Preliminary analysis on formation mechanisms of summer low oxygen zone in the Bohai Sea

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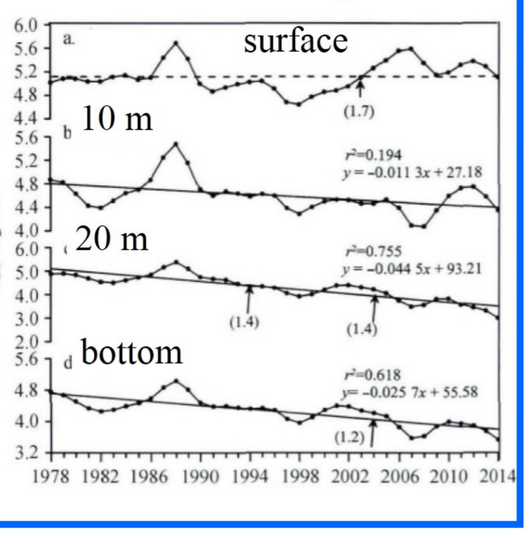
Background

In recent forty years, bottom low dissolved oxygen (DO) conditions in summer have indicated an intensifying trend (Fig. 1) in the Bohai Sea (BS), which imposes great stress on marine ecosystems and implies the need for effective management to improve eco-environments.

The formation of low oxygen zone results from the interaction of physical and biogeochemical processes. The formation of low oxygen zone results from the interaction of physical and biogeochemical processes.

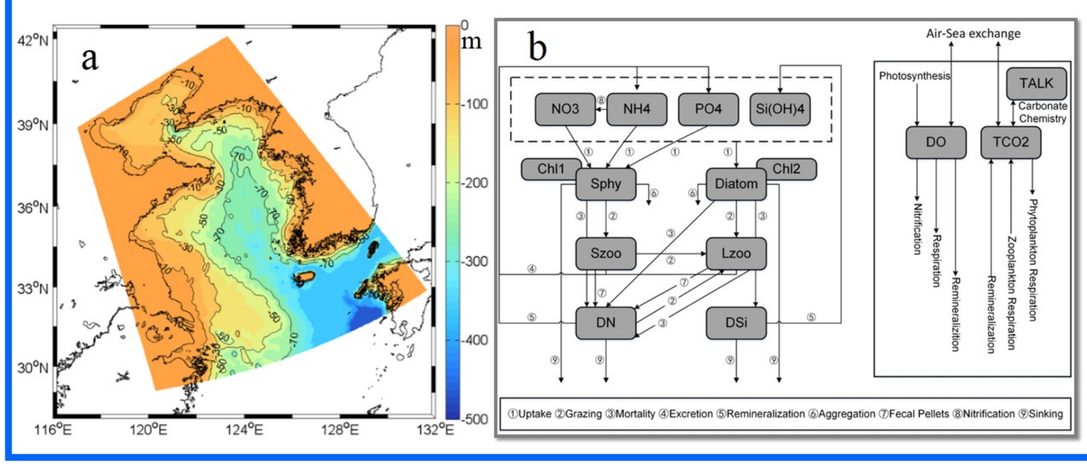
Fig. 1 DO variation in recent years (from Shi, 2016)



Methods and Materials

To explore oxygen dynamics and low-oxygen formation mechanisms, a coupled physical-biological model (**ROMS-CoSiNE**) is established, covering the BS and the Yellow Sea (YS), with a horizontal resolution from 2.2~4.0 km. Atmospheric conditions are from the ECMWF ERA-Interim. Open boundaries are from HYCOM and includes eight tidal constituents.

Long term observations (1978-1999) of temperature, salinity and DO are also analyzed.



The biological model includes NO_3, PO_4, $Si(OH)_4$, and two kinds of phytoplankton, zooplankton and contains oxygen and carbon cycles.

Fig.2 Model domain(a), biological schematic(b).

Analysis of long term trend

- Bottom DO concentration shows a decreasing trend (Fig.3) which is controlled by biological processes rather than physical conditions.

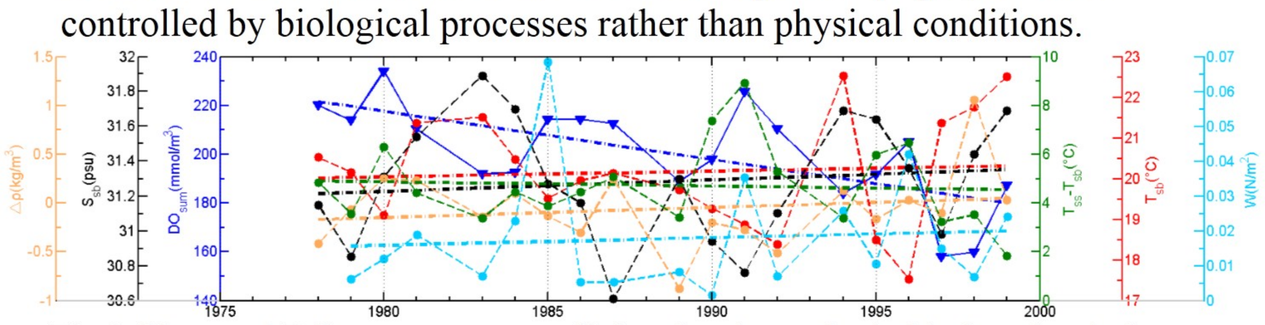


Fig.3 Observed DO, temperature, salinity, density and wind induced turbulence.

$$\mathbf{DO = DO_{sat} - \gamma * exp(0.055 * T_{sb})};\ \gamma = 2.991 * exp(0.065 * (year - 1970))$$

$$\mathbf{DO = DO_{sat} - 2.991 * exp(0.065 * (year - 1970)) * exp(0.055 * T_{sb})}$$

- Regression analysis proposes a relationship, emphasizing the importance of biological oxygen consumption SOC and/or WR (SOC: Sediment Oxygen Consumption, WR: Water column Respiration).
- Increasing biological oxygen consumption implies an aggravation of eutrophication, corresponding to chlorophyll increasing.

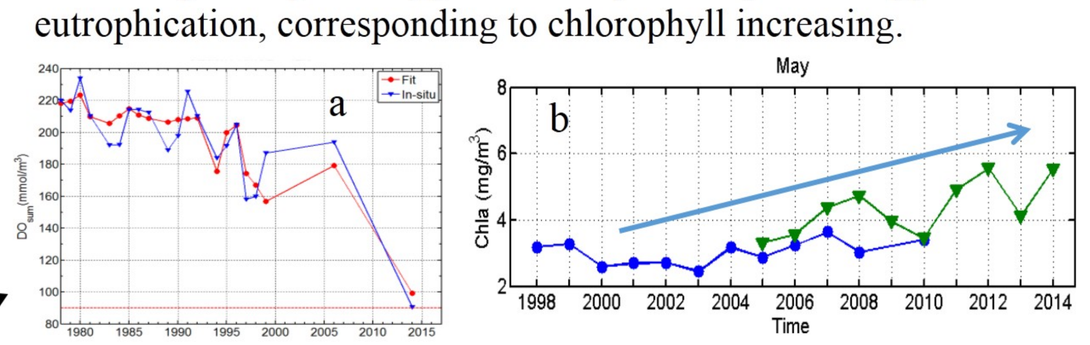


Fig.4 Bottom DO fit (a) and surface chlorophyll from SeaWiFS and MODIS (b).

Distribution of low DO zone

- The model reproduces bottom low DO zone (DO < 3 /4 mg/L) and its seasonal variation in the BS.
- Two low DO cores are distributed near Qinhuangdao and Yellow River estuary, respectively.
- Low DO areas correspond to spatial distribution of cold water masses.

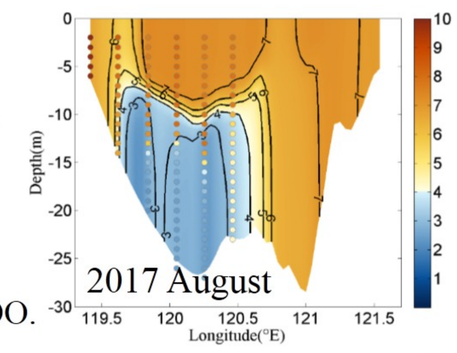


Fig.5 Simulated (map) and observed (dots) DO.

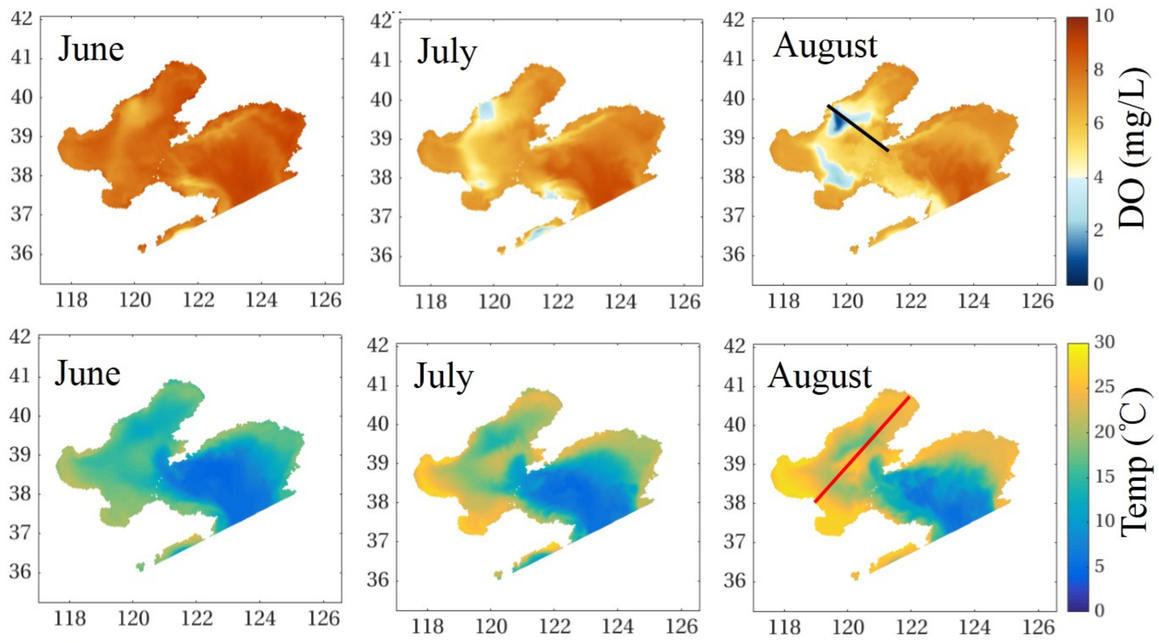


Fig. 6 Simulated bottom DO and temperature in June, July and August.

- Low DO conditions are confined by vertical thermocline and horizontal front which are controlled by temperature structures.

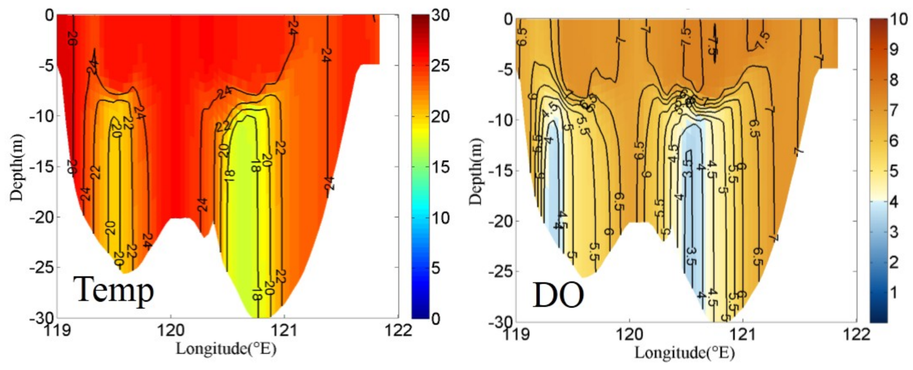


Fig.7 Simulated temperature (℃) and DO(mg/L) in August at the central transect, which is indicated by a red line in Fig. 6.

- Significant differences in DO minima and low DO extent with different mineralization rate of bottom organic matter.
- SOC plays an important role in controlling oxygen evolution and low DO extent in the BS.

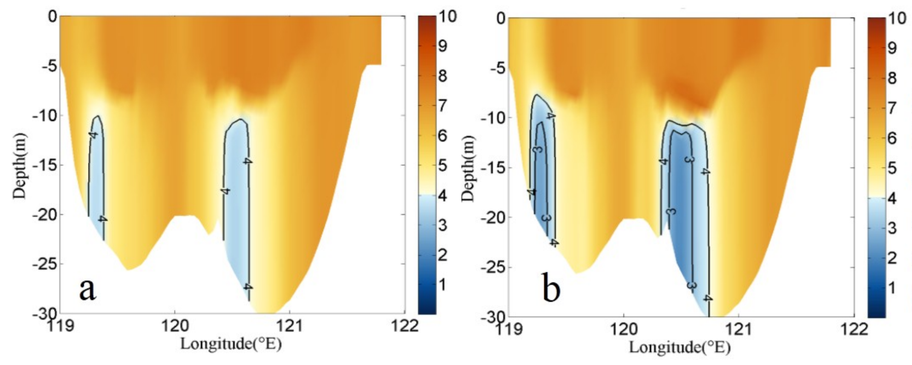


Fig. 8 Simulated DO (mg/L) distributions in August at the central transect with mineralization rate of $0.7d^{-1}$ (a) and $0.5d^{-1}$(b) respectively.

Summary

- The decreasing of bottom DO concentrations is controlled by biological rather physical processes, induced by eutrophication aggravation.
- Bottom DO concentrations become unsaturated in June and reach a minimum in August in the BS.
- Low DO areas correspond to spatial distribution of cold water masses, which determines water column stratification.
- SOC plays an important role in controlling oxygen evolution and low DO formation.
- Further studies are required to quantify contributions of physical and biological processes and investigate oxygen dynamics comprehensively in the BS.