ISIMIP lake sector meeting

水资源工程与调度全国重点实验室
STATE KEY LABORATORY OF WATER RESOURCES ENGINEERING AND MANAGEMENT

Enhanced heating effect of lakes under global warming

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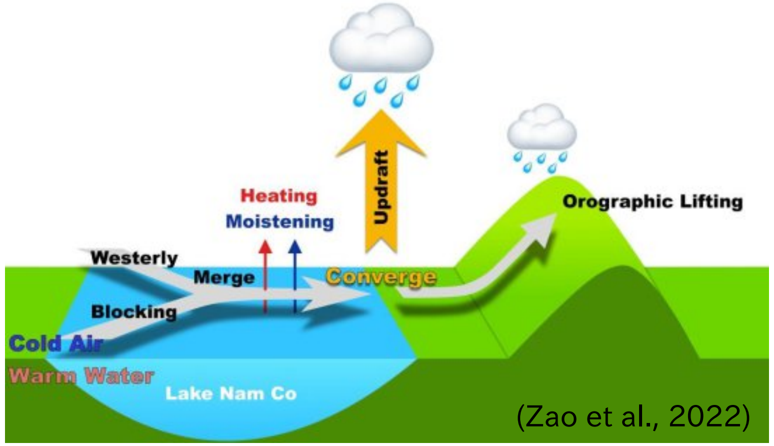
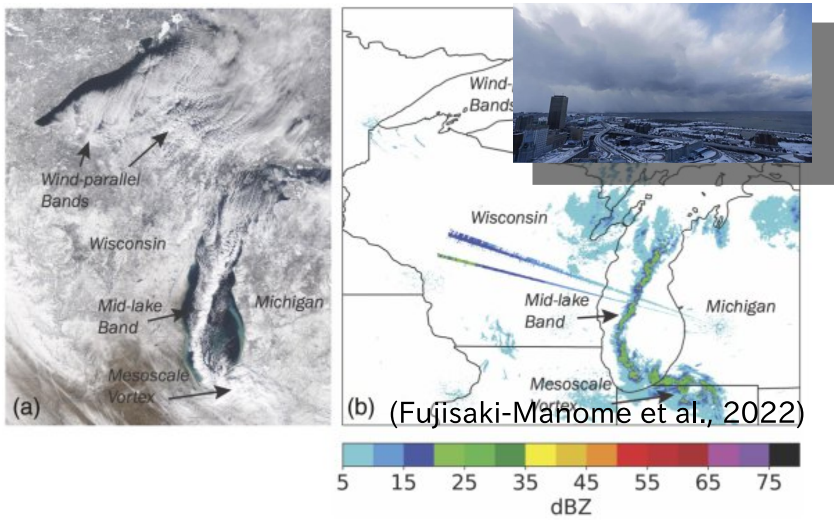
1 Background

Lakes play a vital role in land-atmosphere interactions

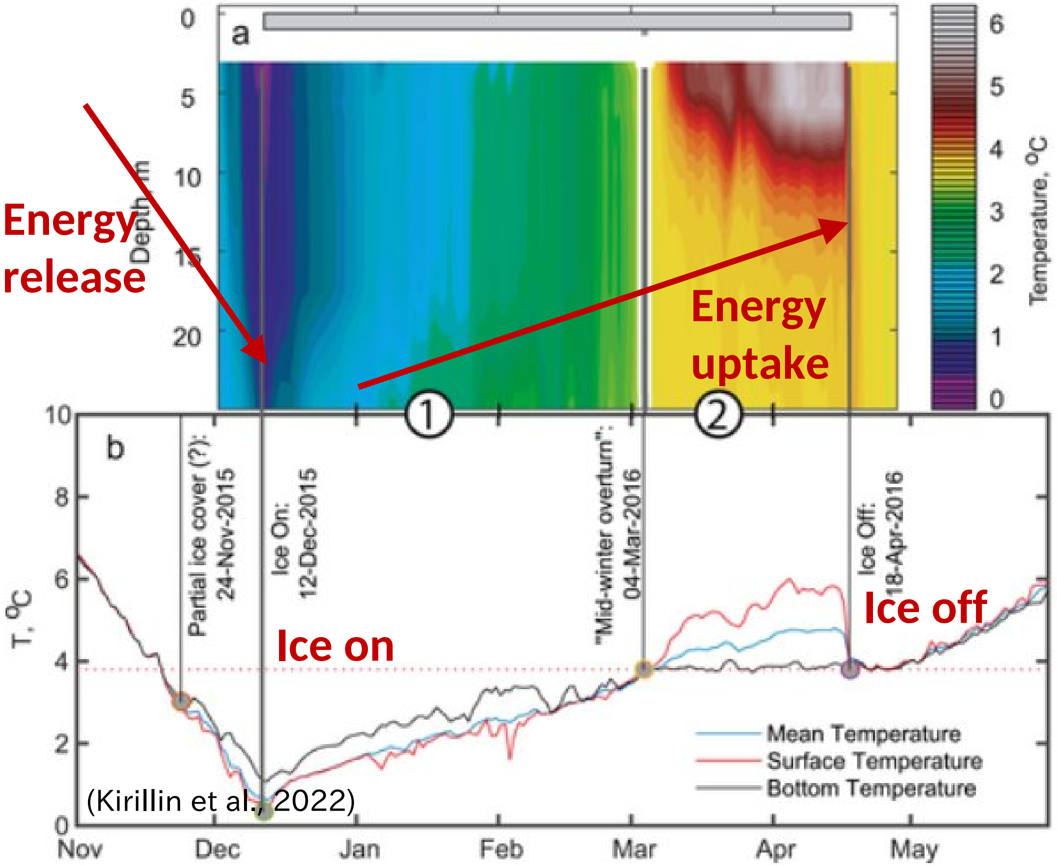
Lake-atmosphere interaction



Lake-effect snow



Seasonal energy redistribution

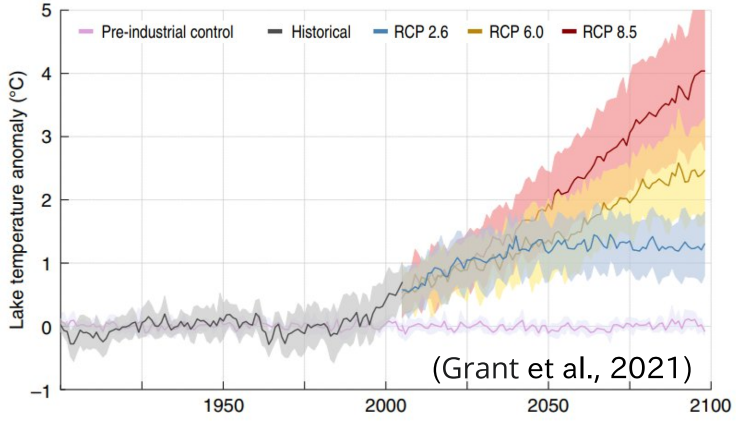


- Large thermal inertia
- Seasonal freeze-thaw cycles

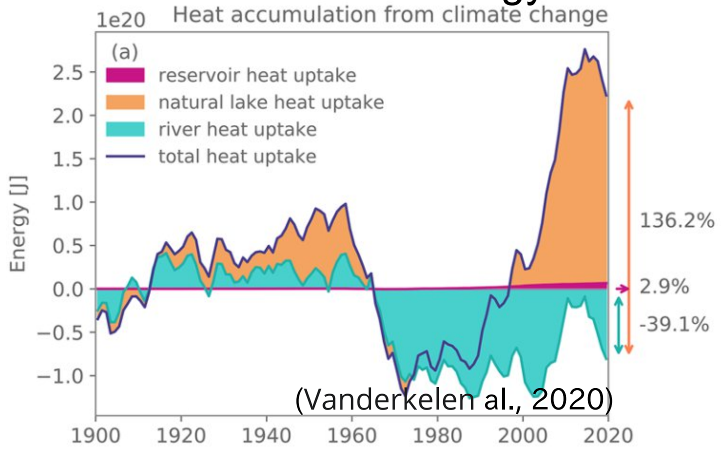
1 Background

Lakes are changing under global warming

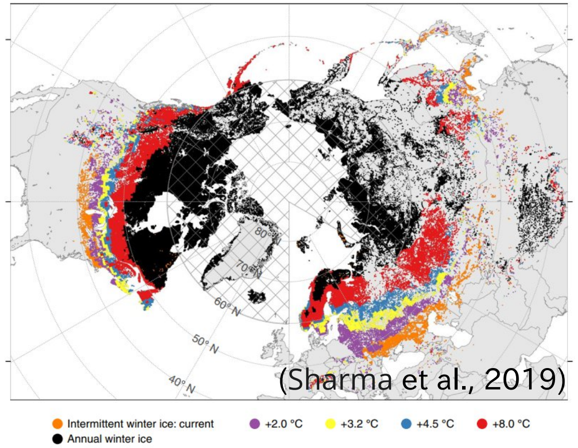
Lake temperature increase



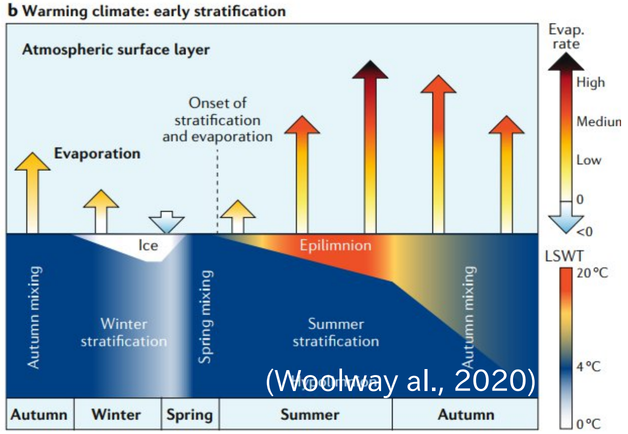
Accumulated energy



Lake ice cover decline



Reduced insulation

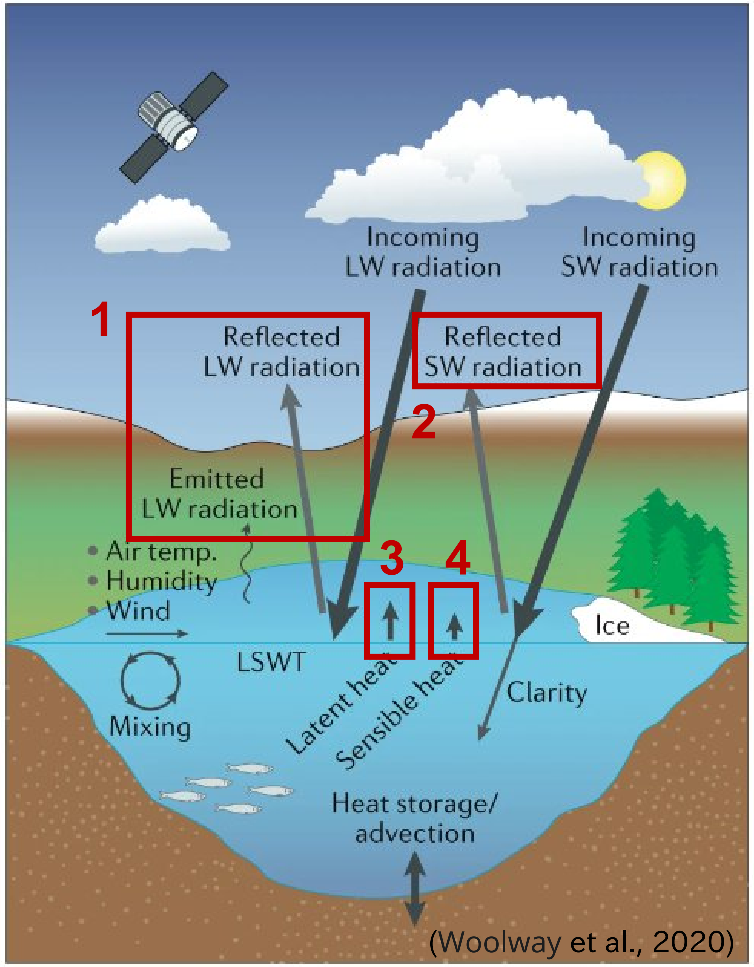


Objectives:

The objectives of this study are to quantify changes of lake heat release (LHR) globally and investigate their underlying mechanism.

Definition of lake heat release

Lake's energy budget



Lake heat release (LHR):

LHR = LWup + SWup + SH + LH

Lwup: upward longwave radiation
Swup: upward shortwave radiation
SH: sensible heat flux
LH: latent heat flux

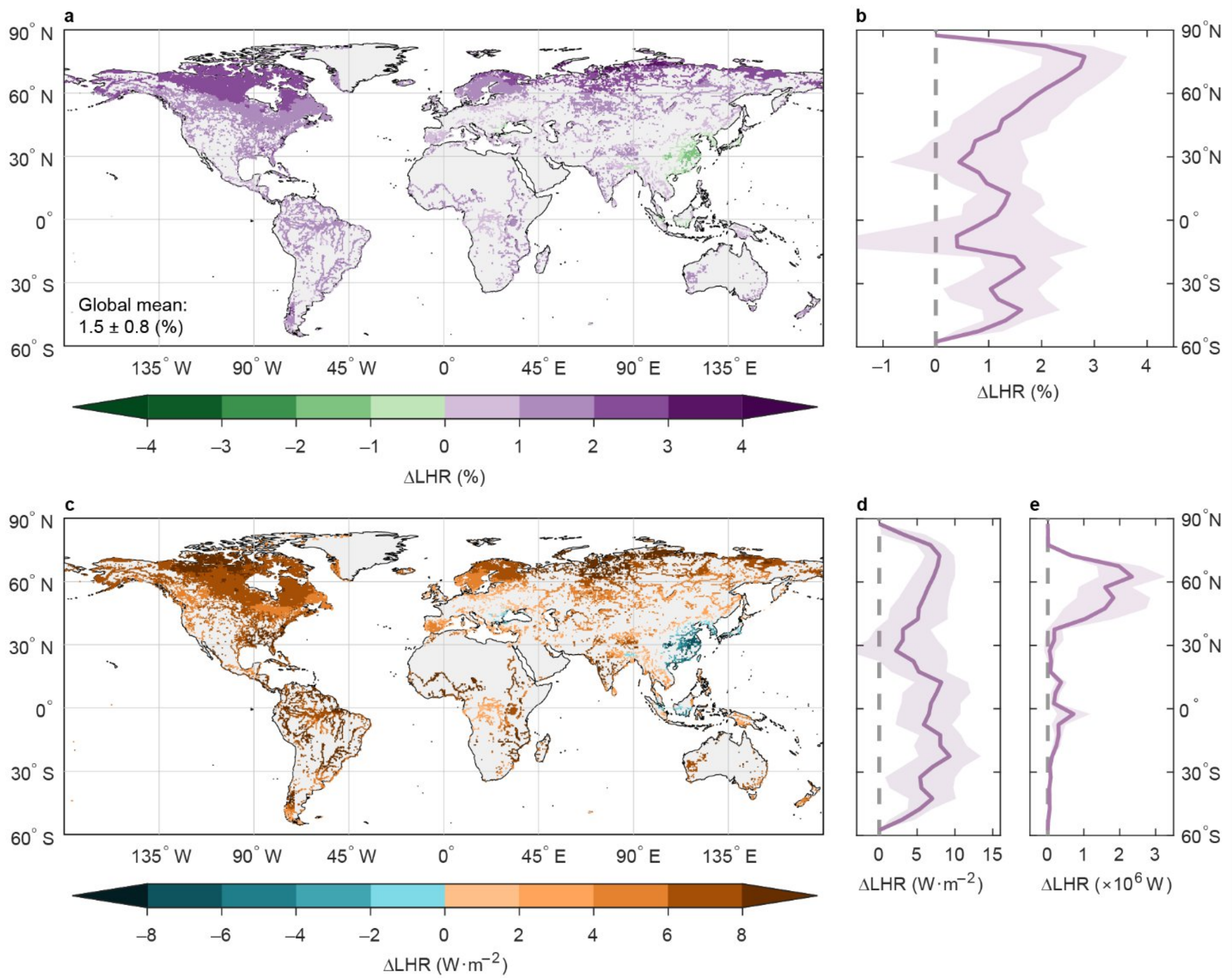
ISIMIP
Inter-Sectoral Impact Model
Intercomparison Project

Lake energy budget data from ISIMIP 2b Lake Sector was employed

3 Results

Amplified LHR change in northern mid-high latitudes

Present-day (1991–2020) vs. Pre-industrial



Relative change

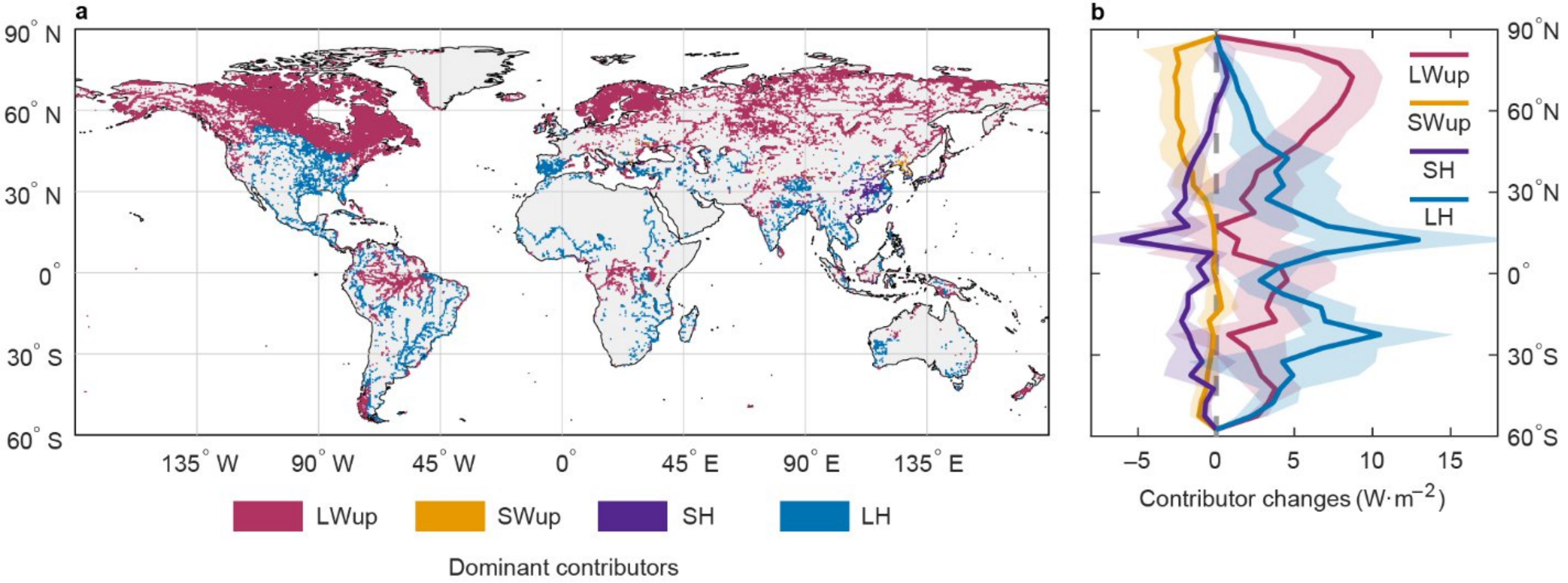
- Most of the lake show increased LHR globally, the average increase is 1.5 ± 0.8%.
- Relative increase in LHR at mid-high latitudes (>45°N, 1.8 ± 0.8%,) is double that of lakes at low latitudes (30°S–30°N, 0.9 ± 1.0%).

Absolute change

- The majority of lakes are concentrated at mid-high latitudes. Therefore, the regional totals amount to $10.0\cdot10^6 \pm 4.4\cdot10^6$ W for mid-high latitudes and $2.7\cdot10^6 \pm 1.5\cdot10^6$ W for low latitudes.

LWup dominate the amplified LHR change

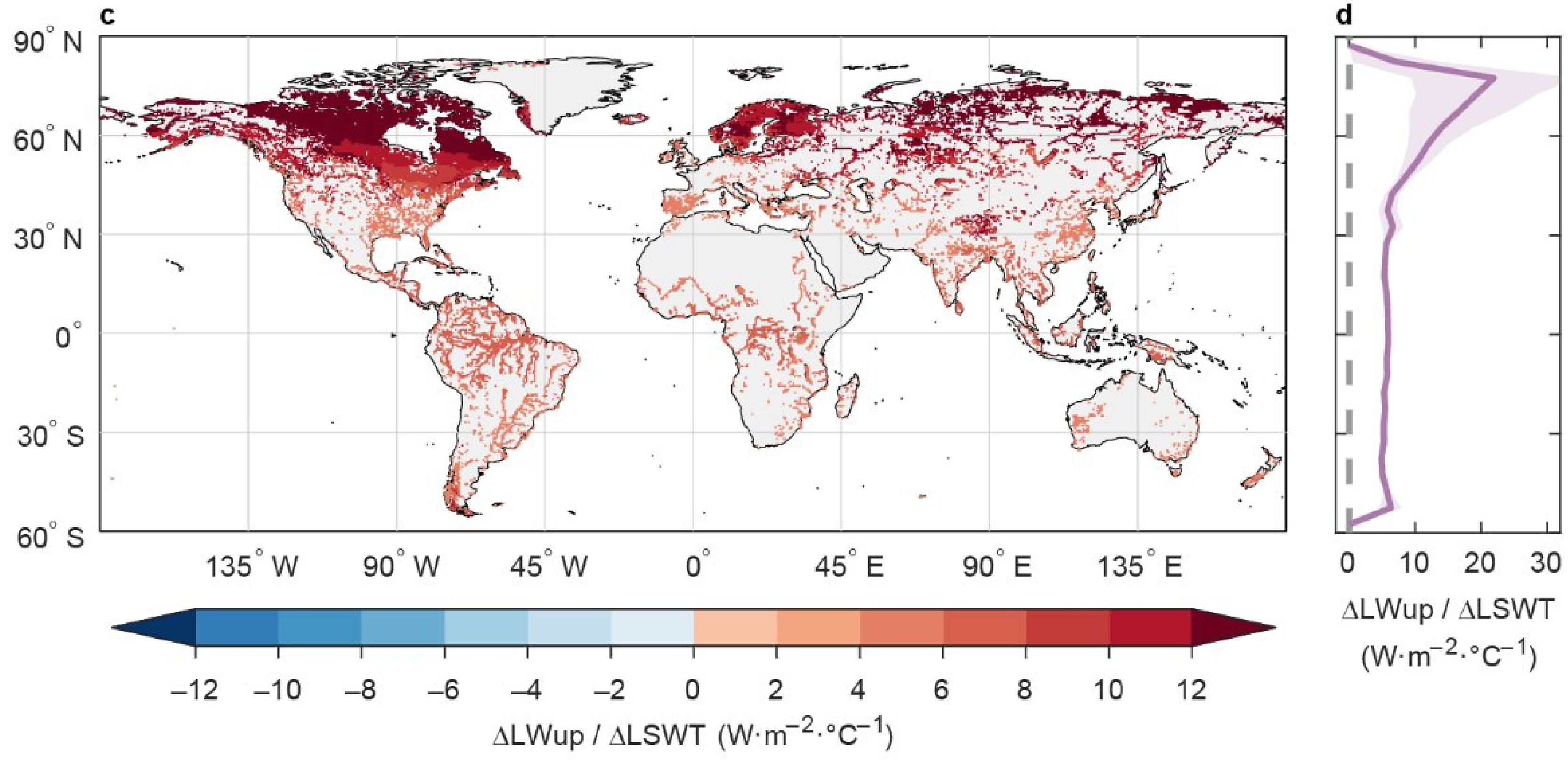
Dominant contributors to the LHR change



- LWup dominates LHR changes in mid-high latitudes, while LH dominates in lower latitudes.
- **Distinct responses exist between lakes at mid-high and low latitudes to global warming**.
- Low-latitude lakes can mitigate warming through enhanced evaporation.
- Lake energy is primarily transferred to the atmosphere by thermal radiation (LWup).

The reasons for amplified LHR change

Sensitivity of LWup to LSWT (lake surface water temperature)



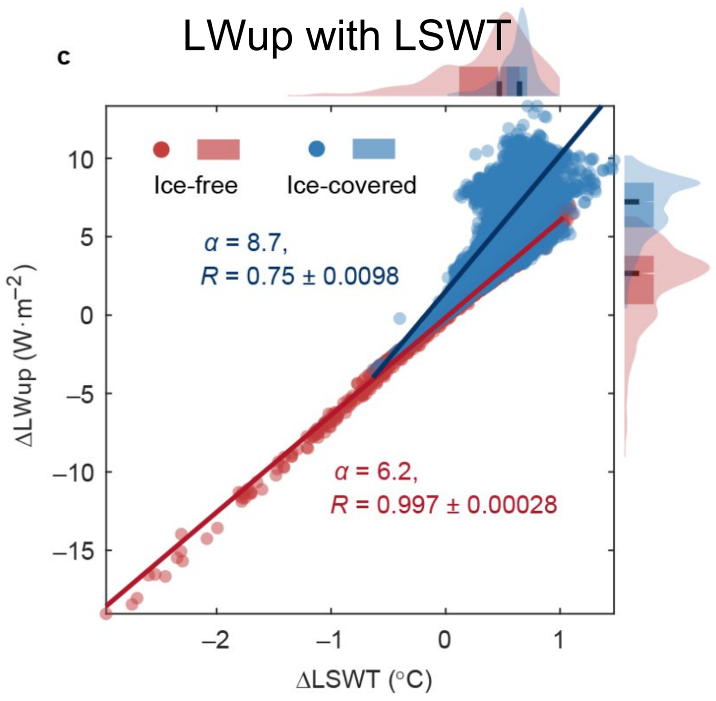
- LWup show higher sensitivity to LSWT at mid-high latitudes. This high sensitivity amplifies the LHR.
- A **decoupling exists between LWup and LSWT** at mid-high latitudes.
- In addition to water temperature, lake ice may also contribute the amplification.

3 Results

The reasons for amplified LHR change

Ice-free and ice-covered lakes

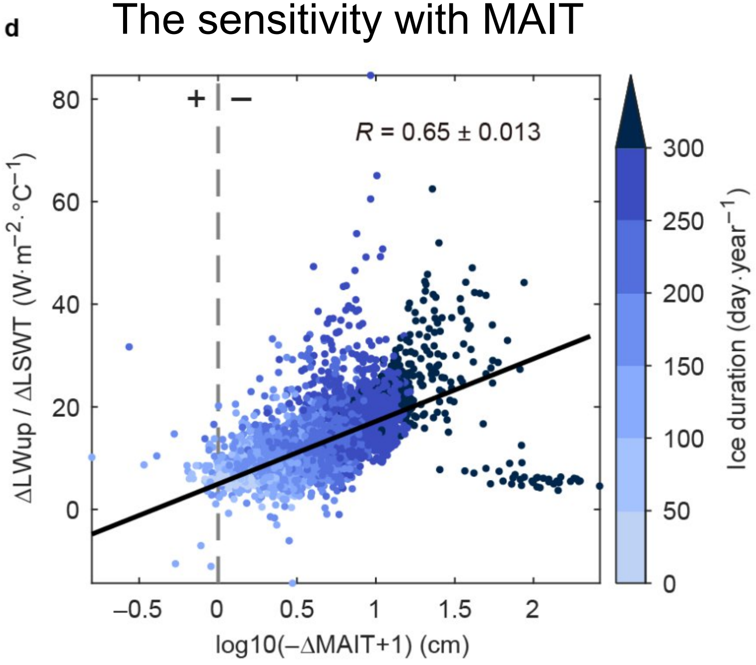
LWup with LSWT



- LSWT governs the changes in LHR.
- **Ice-covered lakes show heightened sensitivity of LWup to LSWT, and experience more pronounced LSWT increases.**

Using mean annual ice thickness (MAIT) to characterize lake ice phenology

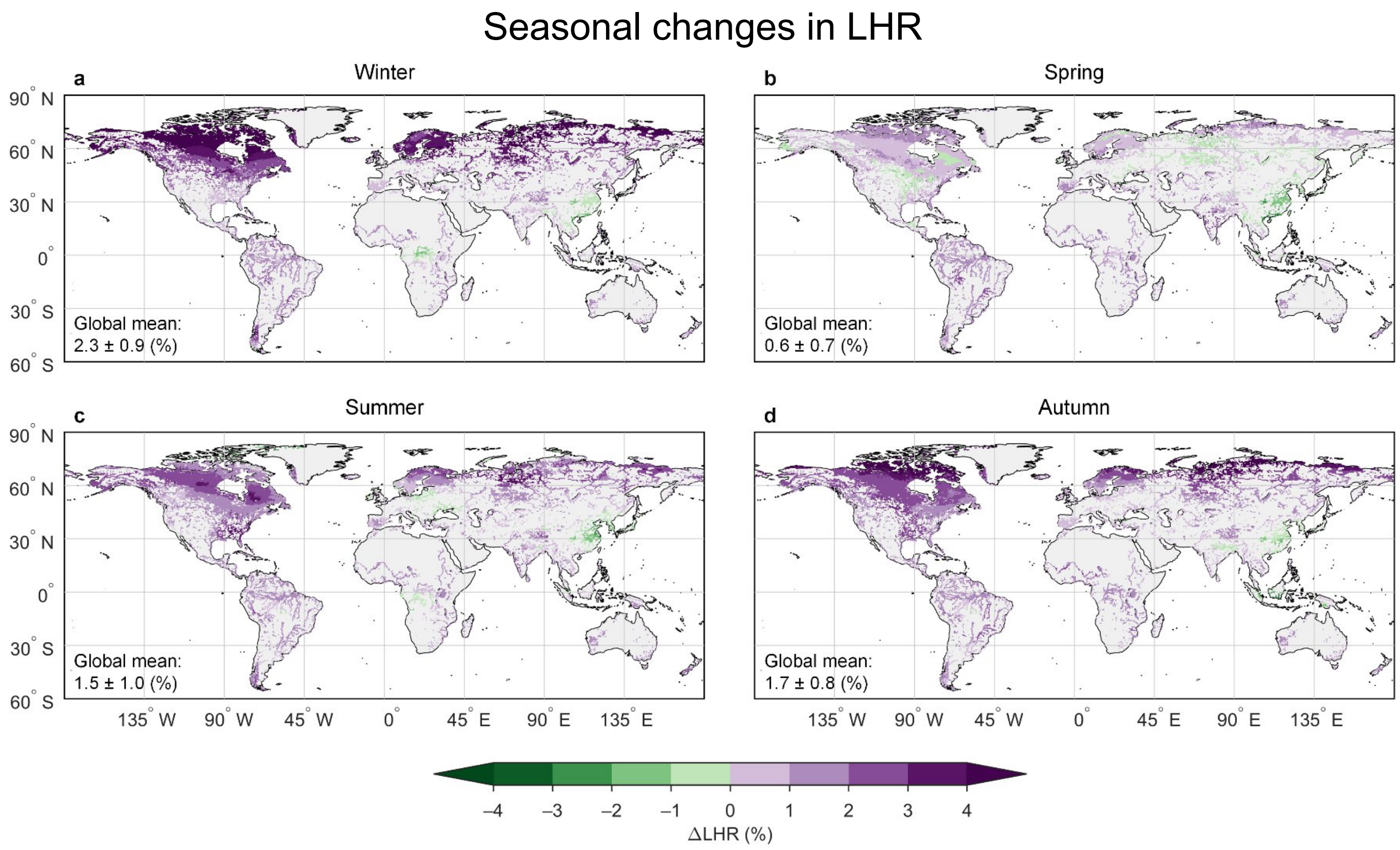
The sensitivity with MAIT



- Changes in lake ice phenology results in the high sensitivity of LWup to LSWT

3 Results

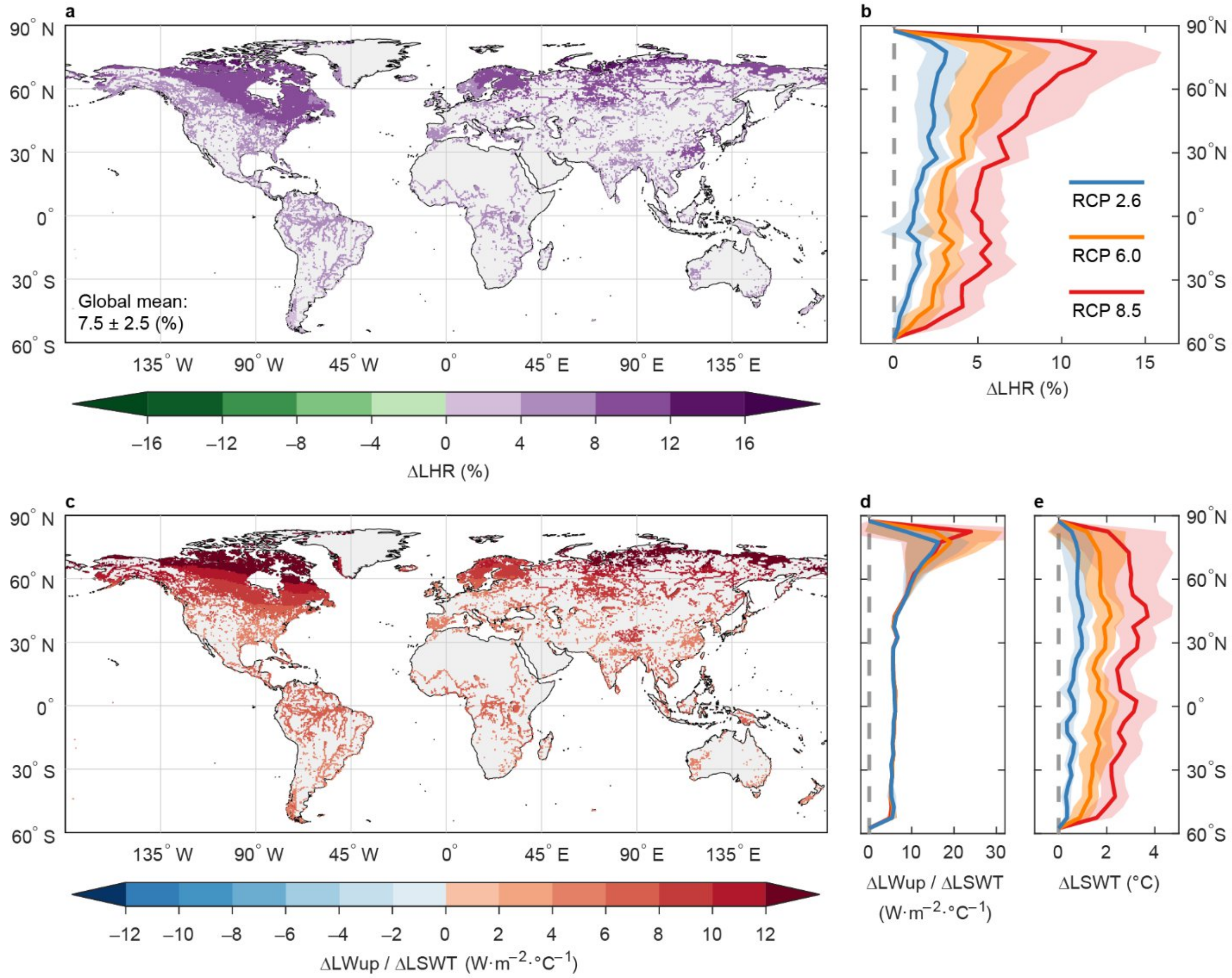
Seasonality of the LHR change



- The global strengthening of LHR, as well as the amplified LHR at mid-high latitudes, is also evident on a seasonal scale.

Future changes in the LHR

End-of-century (2070–2099) vs. Present-day (1991–2020))



Relative change

p Towards the end of this century, LHR increases globally, with a global average rise of 2.1 ± 0.8%, 4.5 ± 1.4%, and 7.5 ± 2.5% relative to the present-day (1991–2020) for RCPs 2.6, 6.0, and 8.5, respectively.

p Amplified increase of LHR at mid-high latitudes persists under all RCPs.

The sensitivity of LWup to LSWT

p The sensitivity of LWup to LSWT across all RCPs remains consistent in both spatial patterns and latitudinal averages.

Take home messages

- Amplified LHR changes exist at mid-high latitudes, which is double that of lakes at low latitudes.
- LWup dominates the amplified LHR changes at mid-high latitudes.
- The amplification is linked with a feedback mechanism: the reduction in lake ice cover not only reduces the insulating effect between the warmer lake water and the colder atmosphere, but also leads to increased warming of lakes.

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Thanks for your attention!

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