

The role of over-winter oxygen dynamics in setting the spring-summer dissolved oxygen levels in a large ice-covered lake (Lake Simcoe)



Before this presentation, we should bring one question in our mind:

- Does the under-ice dissolved oxygen in winter show any ecological memory between lake phenological seasons ?

High frequency field measurements over 6 winters were conducted in Lake Simcoe: 2015~2017, 2022~2024



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Why care about deoxygenation of lakes?

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Climate-driven deoxygenation of northern lakes

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Article


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 Check for updates

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- Deoxygenation of lakes due to a combination of eutrophication and climate change is a pressing issue world-wide
- Many cold water fish need at least 6-7 mg/L of DO to survive

[1] Jansen J, Simpson G L, Weyhenmeyer G A, et al. Climate-driven deoxygenation of northern lakes[J]. *Nature Climate Change*, 2024, 14(8): 832-838.

[2] Jane S F, Hansen G J A, Kraemer B M, et al. Widespread deoxygenation of temperate lakes[J]. *Nature*, 2021, 594(7861): 66-70.

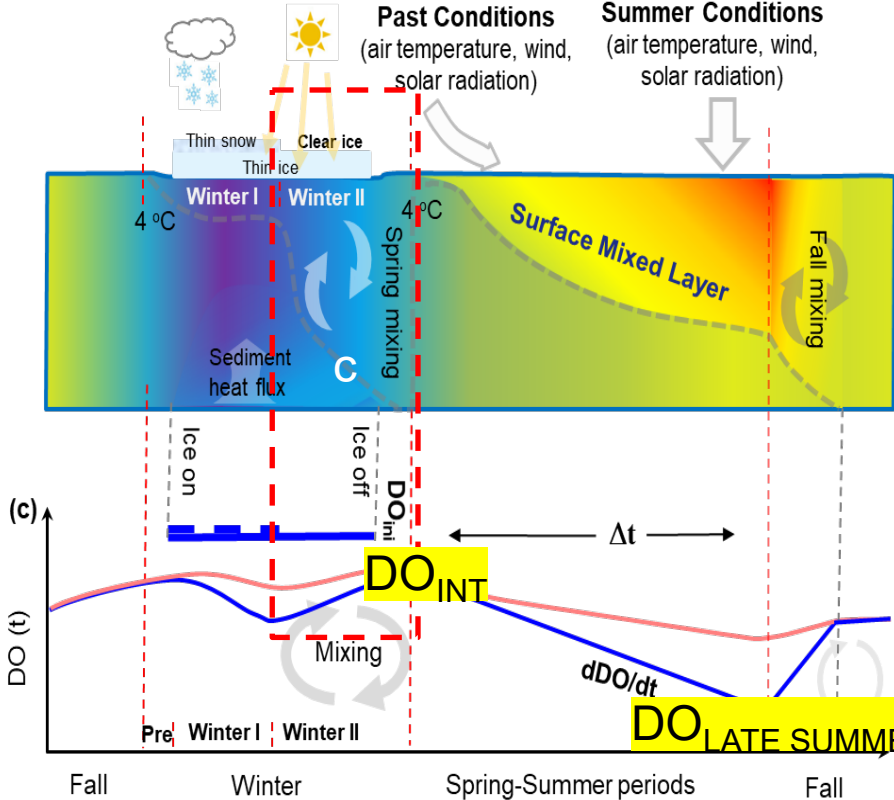
[3] Tu Z, Zhang Y, Shi K, et al. Landsat data reveal lake deoxygenation worldwide[J]. *Water Research*, 2024: 122525.

What are Possible drivers of deoxygenation in Dimictic Lakes?

1) Historically, open-water deoxygenation has been related to hypolimnion oxygen demand

Hypolimnion oxygen demand

- D1. Longer stratification (+t)
- D2. Increased oxygen sink (+dDO/dt)



2) How does initial values of DO_{INT} influence the late summer hypoxia (DO_{SUMMER})

Winter conditions

D3. A change in initial values ($-DO_{init}$)

Hypothesis: ecological memory ???

1. Most studied on summer hypoxic **are often separated to winter periods** due to the spring mixing; 2. If the mixing is **shorter** or **incomplete**, the winter DO depletion could last into the following summer seasons

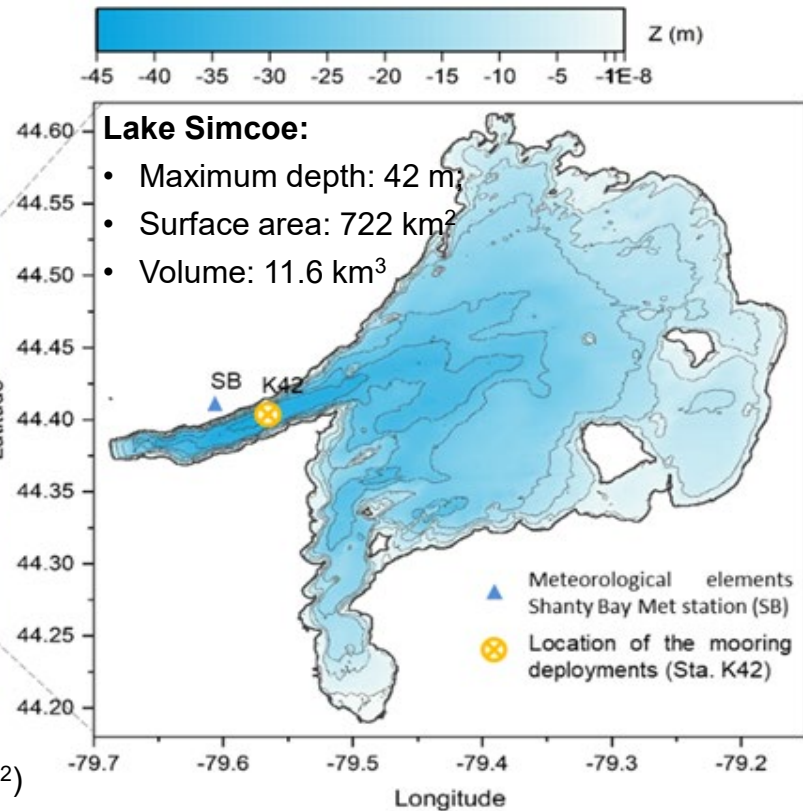
Scientific questions and study site:

Primary objective:1) Does the under-ice dissolved oxygen in winter show any **ecological memory** between lake phenological seasons ?

- **Datasets:** 6 years of high-frequency water temperature and DO



Great lakes: Superior (82100 km²), Michigan (58000 km²), Huron (59600 km²), Erie (25700km²) and Ontario (18960 km²)



1. DO dynamics over the 6 winters were closely related to water temperatures

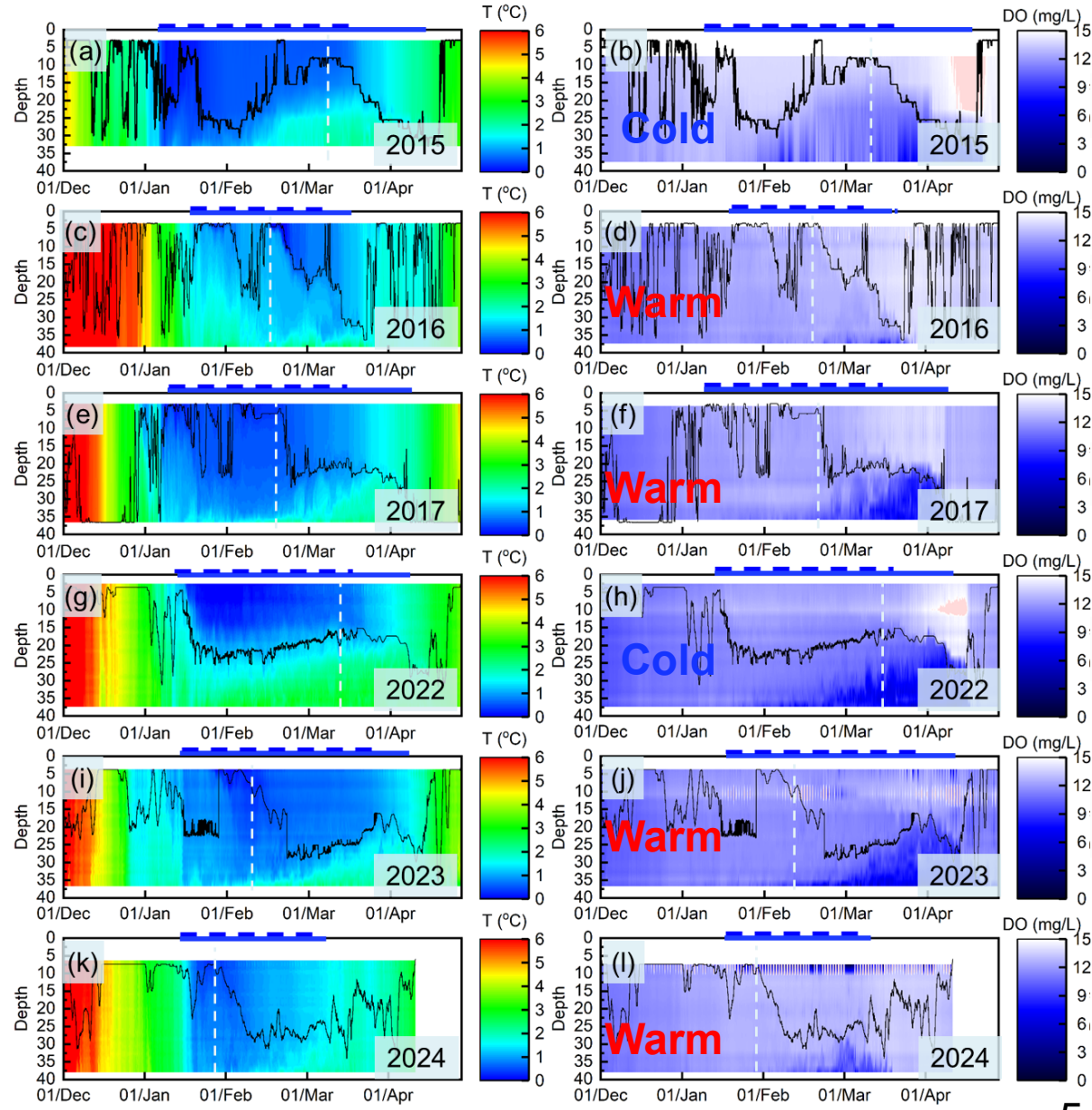
2. Water temperature and DO distributions show different patterns for cold and warm winters

- the longer ice-cover duration could lead to a longer inverse stratification
- the hypolimnion hypoxic zones were more extensive in cold winters.

3. The supersaturated DO were detected at the end of the cold winters

• Temperature

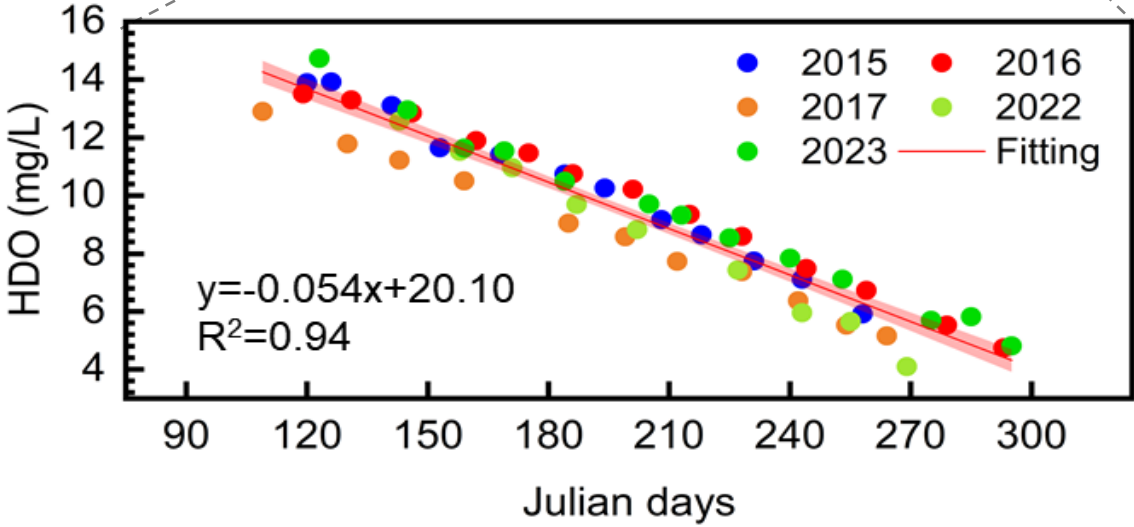
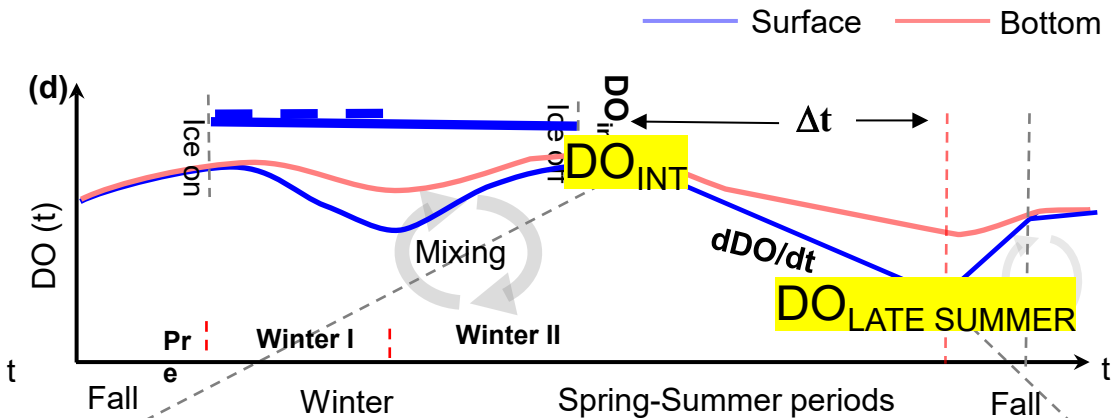
Dissolved oxygen



DO could continuously decrease in the following spring and summer

$$DO_{hypo}(t) = DO_{initial} - \Delta t \times dDO / dt$$

- Possible components:**
- **Longer Stratification (t)** .
Increased Oxygen Sink (dDO/dt) : DO levels in both the surface and hypolimnetic layers continuously decrease with increasing water temperature;
 - **Initial values:** At ice off DO reach peak just before ice melt with a 6-year average of 13.68 mg/L;



Hypolimnetic oxygen reduction is ~ 7.45 mg/L, representing 54.5% of the initial values, indicating that the **initial DO levels** have a **carryover effect** on **summer hypolimnetic DO**

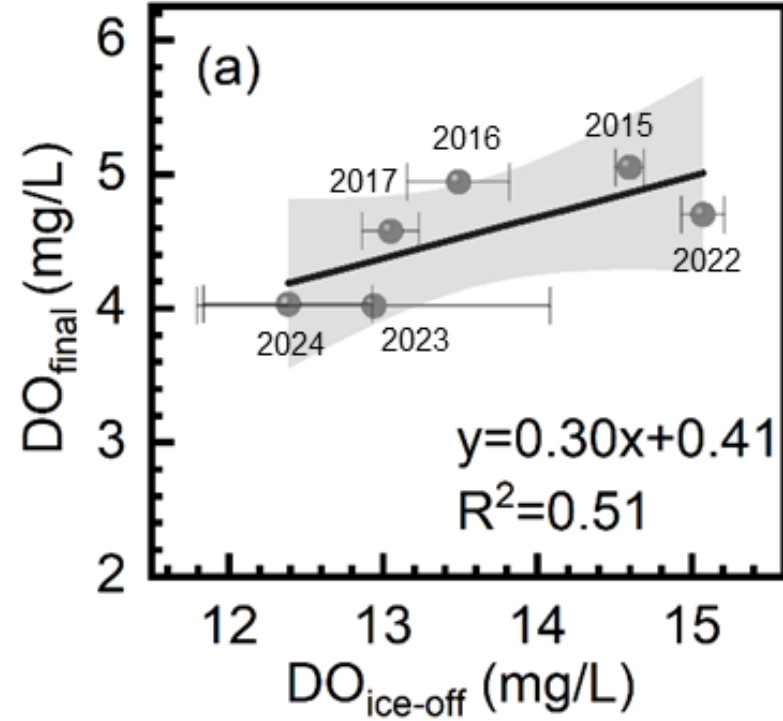
Does the under-ice DO in winter show any ecological memory across different seasons?

Yes! Strong and tight relationship between ice-off and summer DO values

Higher late-winter DO levels, would lead to **higher** end-of-summer DO levels



The legacy effect of ice-off DO plays a key role in determining the extent of late-summer hypoxia



CAVEATS: only 6-year data; number of other variables could be influencing, work is ongoing