Decline of the Black Sea Oxygen Inventory:
Foreseeing future evolution and consequences

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The world's largest anoxic basin

THE Black Sea is quasi-enclosed and permanently stratified basin. Exposed to large external pressures, its ecosystem is highly sensitive and prone to large and quick response.

Oxygen conditions are challenged by the combination of two main drivers

- Eutrophication, peaking in the 80's.
- Warming, starting from the 2000's.

Seasonal hypoxia

SEASONAL hypoxia appeared on the northwestern shelf in the 80's following **eutrophication** that :

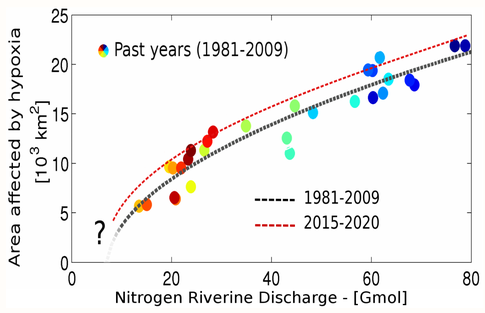
(1) enhances organic matter rain to bottom waters

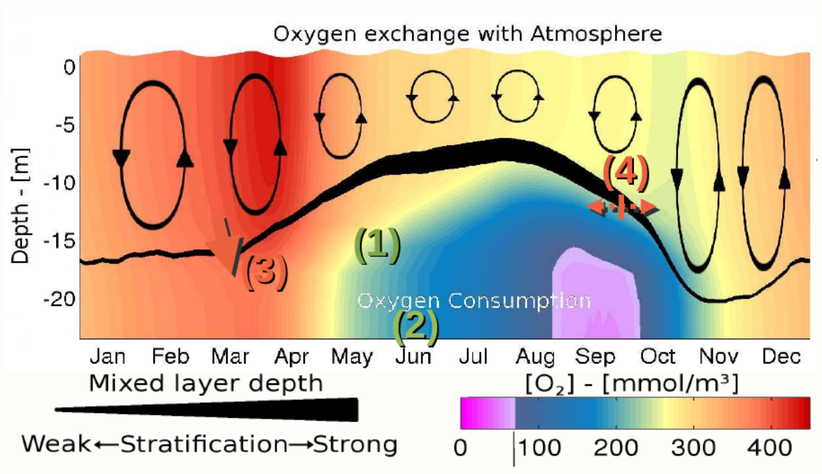
(2) accumulates organic matter in sediments,

and is now sustained by global **warming** that :

(3) restricts the spring ventilation,

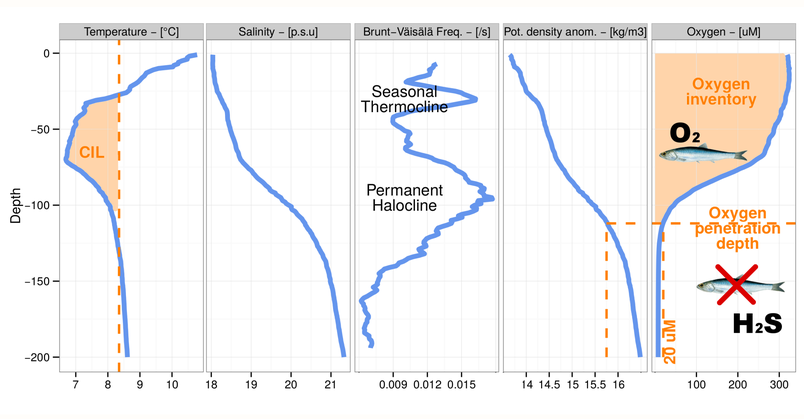
(4) elongates the stratification period.



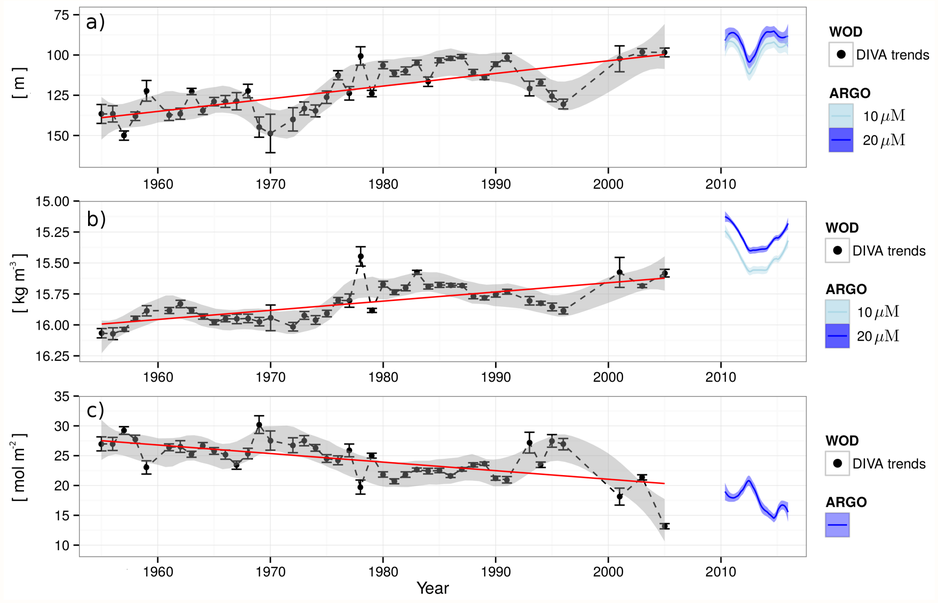


Shoaling of the oxycline

IN the open sea, where permanent anoxia prevails, the limit between oxic and anoxic waters migrated upward during the last decades.



Three diagnostics derived from vertical profiles: oxygen inventory $[\mathrm{mol\,m^{-2}}]$, oxygen penetration depth $[\mathrm{m}]$, oxygen penetration depth on a density scale $[\mathrm{kg\,m^{-3}}]$.



Deoxygenation trends in the Black Sea basin. The volume of oxygenated water has decreased by 44% from 1955 to 2015.

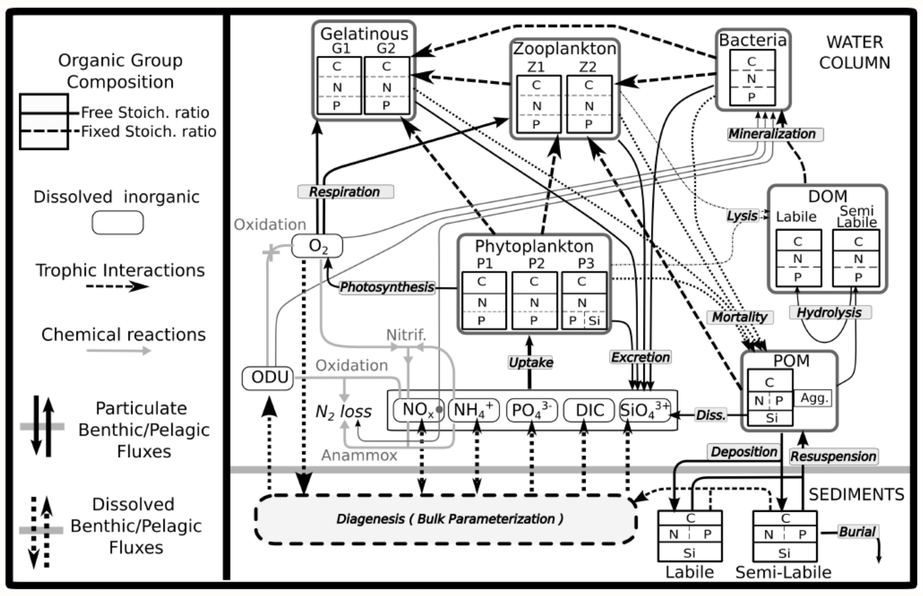
Societal Challenges

AS deoxygenation threathens marine resources and services, foreseeing its evolution is a strategic challenge. Policy-makers should be informed about:

- How will oxygen distribution evolve in the **short, mid and long term future** ?
- May **habitat compression** jeopardizes the survival of fishery stocks ?
- May **hydrogen sulphide** excursions threatens marine and coastal populations ?

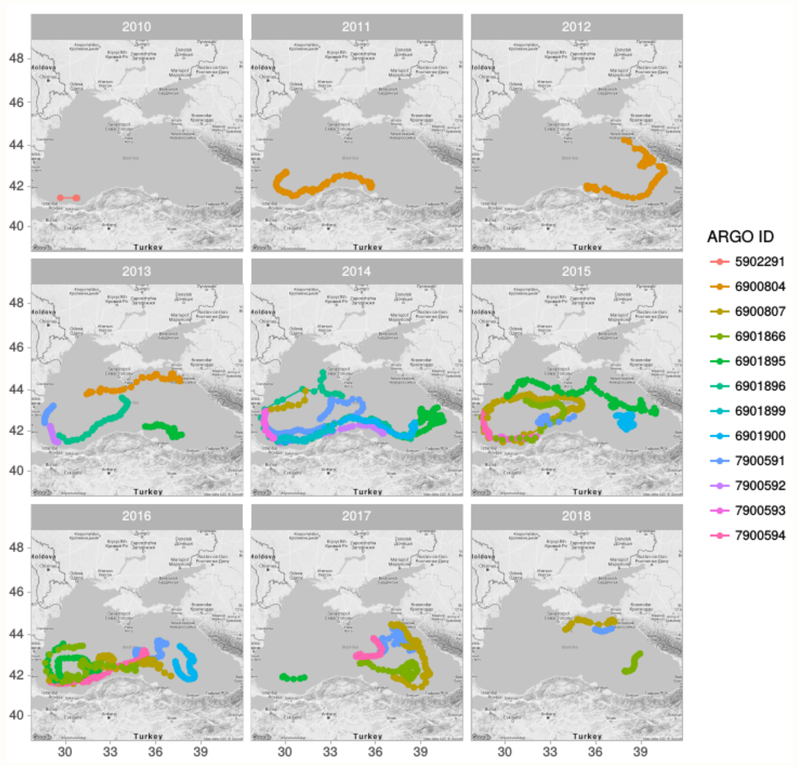
Models

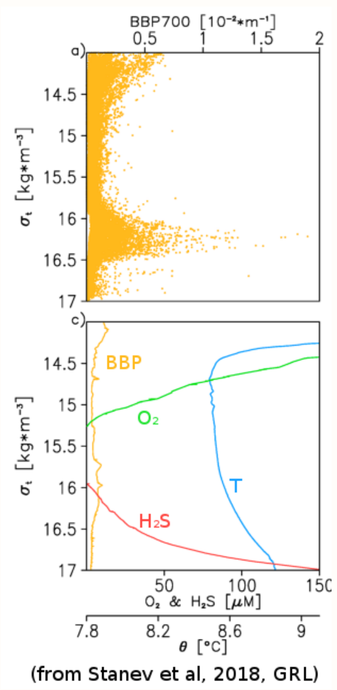
BAMHBI (BiogeochemicAl Model for Hypoxic and Benthic-Influenced area) is a "quite-complex" model (~ 30 State Variables), focusing on benthic-pelagic exchanges and suboxic biogeochemical processes. It is coupled with 3D circulation models for operational (*NEMO*, CMEMS) and process-oriented studies (*GHER*). In addition, a 1D set-up has recently been implemented for development, sensitivity, calibration, and MCMC studies (R framework, FME).



Observations

BGC-Argo Floats presents an opportunity to better constrain the oxygen cycle worldwide. In particular the **detrital loop**, **light penetration** and **suboxic biogeochemistry** are all key sub-surface elements of the basin-scale oxygen dynamics which are poorly constrained by current data set.





(from Stanev et al, 2018, GRL)

Data assimilation challenges

WE target a general biogeochemical data assimilation methodology that

- incorporates sub-surface BGC-Argo observations.
- allows to recognize the uncertainty stemming from the inherent diversity of BGC mediators (plankton, bacteria)
- enhances the reliability of scenario simulations by improving models rather than model results,
- ensures dynamical consistency and conservation in order to keep track of BGC fluxes (eg. C, N, O 2), in terms of transport and transfer among various pools.

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