Temperature constraints of terrestrial ecosystem respiration in global biomes

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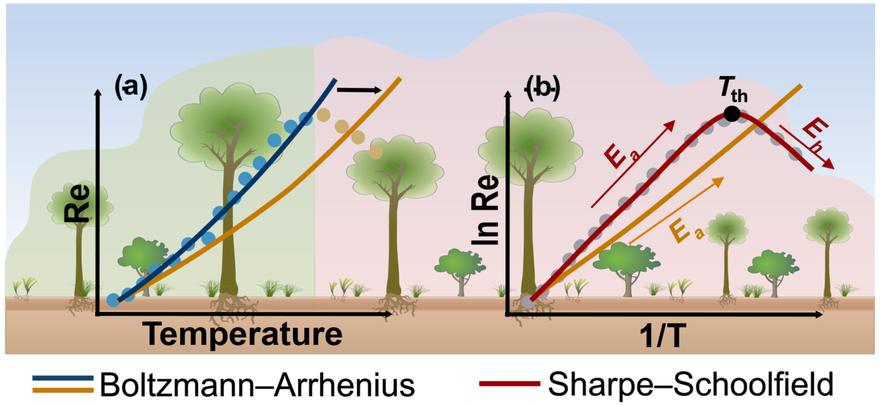
Backgrounds

- Ecosystem respiration (Re) is traditionally modeled with an exponential function dependent on temperature[1], but recent studies suggest this approach overestimates Re at high temperatures.
- Current research[2] indicates a threshold temperature beyond which Re rates decline, highlighting the need for improved models that account for temperature limitations on Re.



Two distinct temperature response of Re:

- **Boltzmann–Arrhenius (B–A) function** $\mathrm{Re} = \mathrm{Re}_0 \cdot \mathrm{e}^{-\frac{E_a}{kT}}$
- **Sharpe–Schoolfield (S–S) function**

$$\mathrm{Re} = \mathrm{Re}_0 \cdot \mathrm{e}^{-\frac{E_a}{kT}} \cdot \left[1 + \left(\frac{E_a}{E_h - E_a}\right) \mathrm{e}^{-E_h \cdot \left(\frac{1}{kT_h} - \frac{1}{kT}\right)}\right]^{-1}$$

B–A function is a special case of S–S function where the high-temperature inactivation term is one, and the temperature-rate relationship is exponential without a maximum[3].

Fig. 1. (a) Re increases exponentially with temperature up to a threshold (T_{th}). (b) Ignoring high-temperature inhibition underestimates activation energy (E_a); a unimodal function provides more accurate predictions. E_h is deactivation energy.

Questions

? Does the exponential model underestimate Re's temperature dependence across biomes?

? How does the unimodal function impact projected Re trends in a warming climate?

? How integrate the function to a processed-based model and automatically optimize parameters?

Data & Methods

- 213 FLUXNET2015 sites were grouped by Koppen-Geiger climate type.
- Temperature dependence was analyzed at 8 heatwave sites.
- Re was predicted for 1990–2100 under four CMIP6 scenarios using two functions.

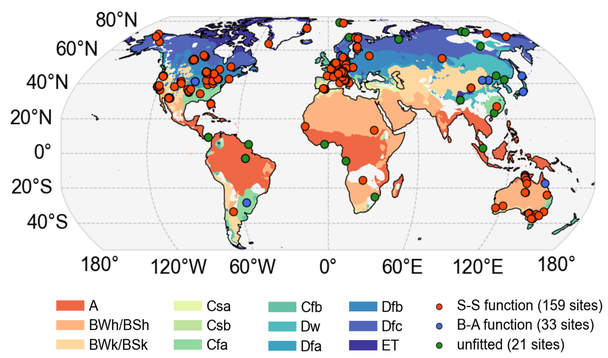


Fig. 2. Distribution of FLUXNET2015 sites in Koppen-Geiger climate biomes.

Curve Fitting (Work 1)

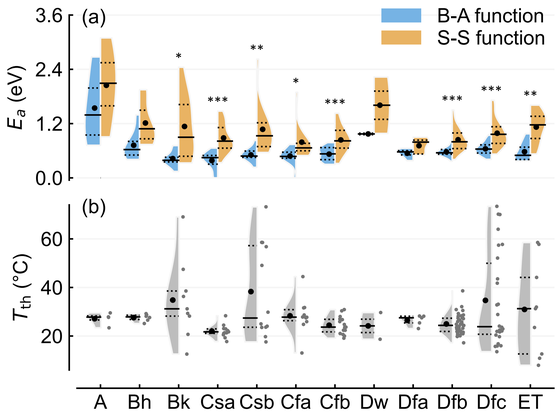


Fig. 3. Boxplots of E_a and T_{th} by biome using B–A and S–S function.

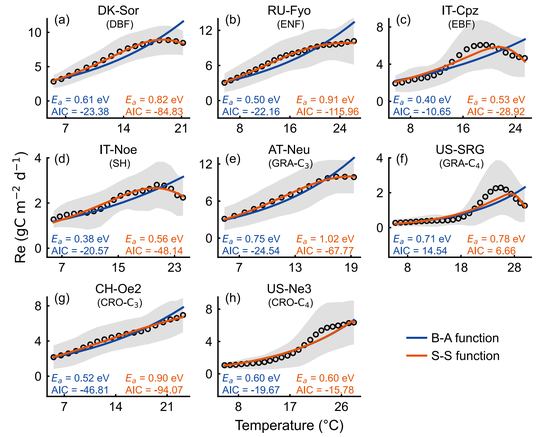


Fig. 4. Thermal response curves of Re during heatwaves years at eight selected sites.

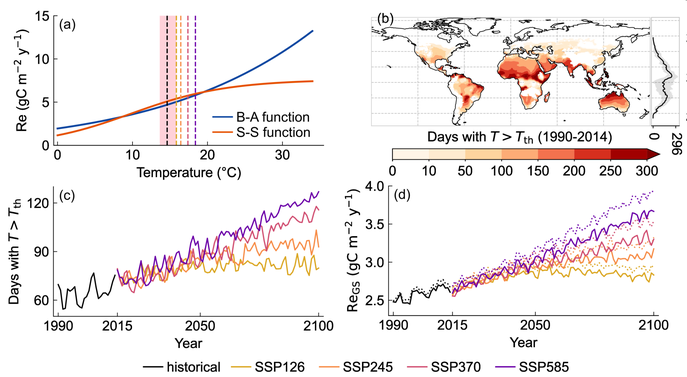
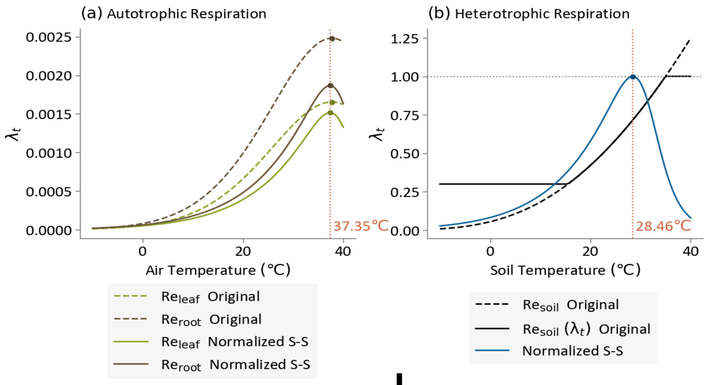
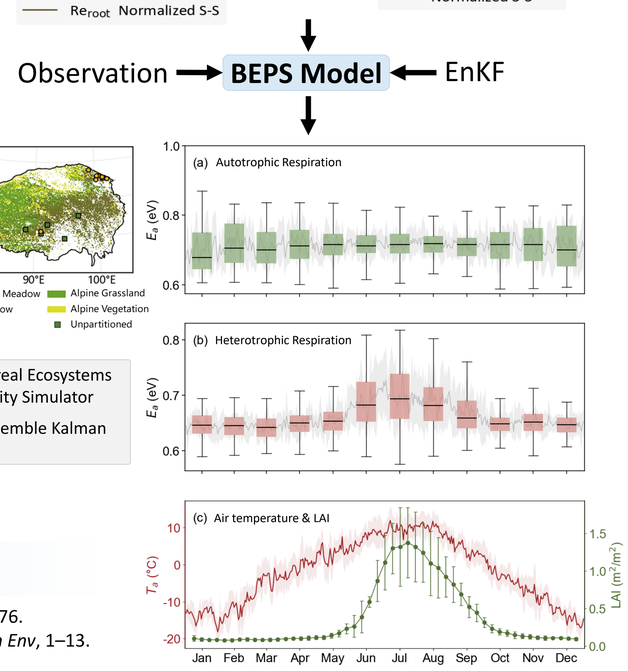


Fig. 5. (a) Temperature response functions for Re in biome Dfb, with observed and projected annual temperatures. (b) Average days exceeding T_{th} historically, with latitude trends. (c) Global annual days above T_{th} under four CMIP6 scenarios. (d) Global growing season Re under four temperature scenarios, excluding non-vegetated areas.

Modeling (Work 2)





BEPS: Boreal Ecosystems Productivity Simulator

EnKF: Ensemble Kalman Filter

Summary

- Conventional models underestimate Re's sensitivity to temperature, overestimating future carbon emissions.
- Incorporating high-temperature effects in Re models is crucial for accurate ecosystem carbon projections.

References

[1] Yvon-Durocher, et. al. (2012). Nature, 487(7408), 472–476.
[2] Niu, S., Chen, W., Liáng, L. L., et. al (2024). *Nat Rev Earth Env*, 1–13.
[3] Michaletz, S. T. (2018). New Phytol, 219(1), 37–44.

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