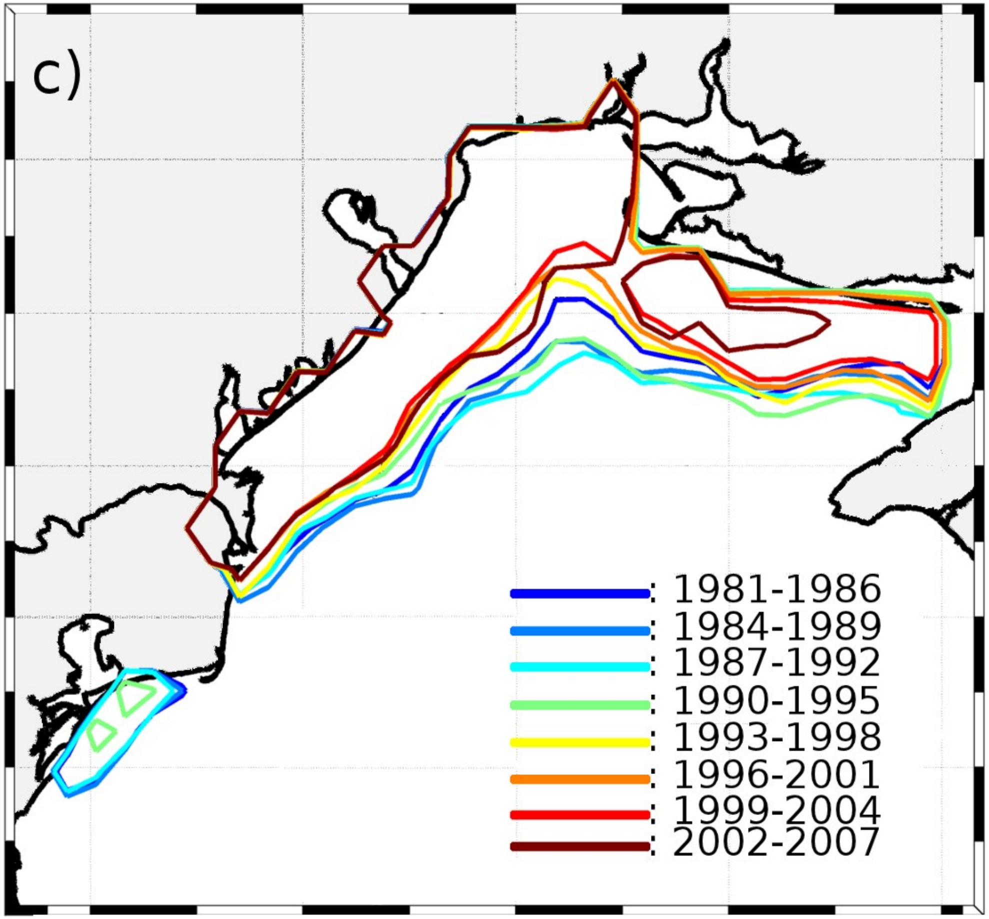
$$H = \frac{1}{\overline{D}} \int_{year} A(t)dt,$$



Recovery ?

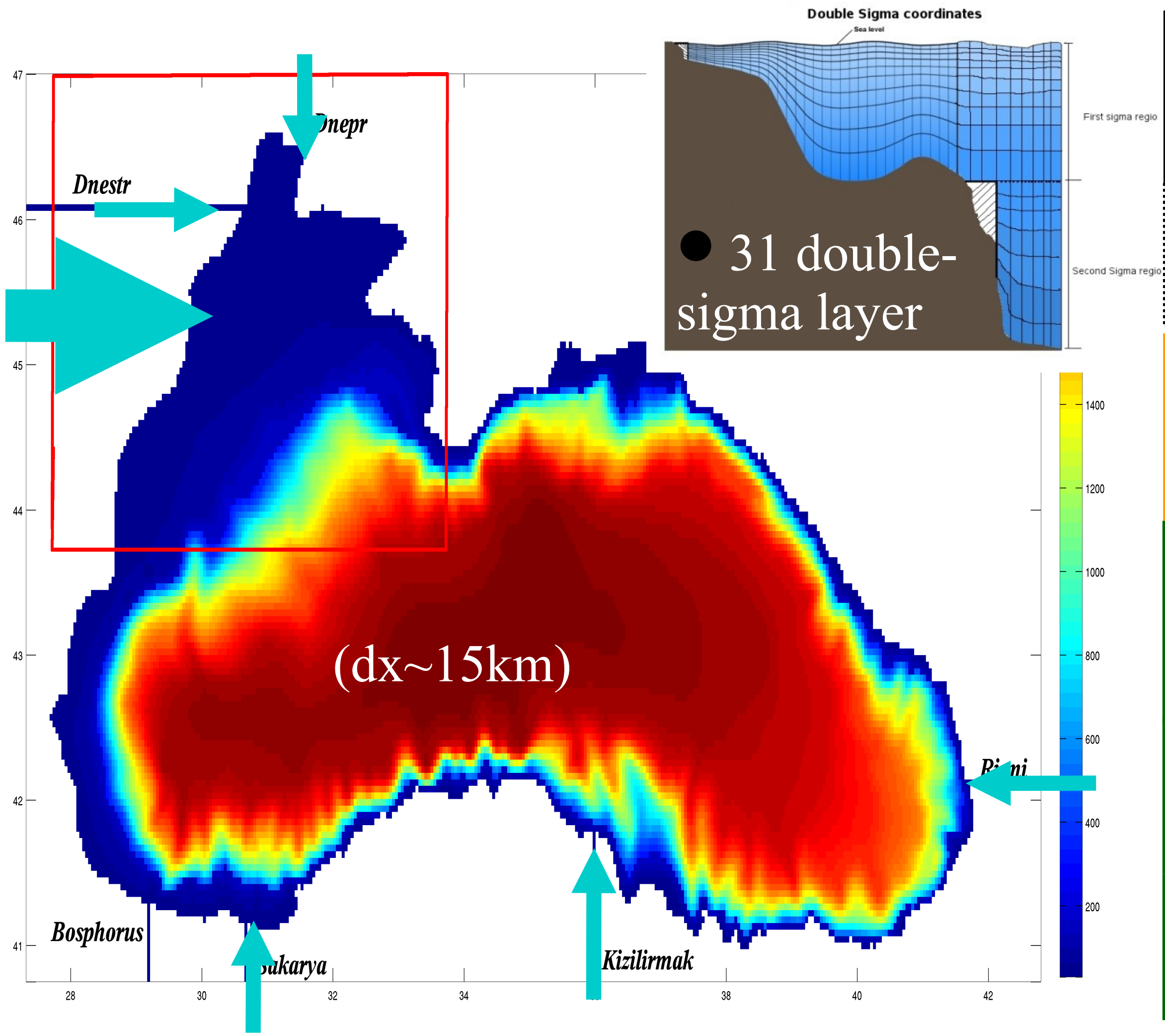


1980-1987
5826
<2mg/l : 50
1988-1995
7647
127
1996-2002
981
0
2003-2009
339
0
a)
b)
Hypoxic areas - [10^3 km^2]
Mee 2006
present study
UkrSCES 2002
0
10
20
30
40
1980
1985
1990
1995
2000
2005
2010


c)
: 1981-1986
: 1984-1989
: 1987-1992
: 1990-1995
: 1993-1998
: 1996-2001
: 1999-2004
: 2002-2007

Selection criteria	All data	$Z > 17$	$Z > 17$ $z > 15$
WOD (1981-2001)	14123	**14088**	7670
Aug., Sep., Oct.	3850	3847	2108
BSC (2000-2009)	636	**382**	86
Aug., Sep., Oct.	113	57	8

The Model



Monthly RIVERS fluxes and nutrients flows (from L. Wolfgang & A. Cociasu)

6h-atmospheric forcings from ECMWF (1.125°). (from ERA40)

36 States variables

Physics (5)
Currents, T°, Salinity, Surface elevation, Turbulence

Oxygen and Dissolved Inorganic Carbon (2)

Inorganic nutrients (5)
SiO,NO3,NH4,PO4,"Reducers"

3 Phytoplankton (6) (free C/N)
Diatoms,Flagellates, Small Flagellates

Zooplankton (2)
Micro-, Meso-.

Gelatinous zooplankton(2)
Omnivorous , Carnivorous

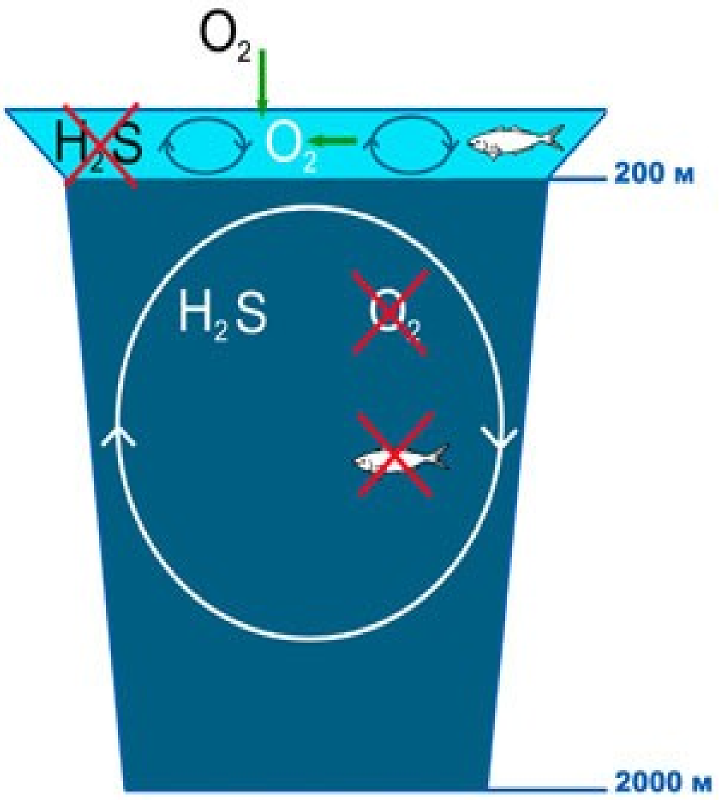
Detrital matter (8)
Particulate, Semi-labile and Labile forms
Silicious Detritus, Aggregates

Bacteria(1)

Model's Specificity

- No data assimilation : Necessity to construct specific Bosphorus representation to ensure conservation of volume and total salt content.

- Anoxic waters : The biological model explicitely includes anoxic chemistry trough the use of a variable 'Oxygen demanding Units', as a proxy for reducers acting in the anoxic zone.



- Sediments compartiment

- Light absorption scheme