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Hypoxia in the Black Sea northwestern shelf: From eutrophication to climatic stressors

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PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS
SEVENTH FRAMEWORK PROGRAMME
Biogeoscience, 10(6), 2013

Objective

Hypoxia affected the Black Sea north-western shelf since the late 70's, with severe consequences on ecosystem health and fisheries resource.

This study intents to **isolate the main factors controlling the interannual variability of hypoxia.**

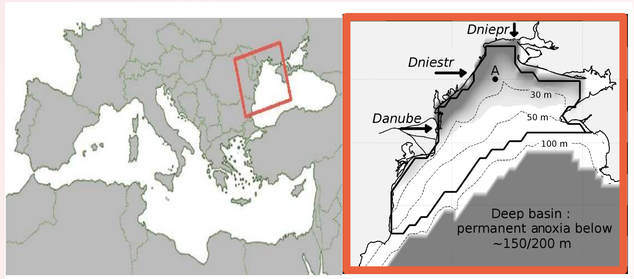

Fig. 1: Enclosed coastlines, shallow depths, and important riverine nutrient discharges (indicated by the arrows) leads to seasonal occurrence of bottom hypoxic conditions (shaded area, Fig. 4 details the seasonal and vertical oxygen dynamics for point A). While the model domain cover the entire Black Sea, the analysis is focused on the northwestern shelf (black contour).

Approach

A **3D biogeochemical model** (GHER) is used to integrate the multivariate aspects of the dynamic behind hypoxia (e.g. mixing and circulation, planktonic dynamics, light penetration, diagenesis, surface fluxes, suboxic chemistry, …).

Specific validation procedures assert the model ability to resolve spatial, seasonal and interannual variability of hypoxia.

Our general approach consists in simplifying a posteriori the complexity of the 3D model results and analyzing the resulting times series by means of statistical tools.

Hypoxia occured every year since the late 70's

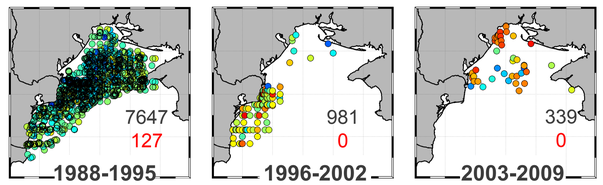

Fig. 2: Numbers of available oxygen measurements (black) and of measurements below 2 mg/l (red). (Datas from World Ocean Database & Black Sea Comission).

Because of the spatial and seasonal variability, **incomplete monitoring** led to **overestimate the recovery** from hypoxia**.**

This is revealed by the model being able to reproduce the observations used to presume the recovery, while simultaneaously predicting hypoxia at unmonitored locations.

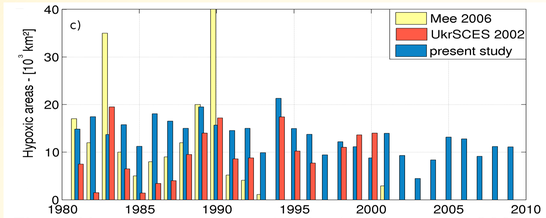

Fig. 3: Hypoxic areas reported by (1) Mee et al., 2006, Scientific American, in situ measurements; (2) Ukraine National Report, 2002 ; (3) Capet et al., 2013, modeling.

Eutrophication and climate both control hypoxia

(1) High nitrogen riverine discharge enhance the influx of organic matter to bottom waters, i.e. the consumption of oxygen where respiration can not be matched by photosynthesis.

(2) High sedimentary organic carbon content enhances the benthic oxygen consumption. This delays (~10yrs) the response of hypoxia to nutrients discharge reduction.

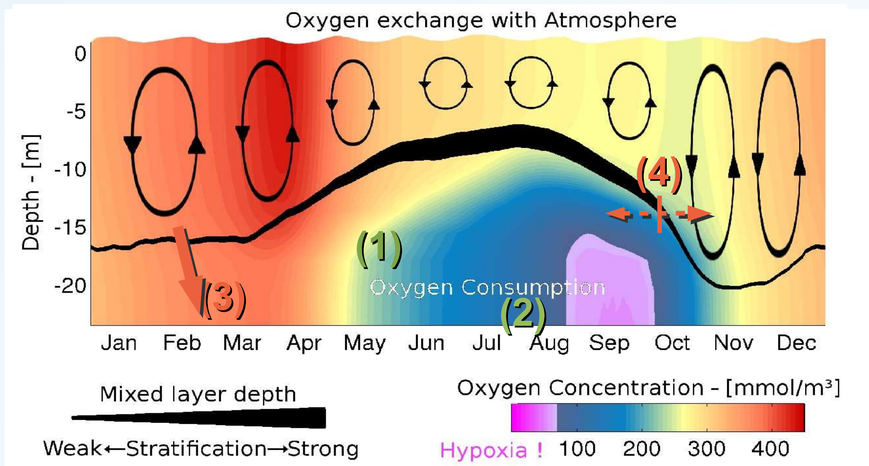

Fig. 4: The annual evolution of a vertical profile of oxygen concentration illustrates the mechanisms leading to the occurrence of hypoxia. The four key factors controlling the interannual variability are indicated.

(3) Warm springs reduce the ventilation of bottom waters, by reducing the oxygen solubility of surface waters just before the onset of the stratification.

(4) Warm summers extend the duration of the stratified period, hence delays the ventilation when hypoxia is at his strongest.

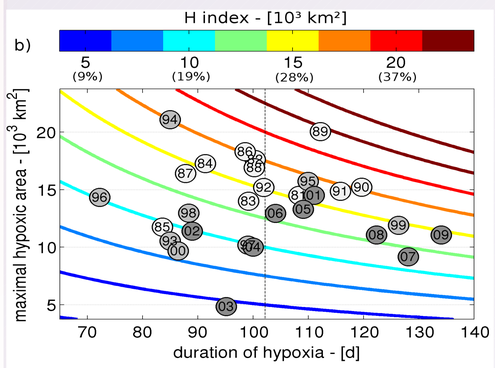

Fig. 5: The intensity of hypoxia is indexed according to the spatial and temporal extension of the hypoxic event

And now ?

During the **eutrophication** period (before 1980-1992), hypoxia is induced by very high **riverine nitrogen discharge**.

During the **recovery** period (1993-2003), hypoxia was sustained by the **organic sedimentary stocks** accumulated during the eutrophication period.

During the last decade **warming summers** increased the duration of the hypoxia event.

Future warming conditions will enhance the sensitivity to nutrients discharge.

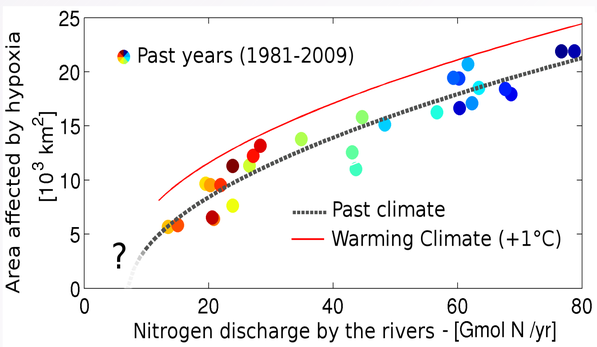

Fig. 6: The intensity of hypoxia is indexed according to the spatial and temporal extension of the hypoxic event