

# Coastal acidification and deoxygenation/hypoxia: the other eutrophication problems

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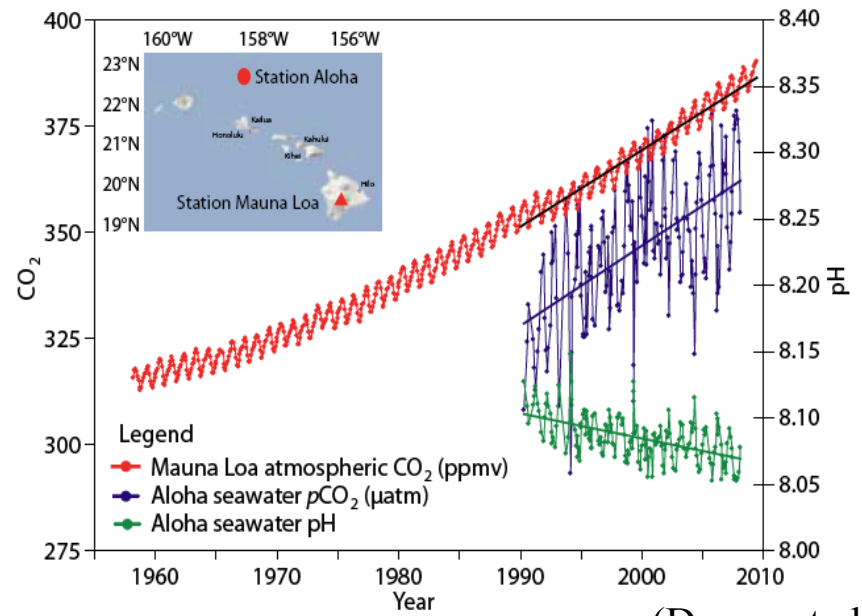
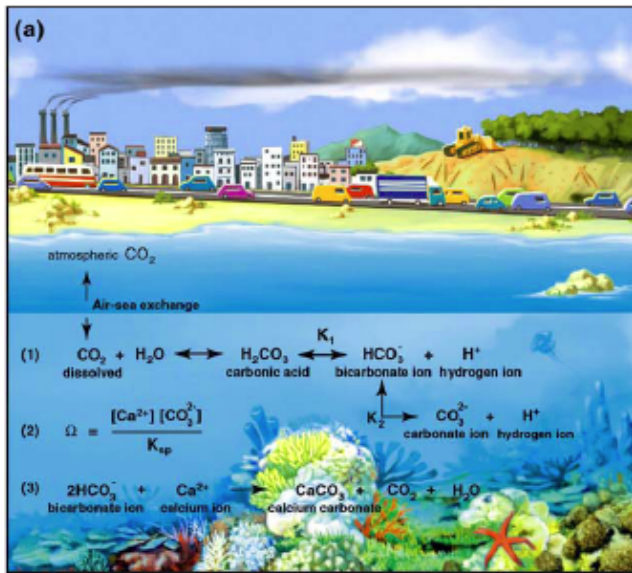


# Contents:

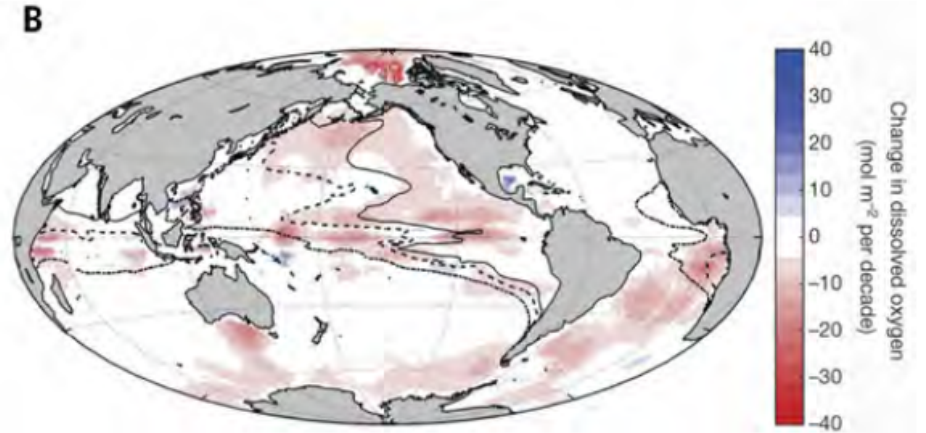
- Background
- Long-term changes of environmental parameters in the YS: Observations on deoxygenation and acidification
- Conceptual view and implications
- Concluding remarks

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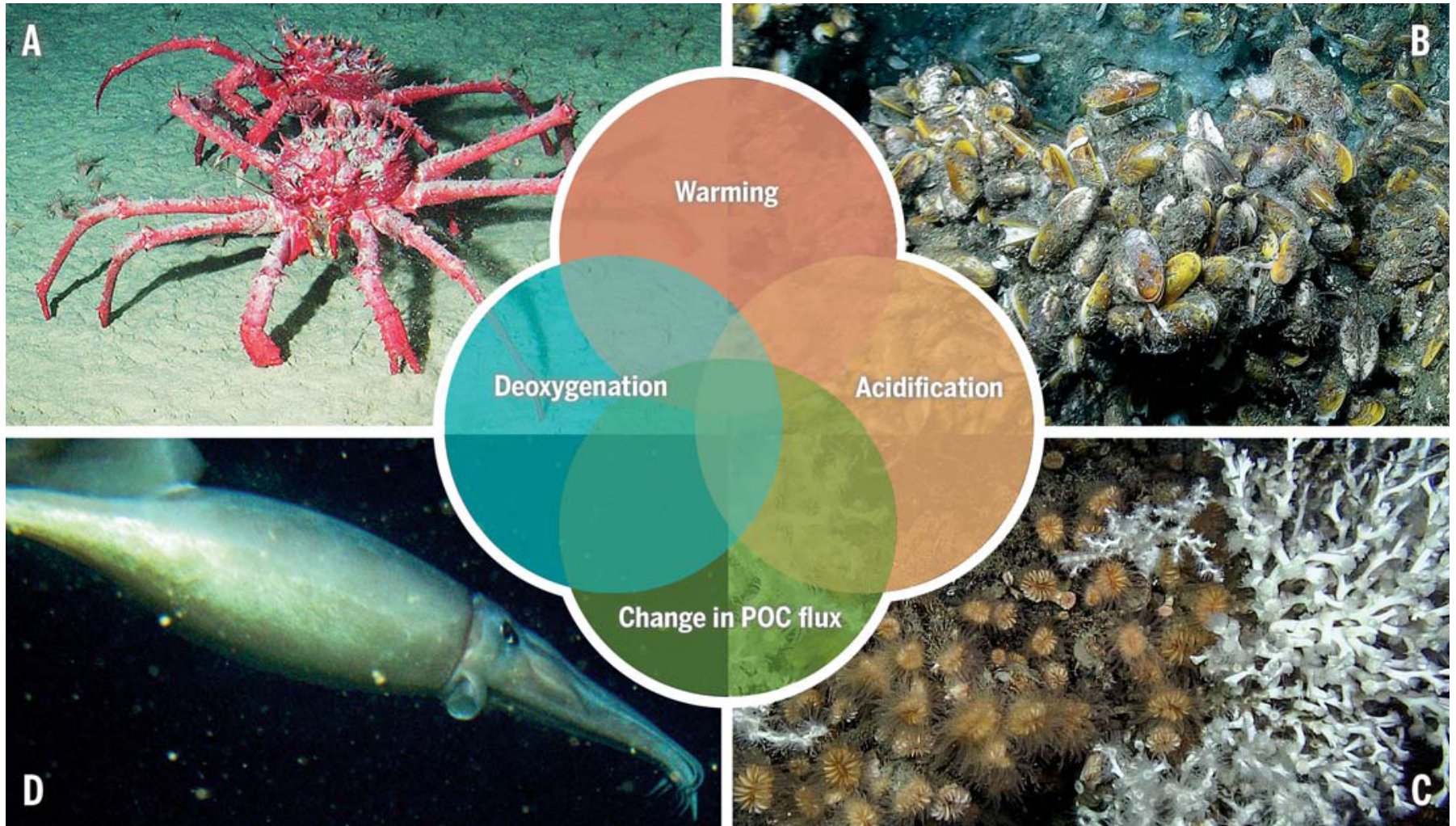
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(Doney et al. 2009)



(Breitburg et al. 2018)



(Levin and Le Bris, 2015)

# Impacts of deoxygenation on ecosystems

Eukaryotic biomass and diversity not limited by oxygen unless increasing temperature increases oxygen demand above oxygen supply

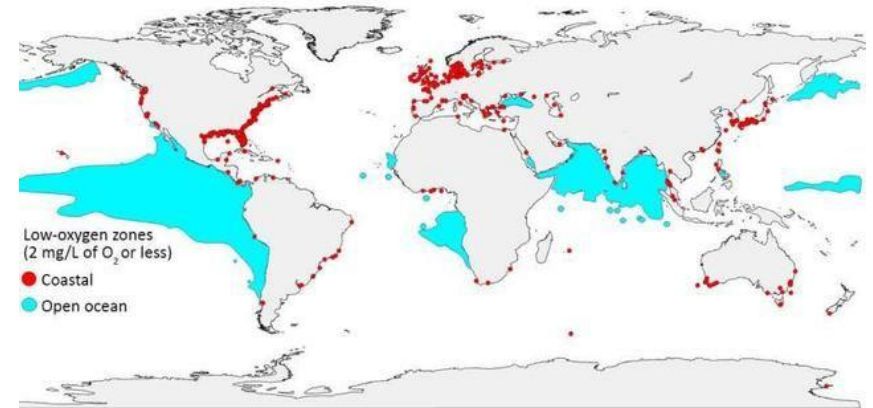
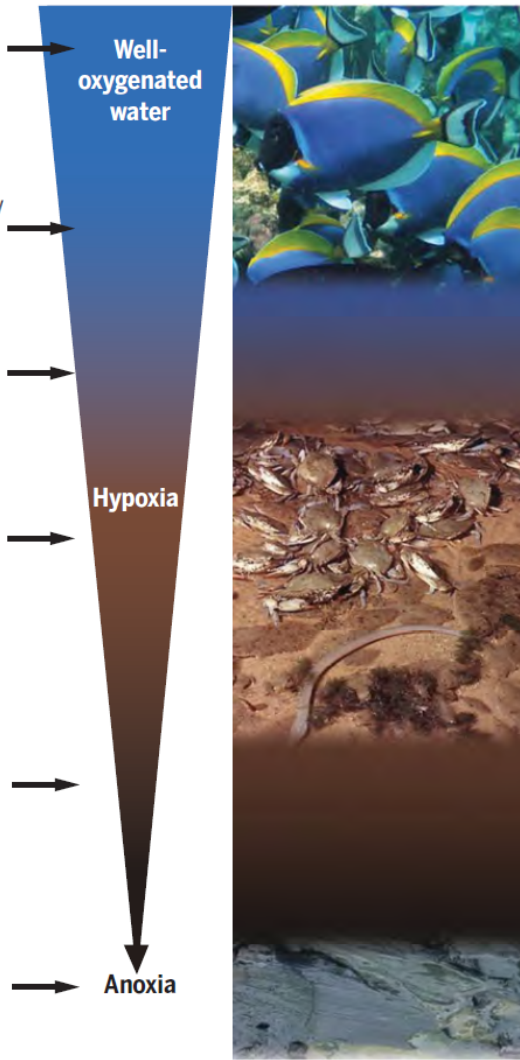
Fishing boats target finfish and invertebrates found at high densities at the edge of low-oxygen zones where they escape physiologically stressful conditions and take advantage of prey that use this edge as a refuge habitat

Upwelling of low-O<sub>2</sub>, high-CO<sub>2</sub> waters can kill and displace fish and benthic invertebrates, but high nutrients in upwelled waters fuel high productivity

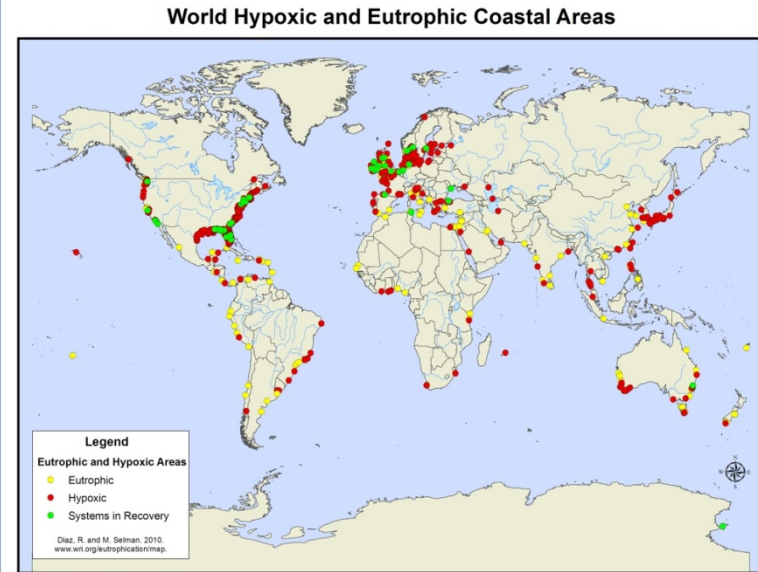
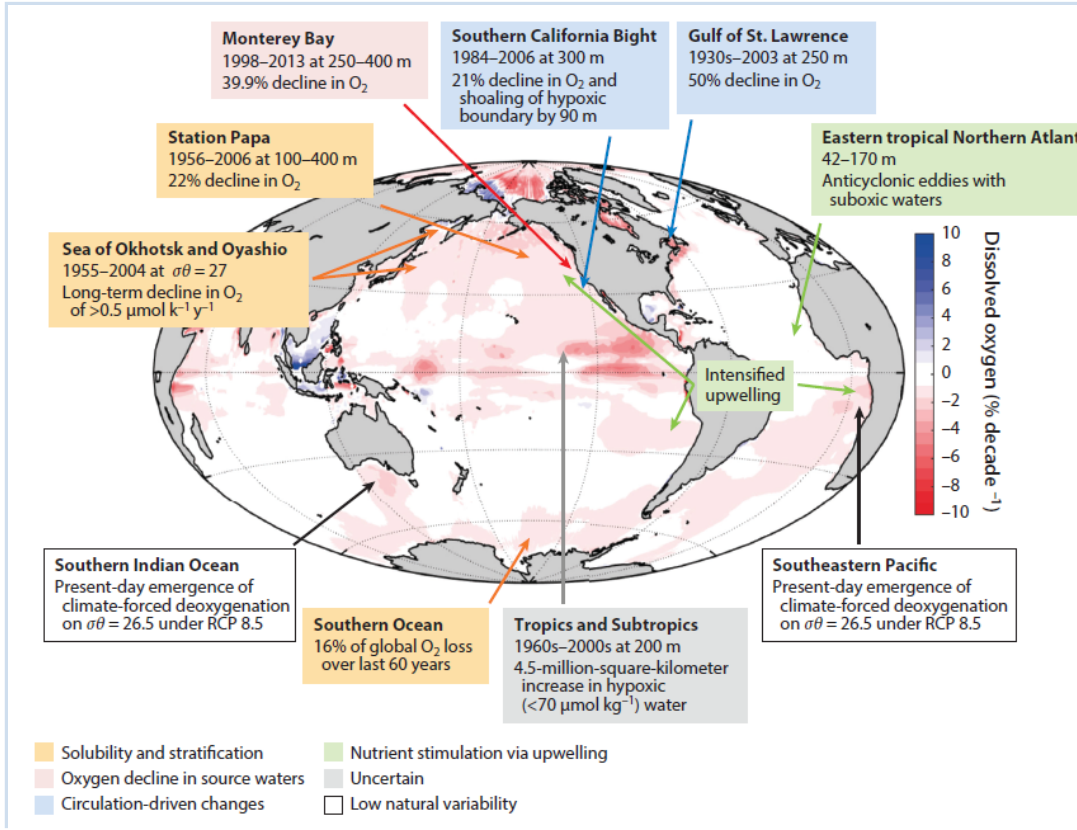
Organisms inhabiting low-oxygen habitats have evolved physiological and behavioral adaptations, but when tolerances are exceeded, survival, growth, and reproduction decline

Global warming is expected to continue to worsen deoxygenation in the open ocean, and both increasing nutrient loads and warming could worsen future deoxygenation in coastal waters

Absence of eukaryotes dependent on aerobic respiration; increased denitrification, production of N<sub>2</sub>O, and release of Fe and P from sediments



# Hotspots of deoxygenation



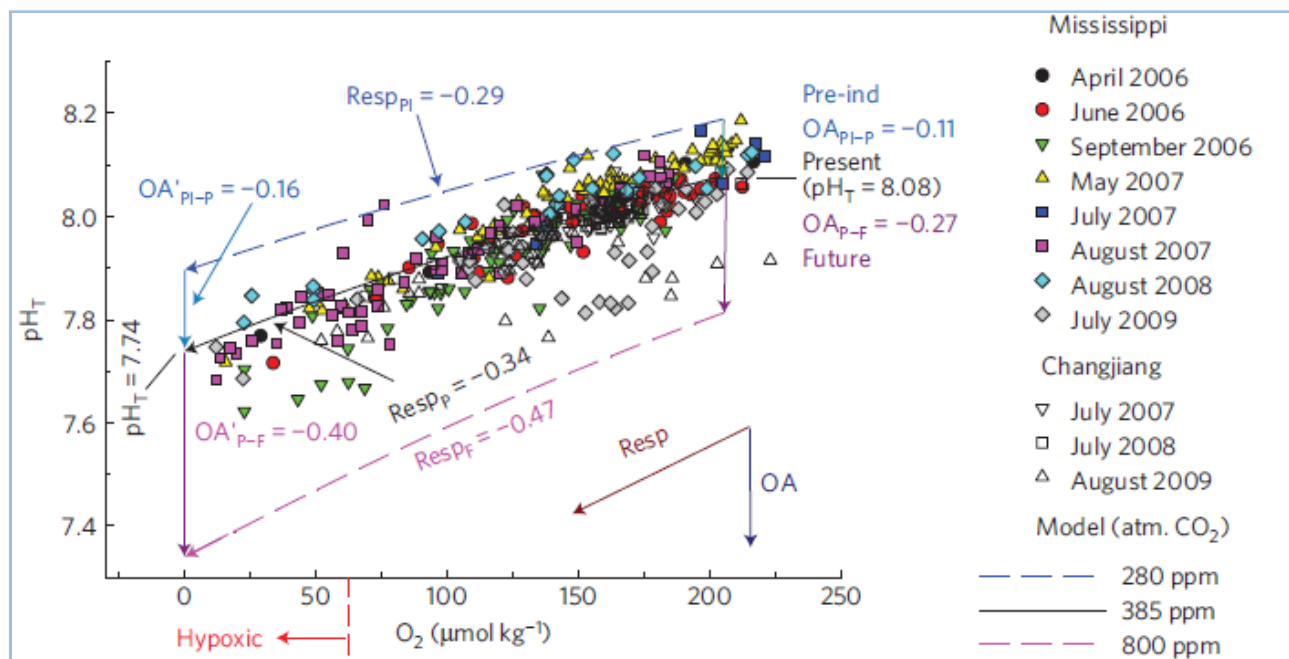
(Breitburg et al. 2018)

Deoxygenation and hypoxia in coastal waters and open ocean has been a global environment issue.

- ✓ OMZ is expanding.
- ✓ More and more hypoxic zones in the coastal area.

# Acidification of subsurface coastal waters enhanced by eutrophication

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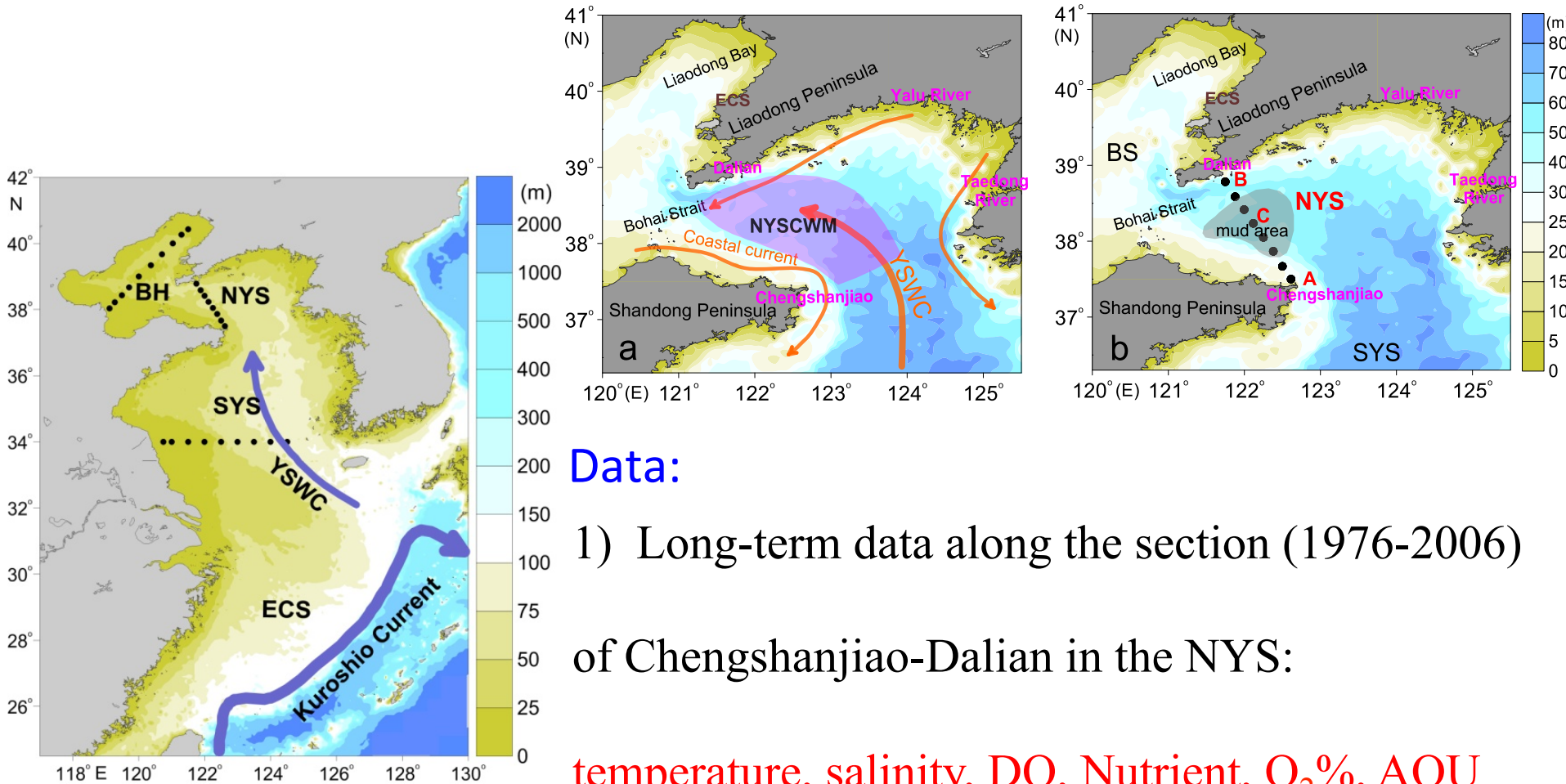




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# Study area



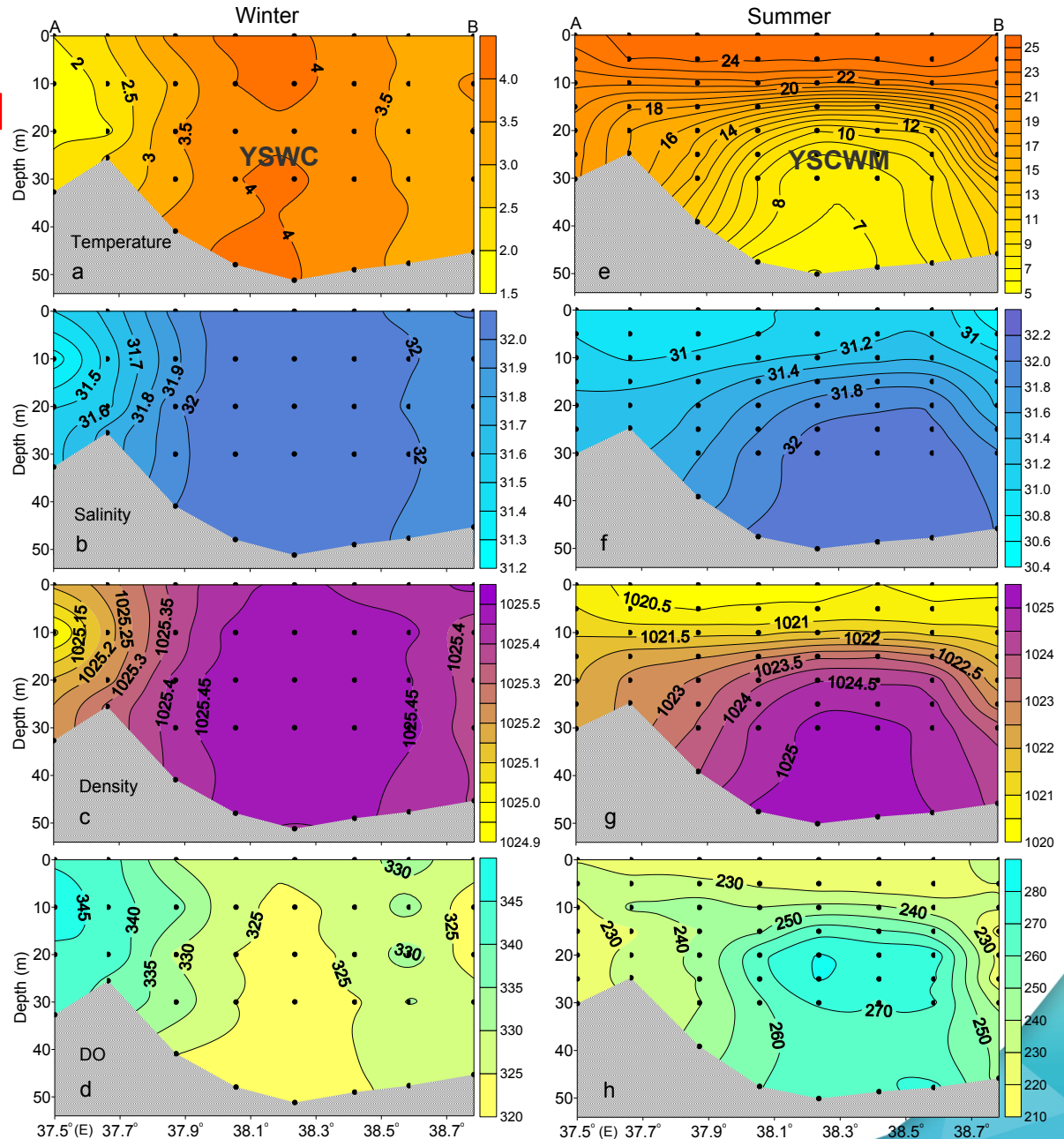
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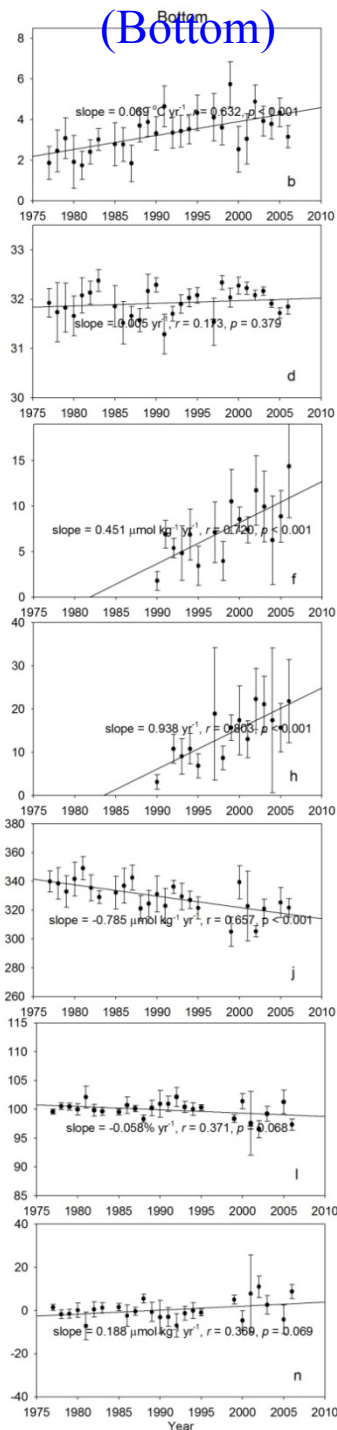
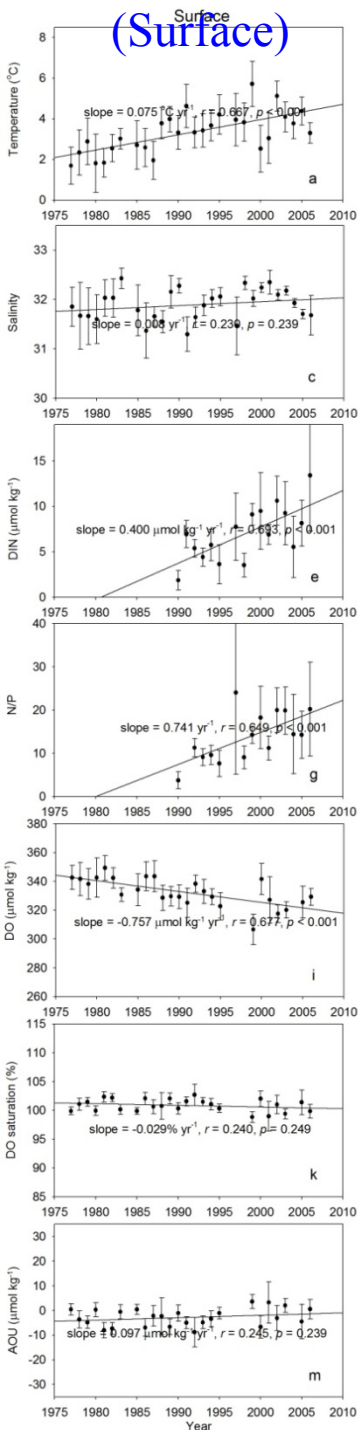
- 1) Long-term data along the section (1976-2006) of Chengshanjiao-Dalian in the NYS: temperature, salinity, DO, Nutrient, O<sub>2</sub>%, AOU
- 2) Sea surface Chl-a derived from multiple-satellite products of SeaWiFS and MODIS

# Climatologic vertical distributions:

Vertical mixing winter

Stratified summer





# Winter

- Temperature: increased
- Salinity: almost no changes
- DIN and N/P: increased
- DO: decreased

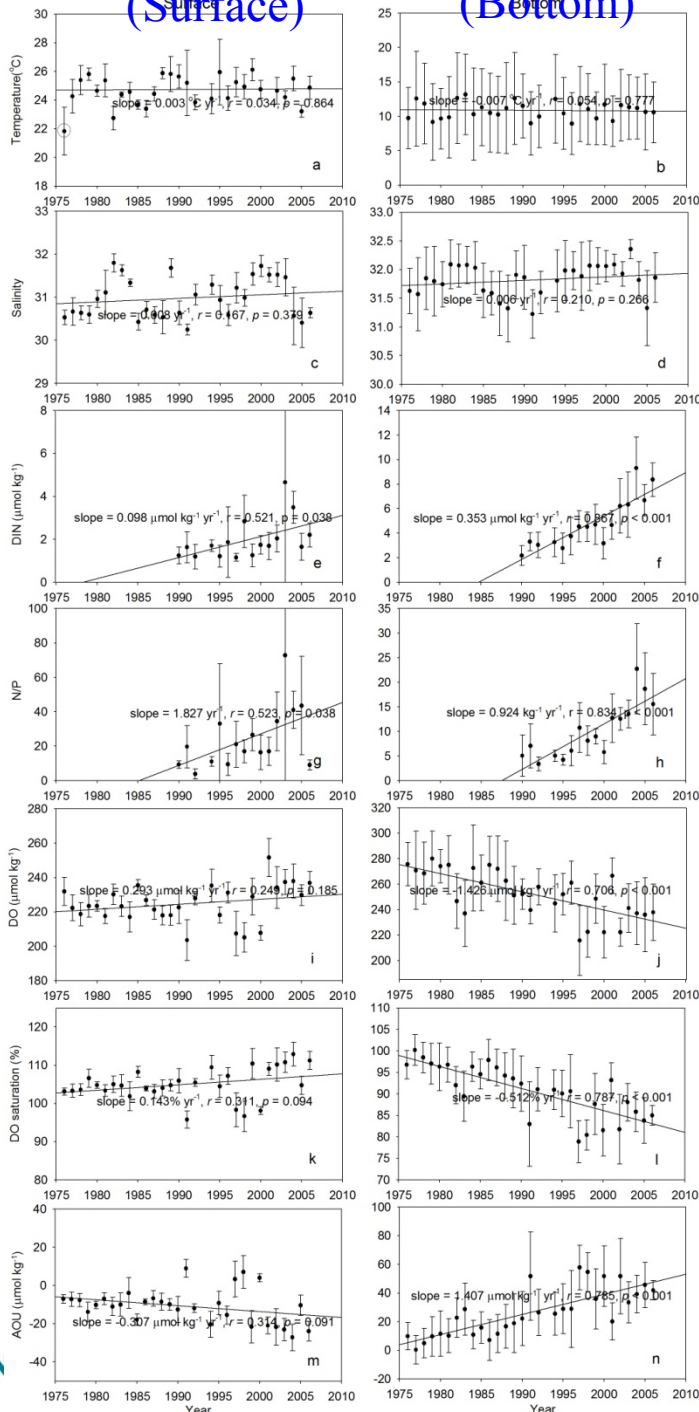
(~0.76 and ~0.78 µmol kg<sup>-1</sup> yr<sup>-1</sup> in surface and bottom, respectively)

- DO saturation and AOU: almost no changes

(Surface)

(Bottom)

# Summer



➤ Temperature and salinity:

almost no changes

➤ DIN and N/P: increased

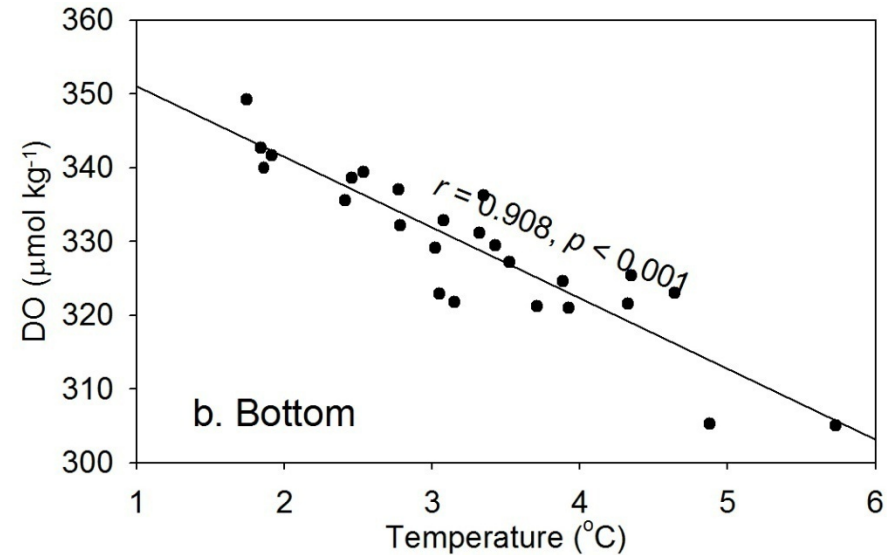
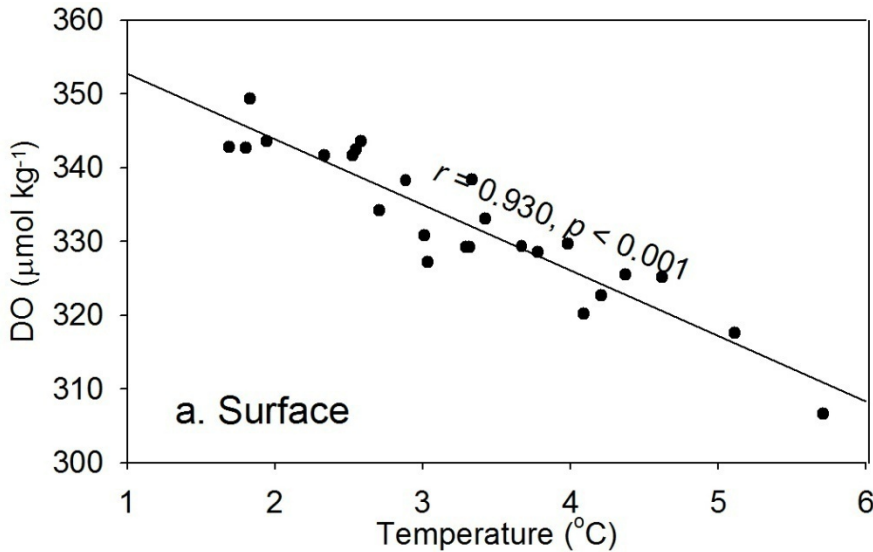
➤ DO: decreased in bottom

(~1.43 μmol kg<sup>-1</sup> yr<sup>-1</sup>)

➤ DO saturation: decrease in bottom

➤ AOU: increased in bottom

# Winter deoxygenation

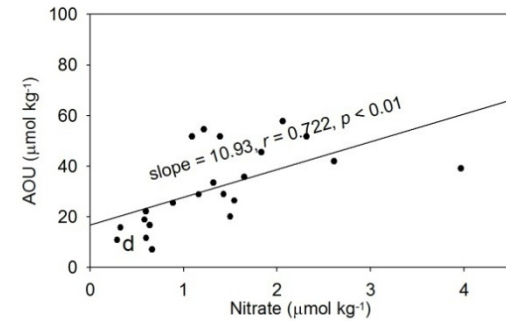
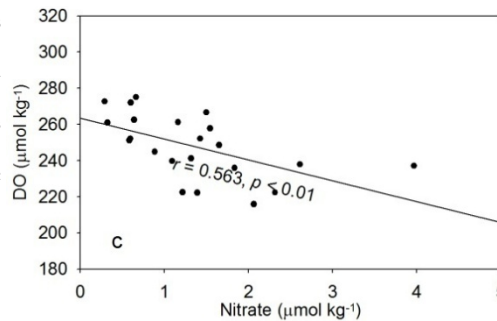
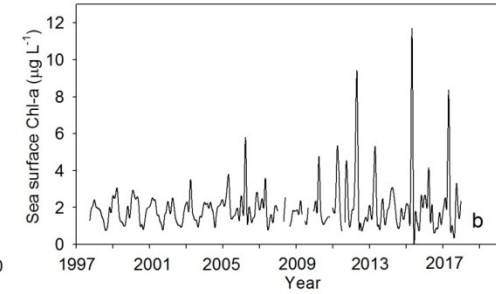
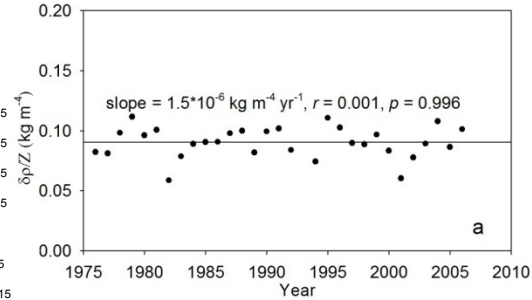
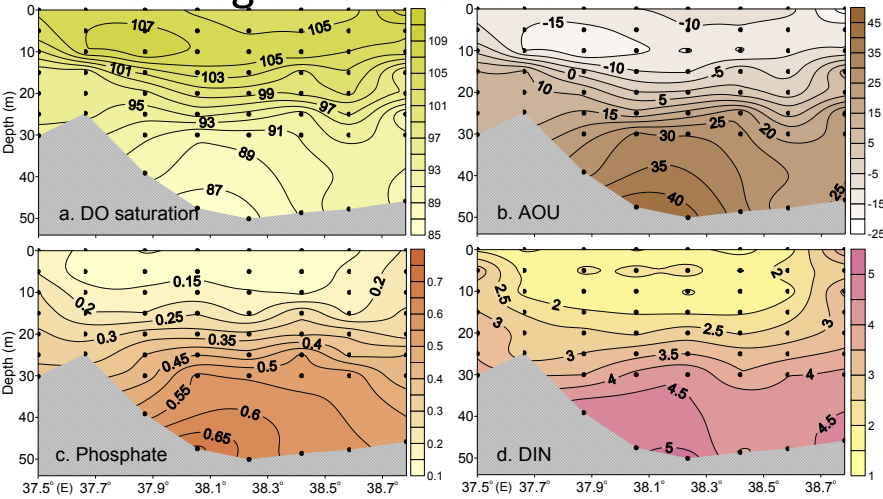


## Relations between the annual average DO content and temperature

➤ In winter, when the water column is vertical homogeneous, DO at near-saturation indicates that physical mixing overwhelmed biological activities, and a linear correlation between DO content and seawater temperature suggests that warming is the most plausible driver of deoxygenation in this region in winter.

# Summer deoxygenation

## Climatologic distributions:



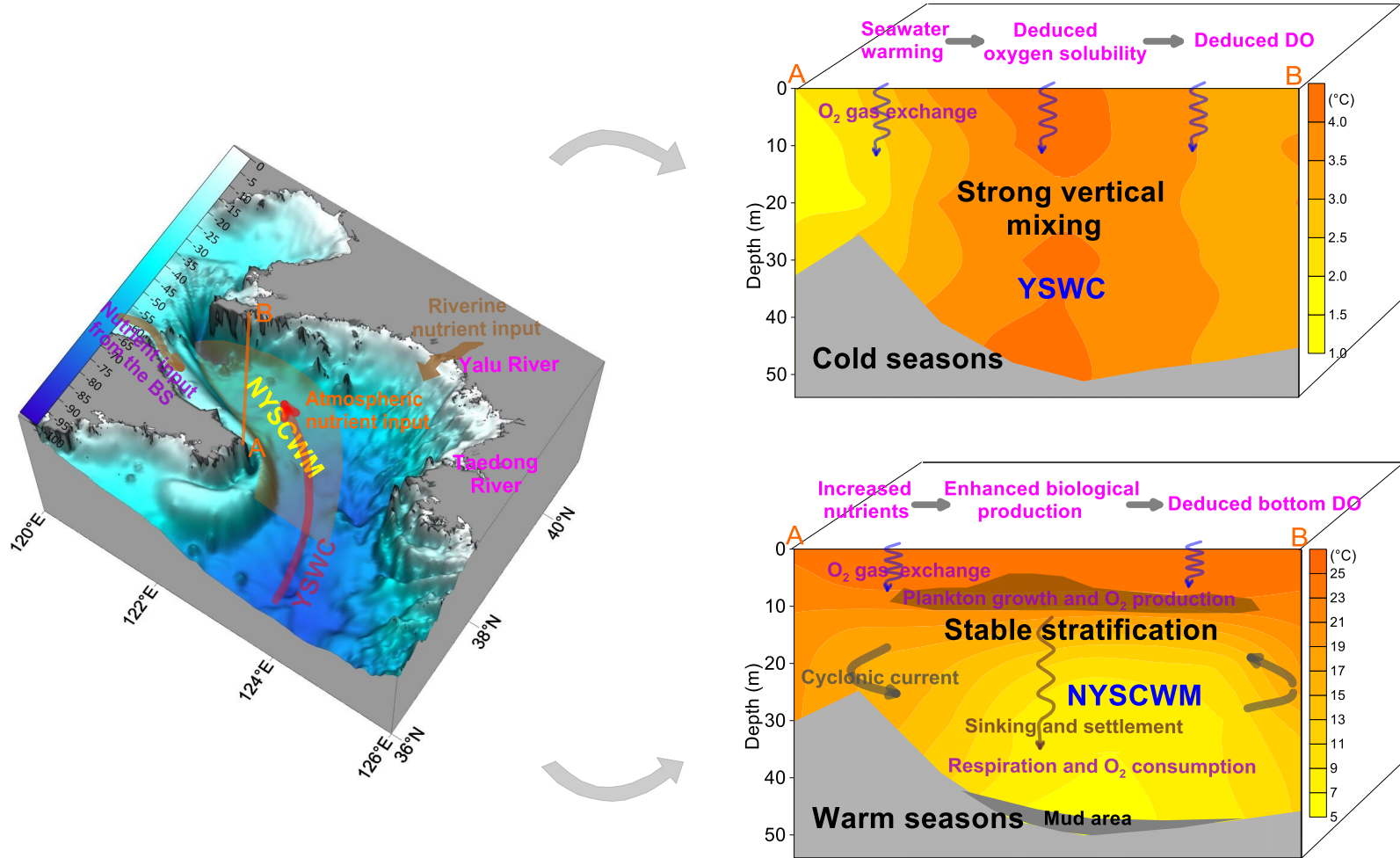
In the stratified summer, increased nutrient availability and consequently enhanced productivity are reasonable for the drawdown of DO in the bottom layer, and the stoichiometric pattern between DO depletion and N also suggests a cascading linkage between the eutrophic conditions and bottom deoxygenation.

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# Conceptual view of deoxygenation



Showing the different mechanisms of DO declining in seasonality

# Concluding remarks

- Shows the drawdown of DO in winter and in the bottom layer in summer ( $\sim 0.76$  and  $\sim 0.78 \mu\text{mol kg}^{-1} \text{yr}^{-1}$  in surface and bottom in winter, respectively;  $\sim 1.43 \mu\text{mol kg}^{-1} \text{yr}^{-1}$  in summer), which is accompanied with seawater warming (especially in winter) and enhanced nutrients.
- In winter, seawater warming is the most plausible driver of deoxygenation in the NYS.
- In the stratified summer, increased nutrient availability and consequently enhanced productivity are reasonable for the drawdown of DO in the bottom layer.

谢谢大家！

*Thank you*