

# The two faces of Black Sea deoxygenation

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James Murray<sup>4</sup>   Marilaure Gregoire<sup>2</sup>

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<sup>2</sup>University of Liège, Liège, Belgium

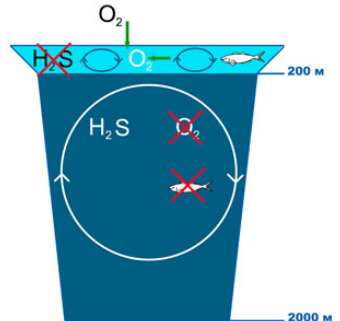
<sup>3</sup>HZG, Helmholtz-Zentrum Geesthacht, Hamburg, Germany

<sup>4</sup>School of Oceanography, University of Washington, Seattle, WA, USA



# Main characteristics

- ▶ Enclosed
- ▶ Large river discharge

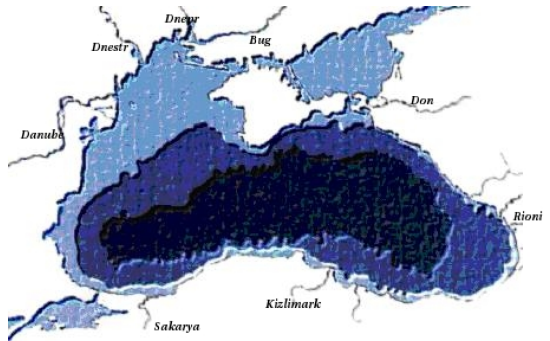


## Northwestern Shelf

- Shallow
- Eutrophic
- Seasonal Hypoxia

## Open Sea

- Deep (2000 m)
- Stratified
- Permanent Anoxia

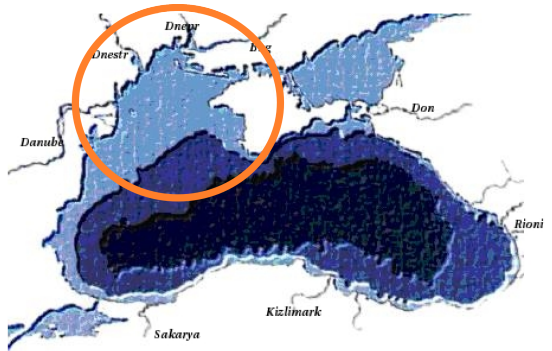




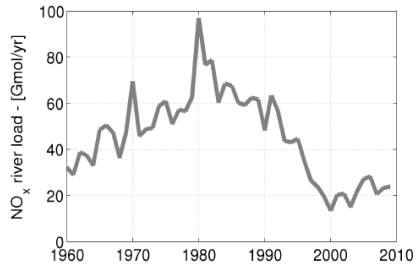


## Northwestern Shelf

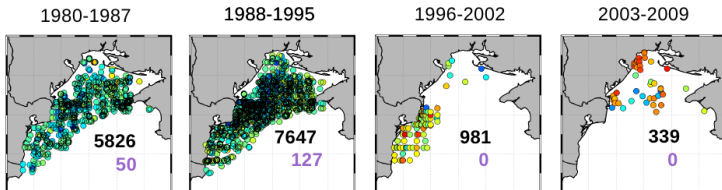
- Shallow
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# Seasonal Hypoxia on the northwestern shelf



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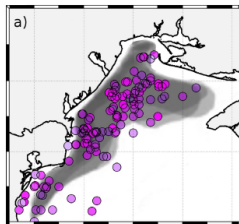


## Oxygen records

(World ocean atlas, Seadatanet,  
Black Sea Commission data)

## Hypoxic records

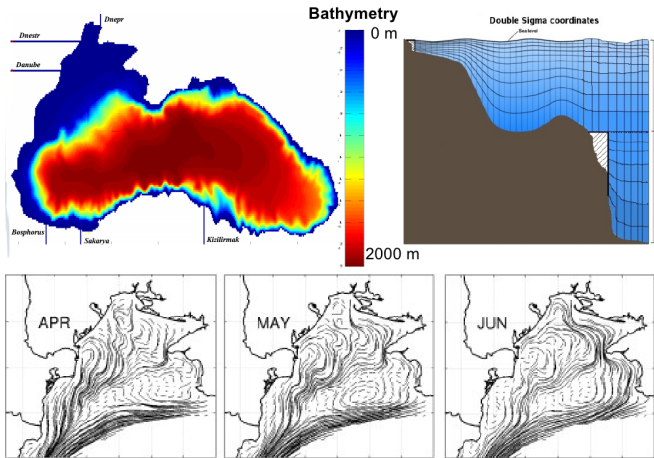
(<math>< 62 \text{ mmol O/m}^3</math>)



# GHER 3D Hydrodynamic Model

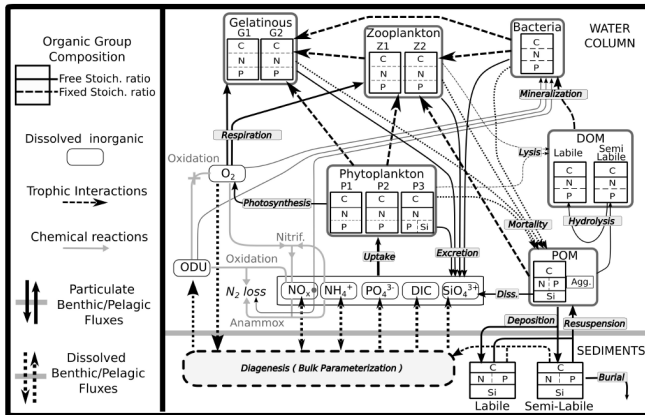
Hydrostatic model, Double Sigma coordinates, Real time forcings (ECMWF)

Provides :  $T, S, TKE, U, V, \eta$



# GHER 3D Biogeochemical Model

Provides : C, N, P, Si, O<sub>2</sub> cycling through various forms.



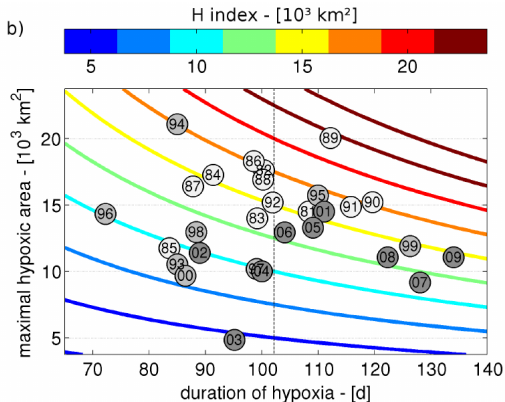
Focus on Benthic-Pelagic coupling

# H index: Annual pressure on Benthic Ecosystems

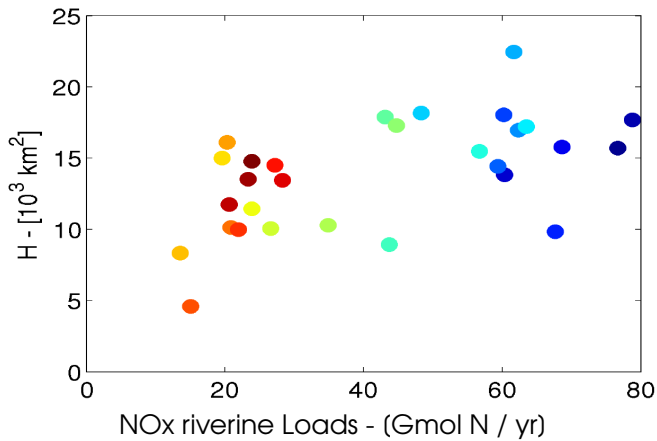
Hindcast simulations : 1980–2009.

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

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

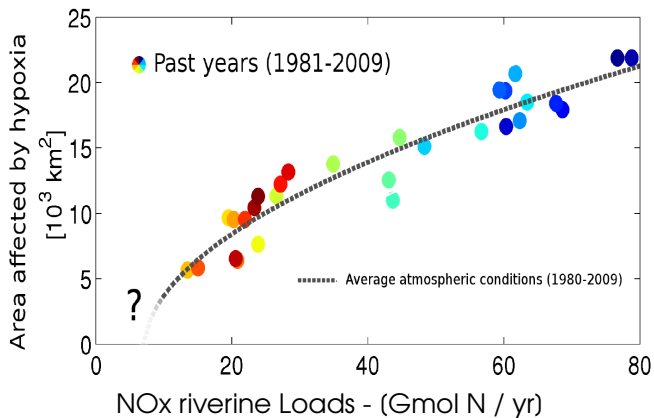


# H response to drivers





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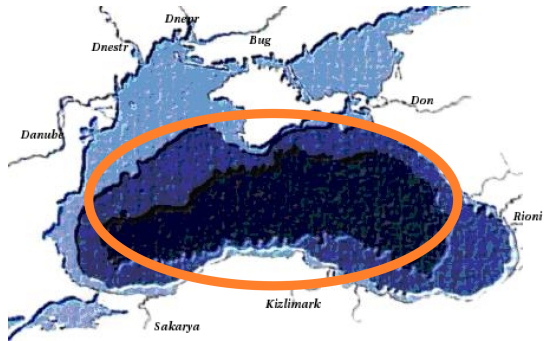




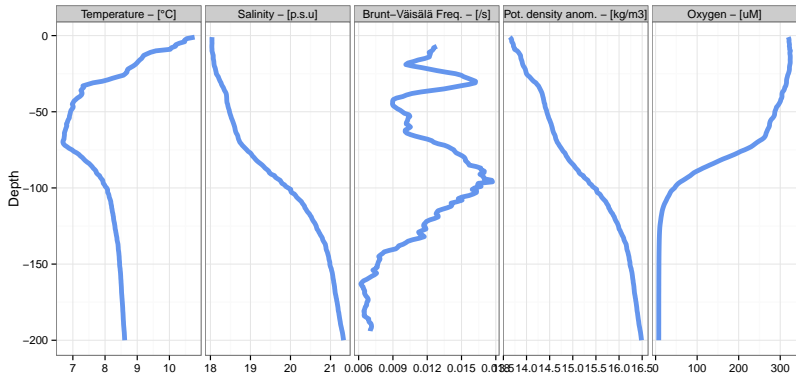


## Open Sea

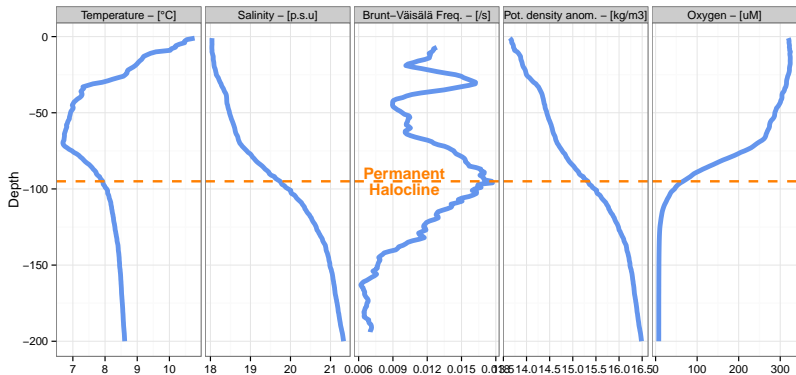
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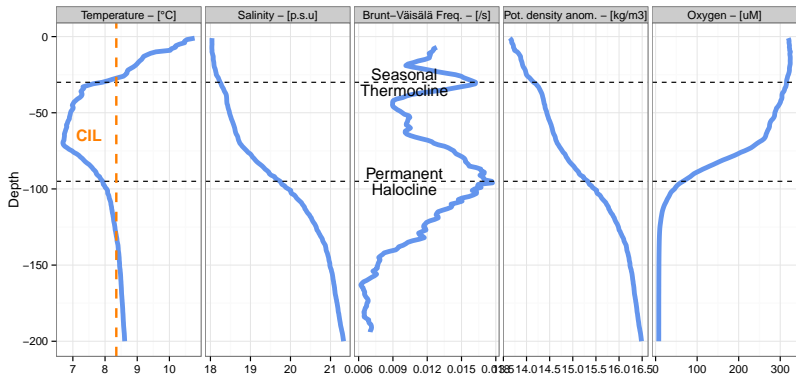
# Vertical structure



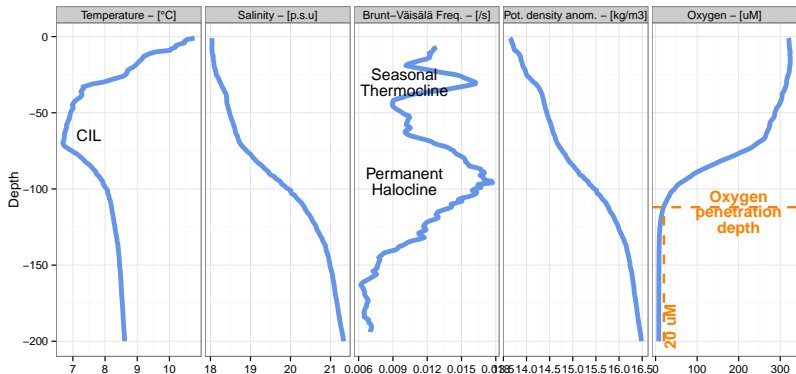
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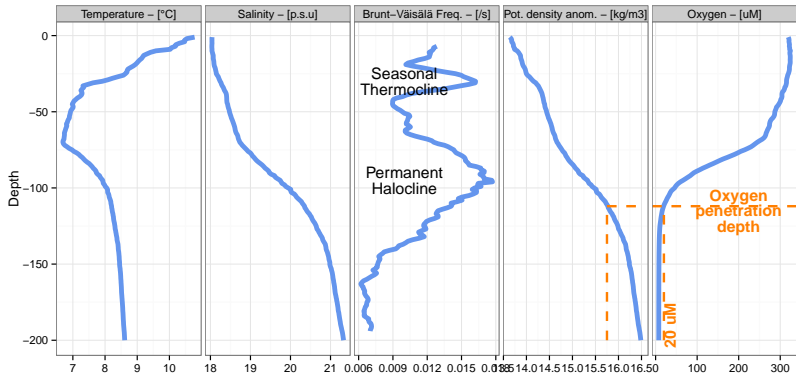


## Diagnostics of oxygen vertical structure

- ▶ Oxygen penetration depth
- ▶  $\sigma_\theta$  at oxygen penetration depth
- ▶ oxygen inventory



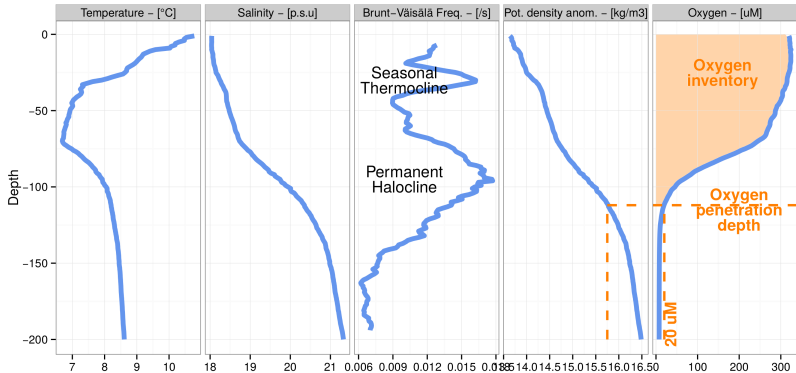
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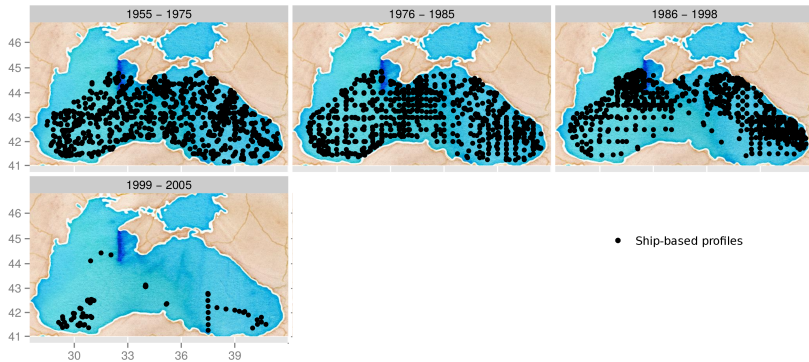
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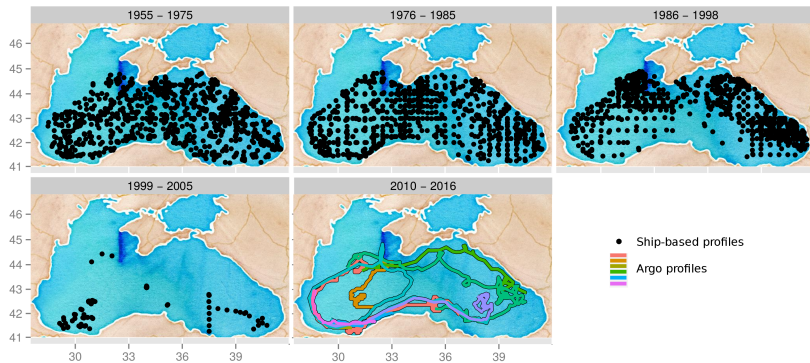
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# Profiles Data



- ▶ World Ocean database, R/V KNORR 2003, R/V Endeavour 2005
- ▶ Argo

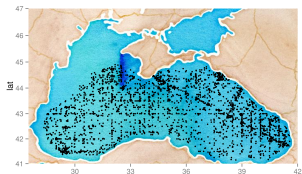
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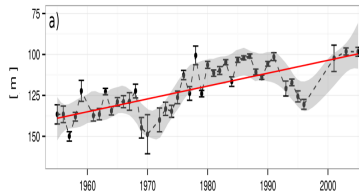
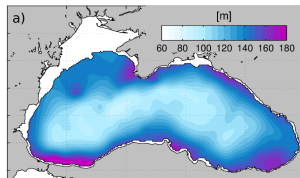
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# Detrending

Data



Spatial Variability

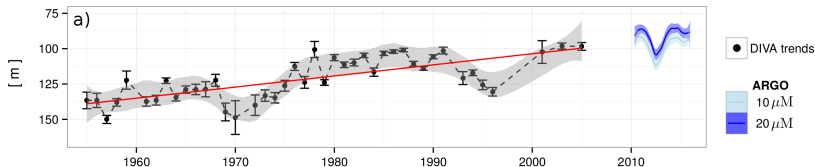


Temporal Variability

Data Interpolation Variational Analysis + detrending algorithm

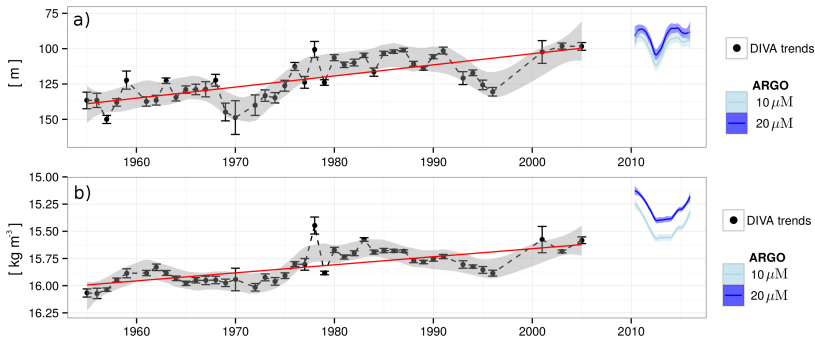
# Interannual trends

- ▶ Oxygen penetration depth (1955 – 2015) : 140m → 90m
- ▶ Oxygen penetration  $\sigma_\theta$  :  $16.05 \text{ kg m}^{-3}$  →  $15.4 \text{ kg m}^{-3}$
- ▶ Oxygen inventory (1955 – 2015) : -44%



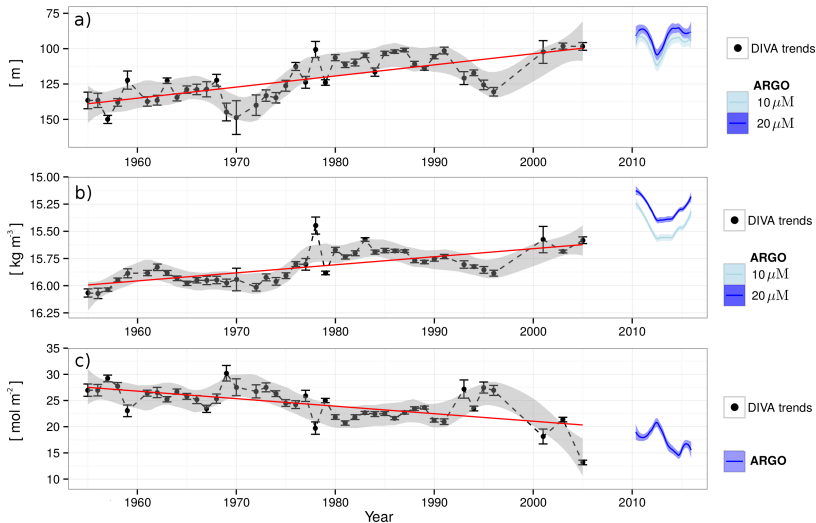
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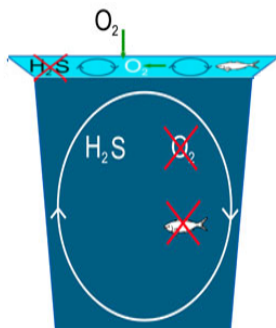
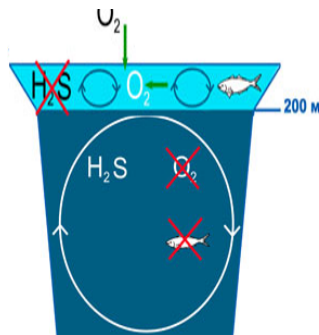






# Concerning issues

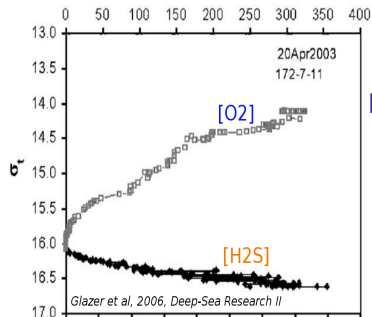
- ▶ What about the fish ?
- ▶ What about H<sub>2</sub>S ?
- ▶ What about synergy between Coastal and Open Sea deoxygenation ?



- ▶ Habitat compression

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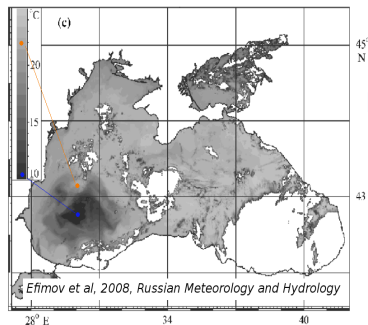


May 2003 significant (H<sub>2</sub>S) concentrations at 80m.

Oct 2005 Quasi-tropical cyclone upwells water from 30 m depth in 5 days.

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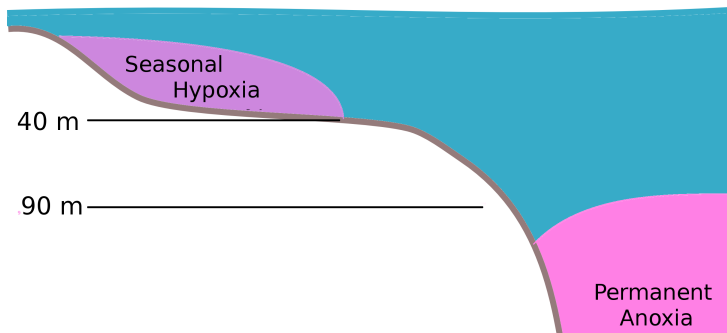


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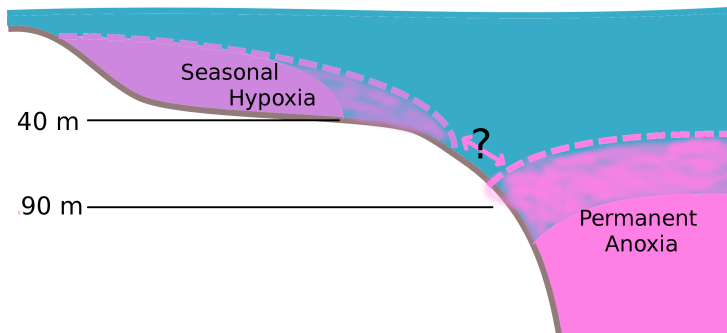
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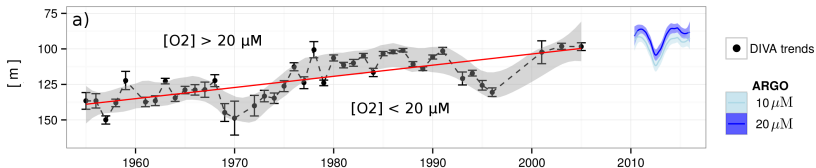
# Take-home message

- ▶ **Northwestern shelf: ongoing seasonal hypoxia**  
H response to N loads increased by
  - ▶ benthic accumulation
  - ▶ warming
- ▶ **Open Sea : shoaling oxycline**  
Black Sea oxygen inventory: -44% in the last 60 years.



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H response to N loads increased by
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- ▶ **Open Sea : shoaling oxycline**  
Black Sea oxygen inventory: **-44% in the last 60 years.**



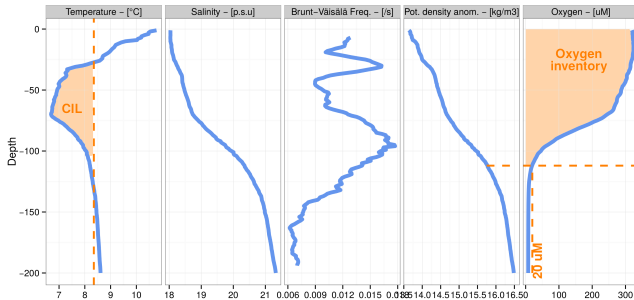
# Thanks for your attention ... ... and questions

More info on :

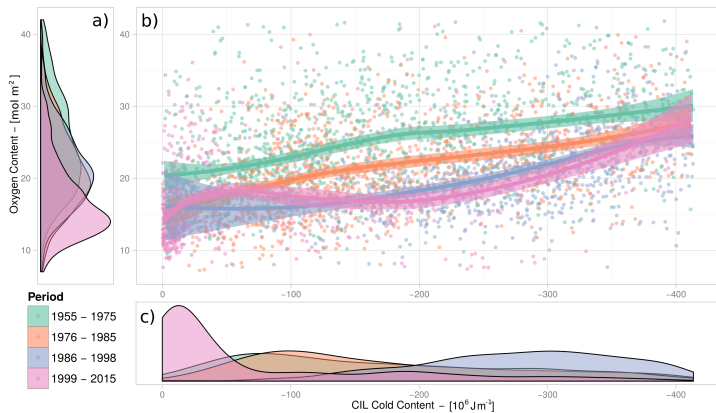
- ▶ Seasonal hypoxia on the northwestern shelf:  
Capet et al, 2012, *Biogeosciences*
- ▶ Decline of the Black Sea oxygen inventory:  
Capet et al, 2016, *Biogeosciences*, *In press*
- ▶ DIVA detrending algorithm:  
Capet et al, 2014, *Ocean Dynamics*



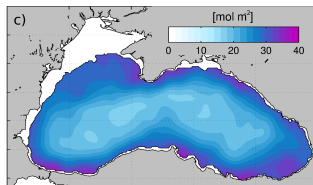
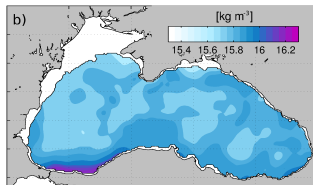
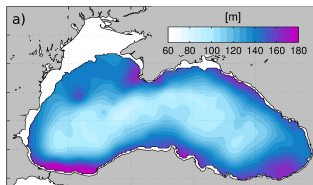
# CIL VS Oxygen inventory



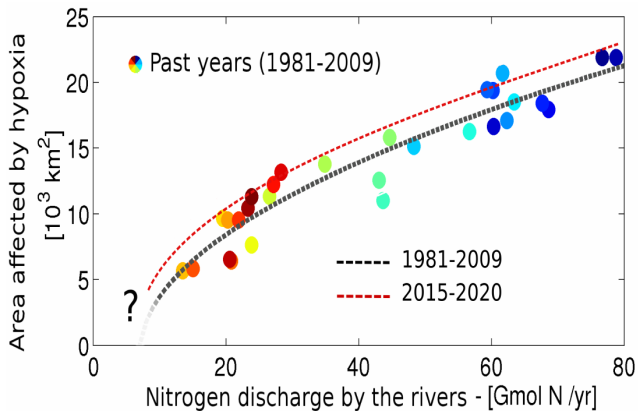
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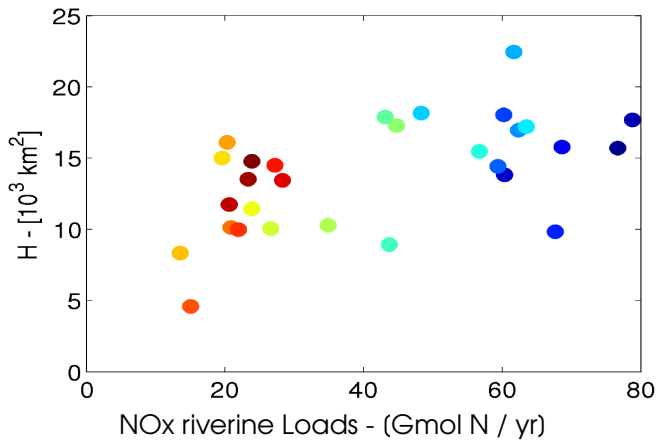
# Spatial variability



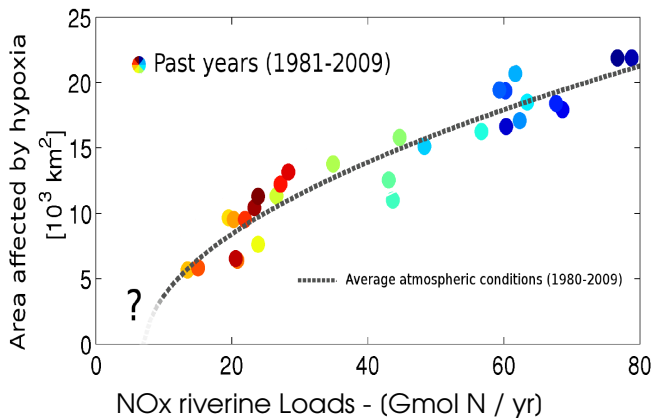
# H index



# H response to drivers



# H response to drivers







# Drivers of interannual variability

(1) High nitrogen riverine discharge enhance the influx of organic matter to bottom waters

(2) High sedimentary organic carbon content enhances the benthic oxygen consumption.

(3) Warm springs reduce the ventilation and set summer bottom temperature.

(4) Warm summers extend the duration of the stratified period.

