Diagnosing temperature sensitivity of respiration across high-latitude ecosystems in Northern hemisphere

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outlines

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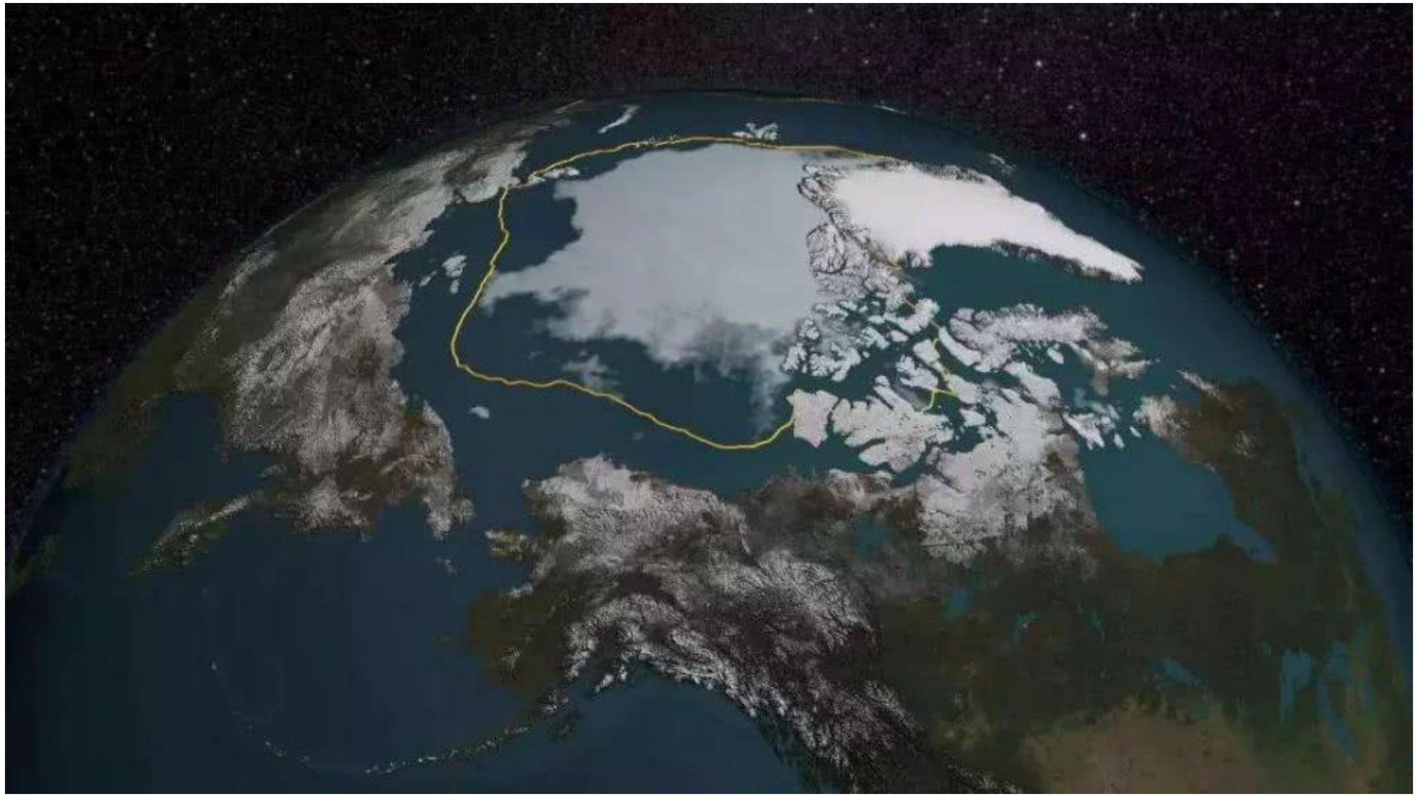
1. Background



Northern High-Latitude: >50°N

✓ **Environment characteristic:**

Annual mean T: 3.34℃,

Annual mean P: 633mm

(derived from FLUXNET2015 36 sites)

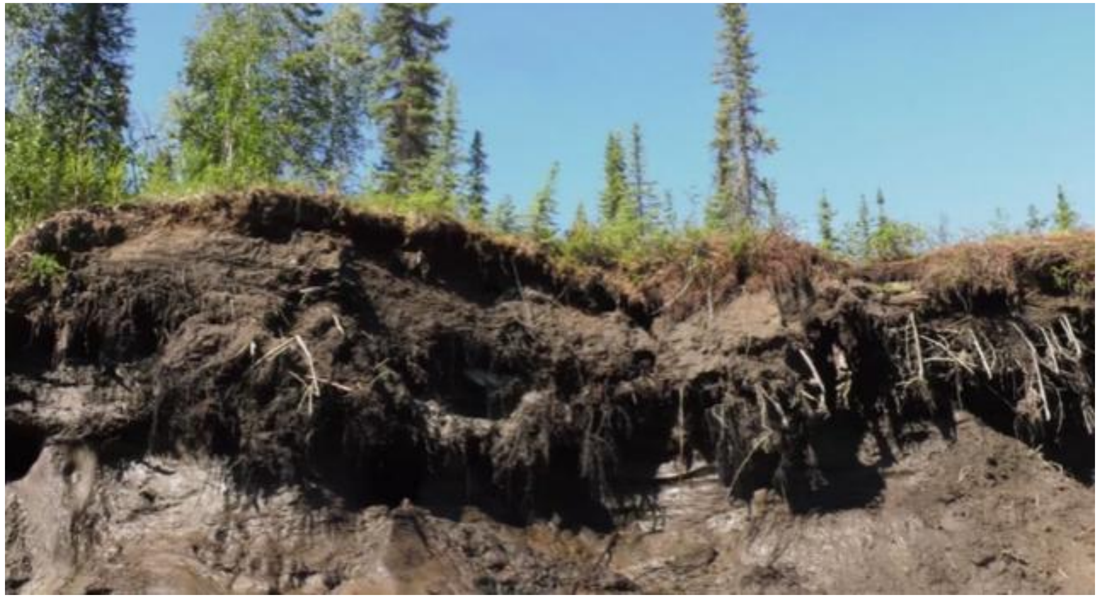
✓ **Vegetation:**

coniferous forest, broadleaved forest,

mixed forest, wetland, peatland, tundra

1. Background

NHL ecosystem: carbon sink



✓ **Slow decomposition**

poor drainage capacity & frequent anaerobic condition

✓ **High carbon density**

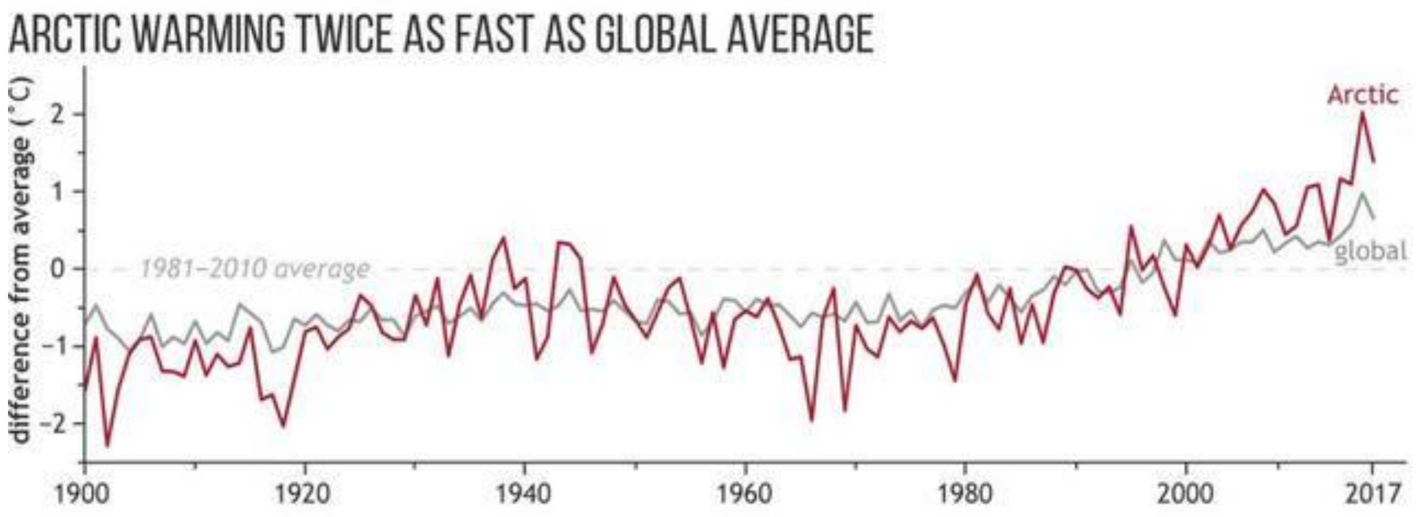
cryoturbation

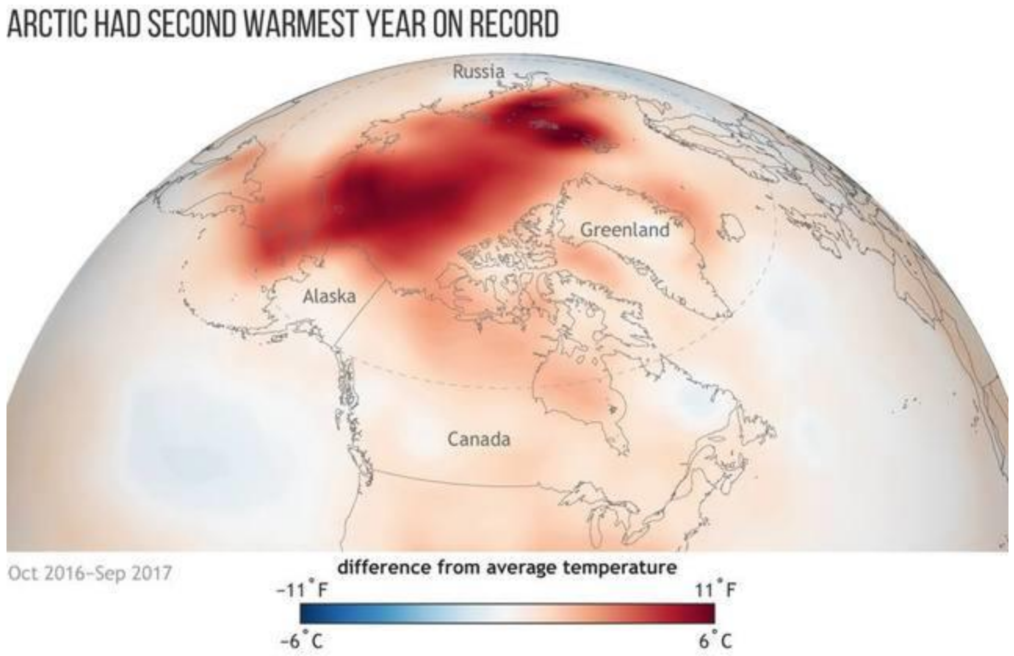
Davidson et al., *Nature* 2006; Ping et al., *Nat. Geosci.* 2008; Schuur et al., *Nature* 2015

1. Background

Arctic amplification:

the rate of temperature increased in the NHL region over the last 30 years is twice as fast as the global average

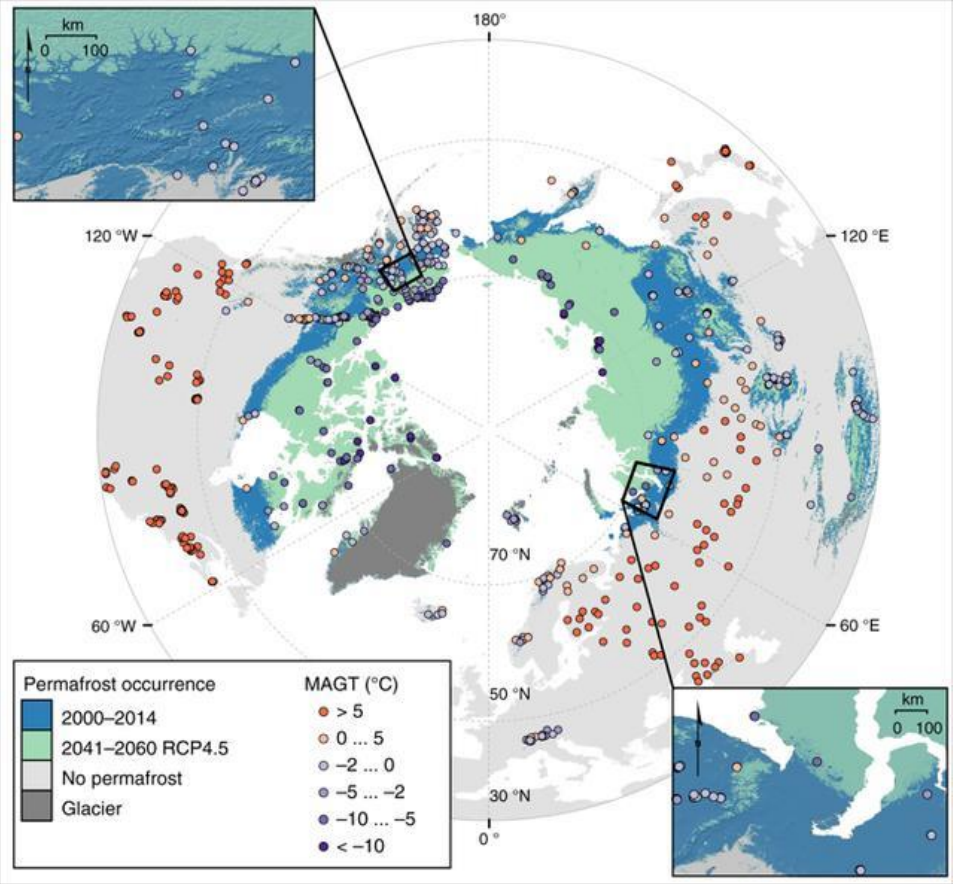




IPCC. 2013; Screen et al., *Geophys Res. Lett.* 2013; Serreze et al., *Glob Planet Change* 2011; Huang et al., *Nat. Clim. Change* 2017

1. Background

NHL warming cause: permafrost degradation



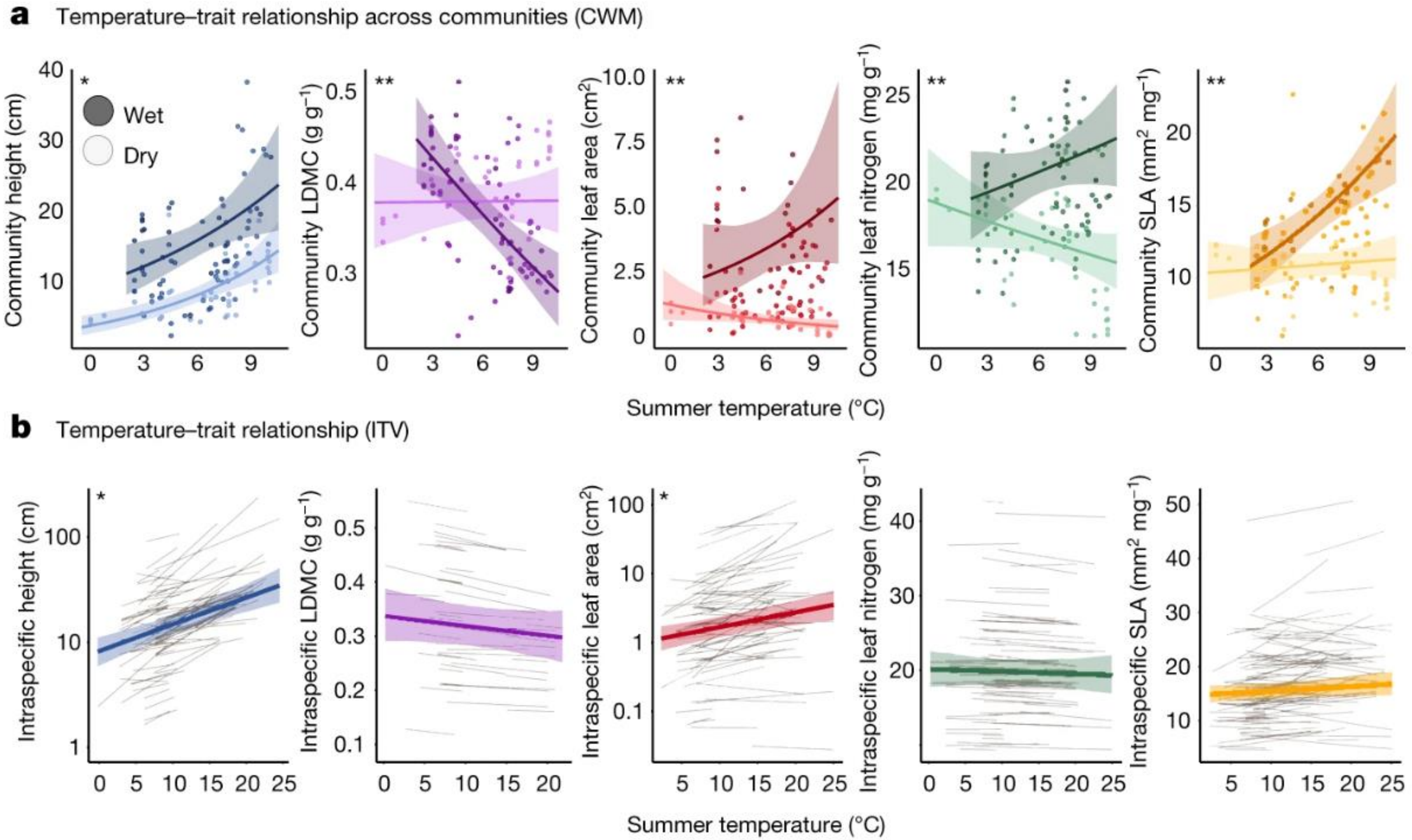
1. permafrost area reduce
2. active layer depth increase
3. thermal stability type changes
4. thermal karst and thermal melt collapse

……

Schuur et al., *Nature* 2015; Hjort et al. *Nat. Communi*. 2018

1. Background

NHL warming cause: vegetation trait changes



Vegetation trait:
height, LAI

Resource economic character:
specific leaf area,
Leaf nitrogen content

Community level character:
lignification,
evergreenness

Bjorkman et al., *Nature* 2018

1. Background

NHL warming cause: atmosphere circulation

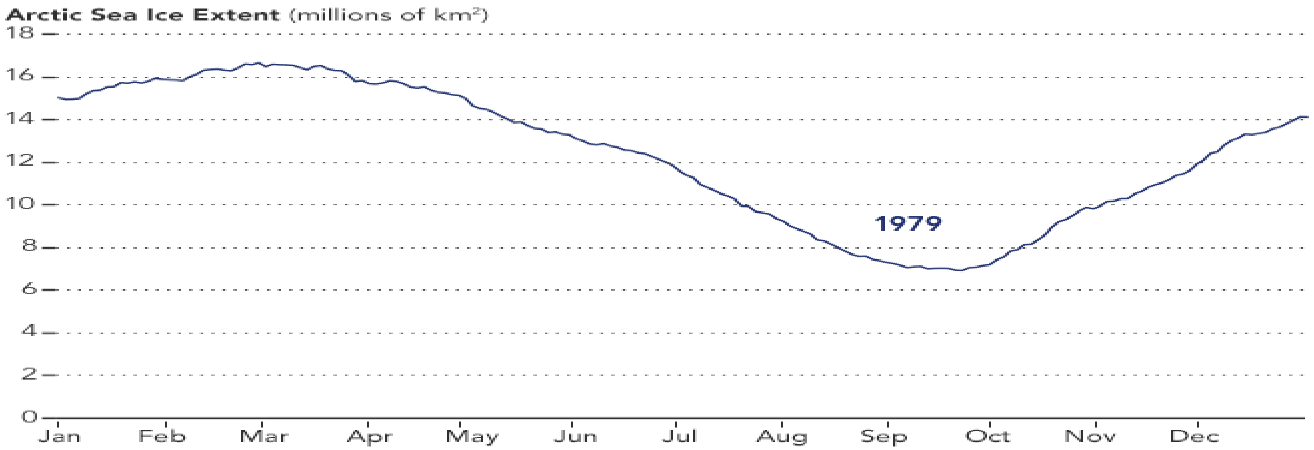
Albedo change

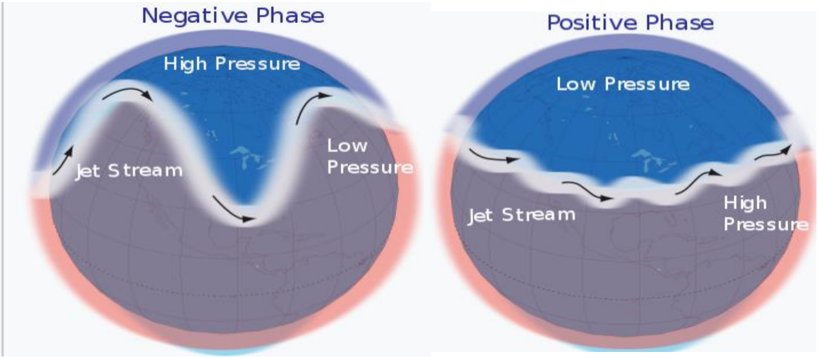
Flux change

Thermohaline circulation

↓

atmosphere circulation





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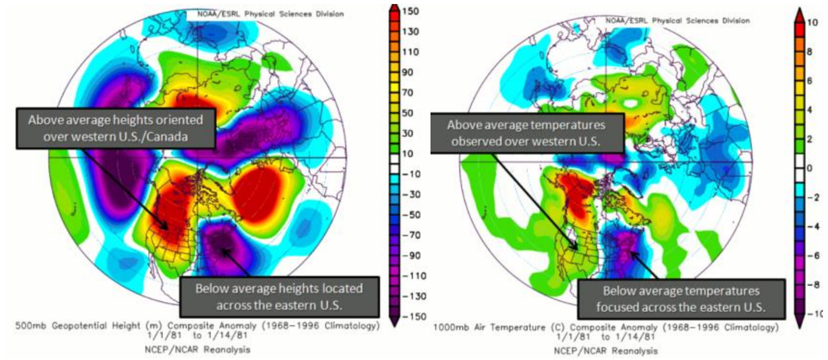
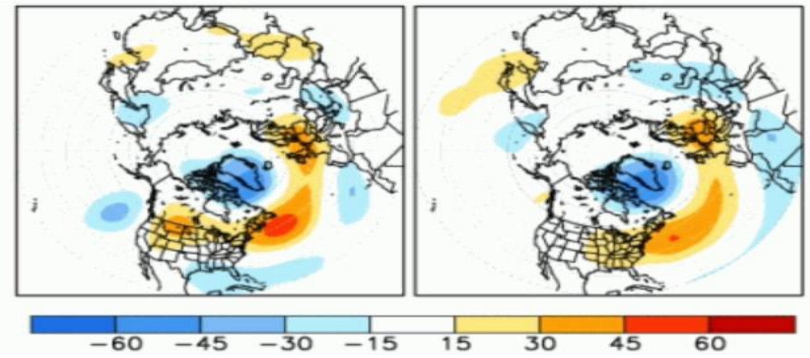


PNA



NAO

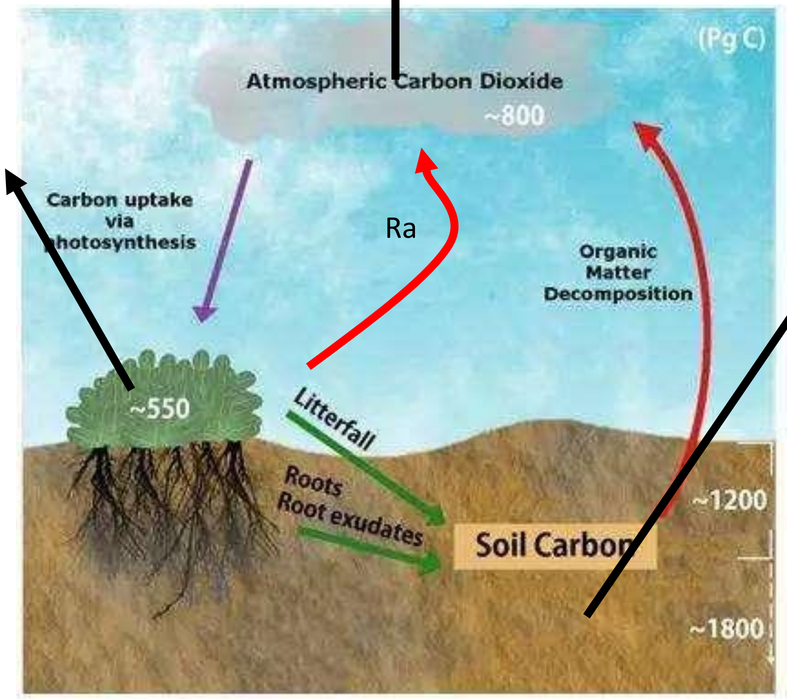
1. Background

NHL warming ⟷ atmosphere circulation

Yvon-Durocher et al., *Nature* 2012

Vegetation trait changes

Absorb more carbon



Permafrost decomposition

Release more carbon

Reco = Ra + Rh

NEE = GPP - Reco

Ecosystem respiration is a biological conversion process by which all organisms in an ecosystem, including consumers and primary producers, convert organic carbon into carbon dioxide

1. Background

The temperature sensitivity of ecosystem respiration is generally expressed as the Q10 indicator, which is the amount of ecosystem respiration increases when temperature increases by 10 degrees

✓ **Regression parameters from temperature-only models of soil respiration**

Name	Equation[a]	a	b	c	r^2	RMSE	Predicted R_s (g C m^{-2})
Q_{10} model [26]	$y = ab^{(x-10)/10}$	0.757	2.288		0.76	0.4575	370
Quadratic [27]	$y = a + bx + cx^2$	0.468	−0.021	0.004	0.76	0.4563	370
Logistic [28]	$y = a/(1 + \exp(b(c - x)))$	10.66	0.01	36.24	0.76	0.4583	368

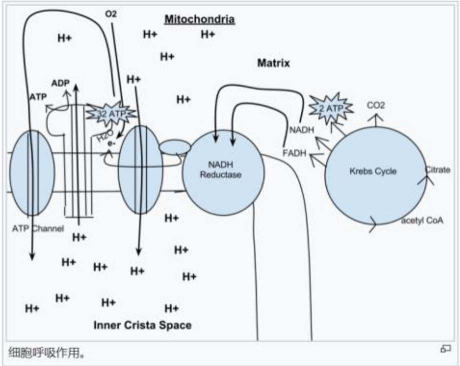
✓ **Comparison of combined two-variable model of soil respiration with Q10 model**

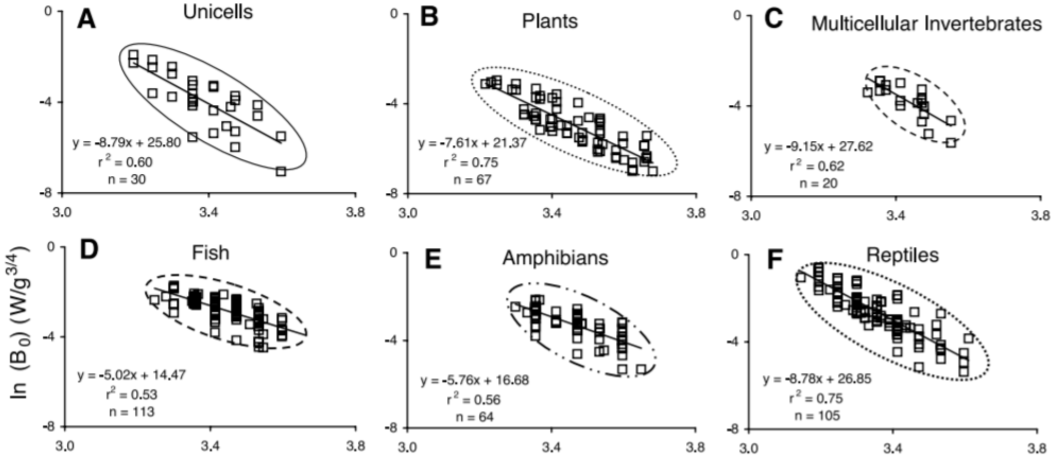
Name	Equation[a]	a	b	c	d	r^2	RMSE	Predicted R_s (g C m^{-2})
Q_{10} model [26]	$y = ab^{(x-10)/10}$	0.765	2.273			0.72	0.4762	359
Asymptote [29]	$y = [ab^{(x-10)/10)}][z/(z + c)]$	1.06	2.209	0.049		0.75	0.4733	359
Polynomial [29]	$y = ab^{(x-10)/10} - (z - c)^2$	1.395	1.756	0.096		0.73	0.4731	358
Logistic-power [4]	$y = [a/(1 + \exp(b(c - x)))][z^d]$	13.35	0.1	33.8	0.214	0.74	0.4535	358
Q_{10}-hyperbolic [12]	$y = b^{(x-10)/10)}][(a + c * z + d/z)]$	2.637	2.321	−5.364	−0.15	0.81	0.3946	360

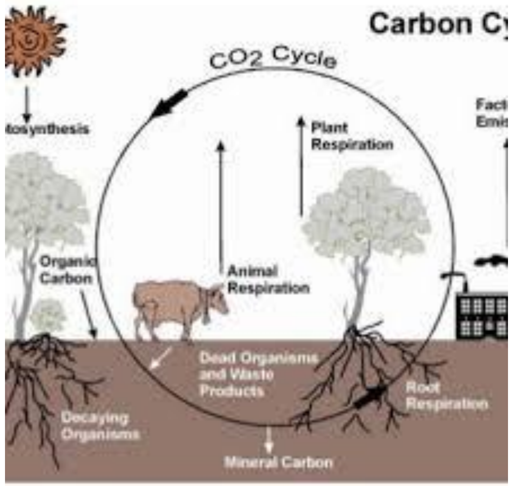
Lloyd et al., *Funct. Ecol.* 1994; Chen et al., *Eur. J. Soil Boil.* 2013; Gaumont-Guay et al., *Agr. Forest Meteorol*. 2006

2. Research progress

cell ➡ individual ➡ population ➡ community ➡ ecosystem ➡ landscape





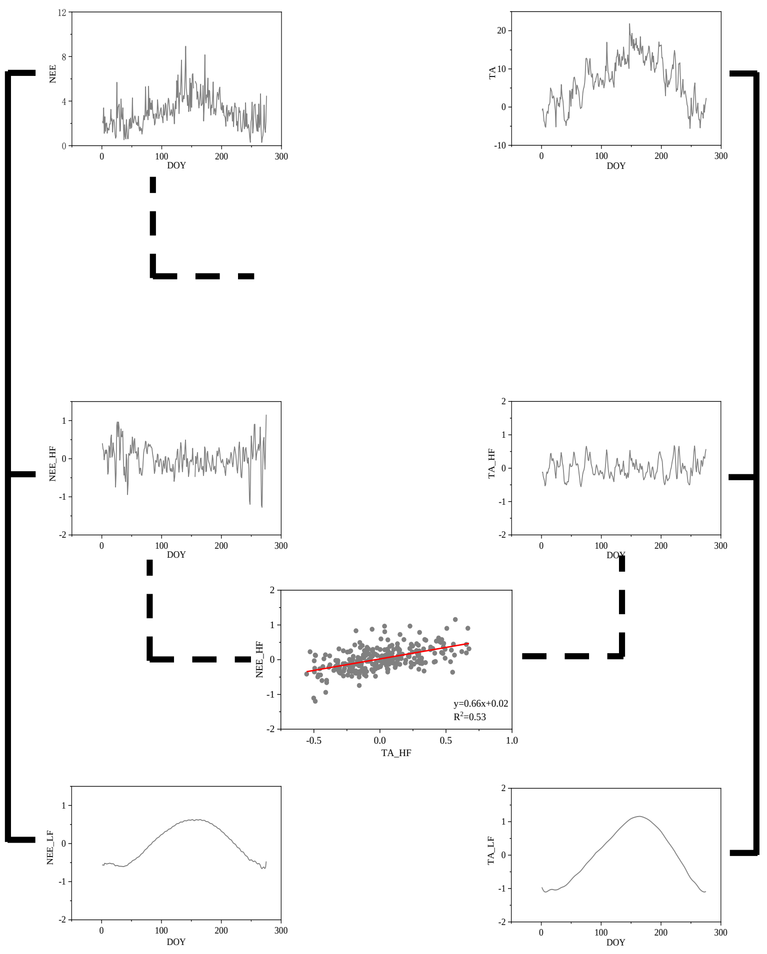


Species richness （Gu et al., *Global Biogeochem. Cy.* 2008）

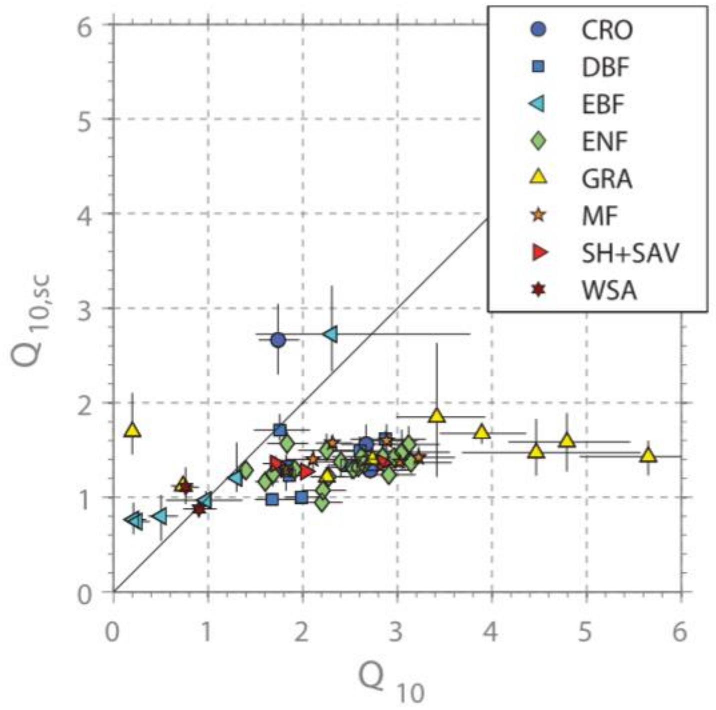
Community structure (Allen et al., *Funct. Ecol.* 2005)

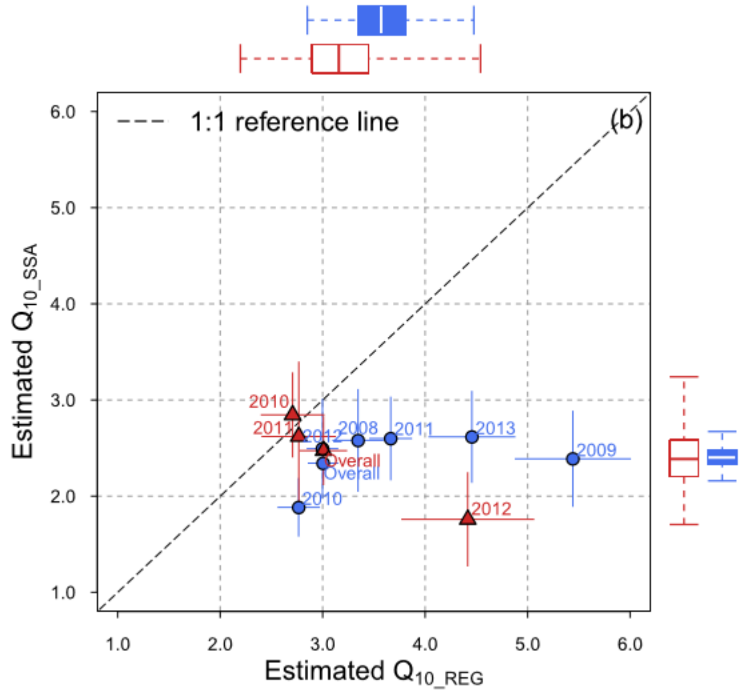
Hydrothermal conditions (Mahecha et al., *Science* 2010)

2. Research progress



SCAPE method





The SCAPE splited time series data into high and low frequencies using singular spectral decomposition, and assumed that the confounding effects driven by non-temperature factors only existed in the low frequencies.

Mahecha et al., *Science* 2010; Wang et al., *Soil Biol. Biochem.* 2018

3. Scientific issue

1. The reason for the difference of Q10sc？

Because of the high temperature sensitivity in the alpine region? or the difference between the selection of soil temperature and air temperature?

2. Variations of Q10 in different spatial scale？

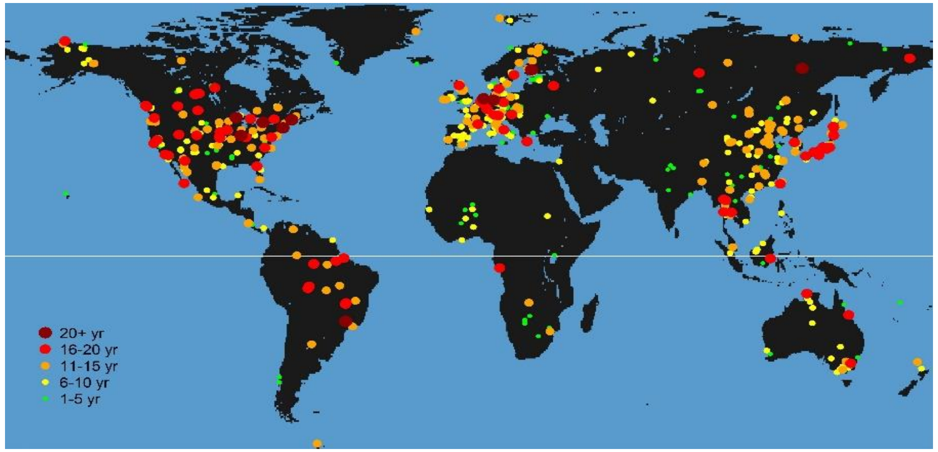
Environmental factors control intrinsic and apparent Q10 on different spatial scales.

3. The intrinsic Q10sc in the NHL？

Discuss land-surface process model overestimates the carbon emissions in the NHL

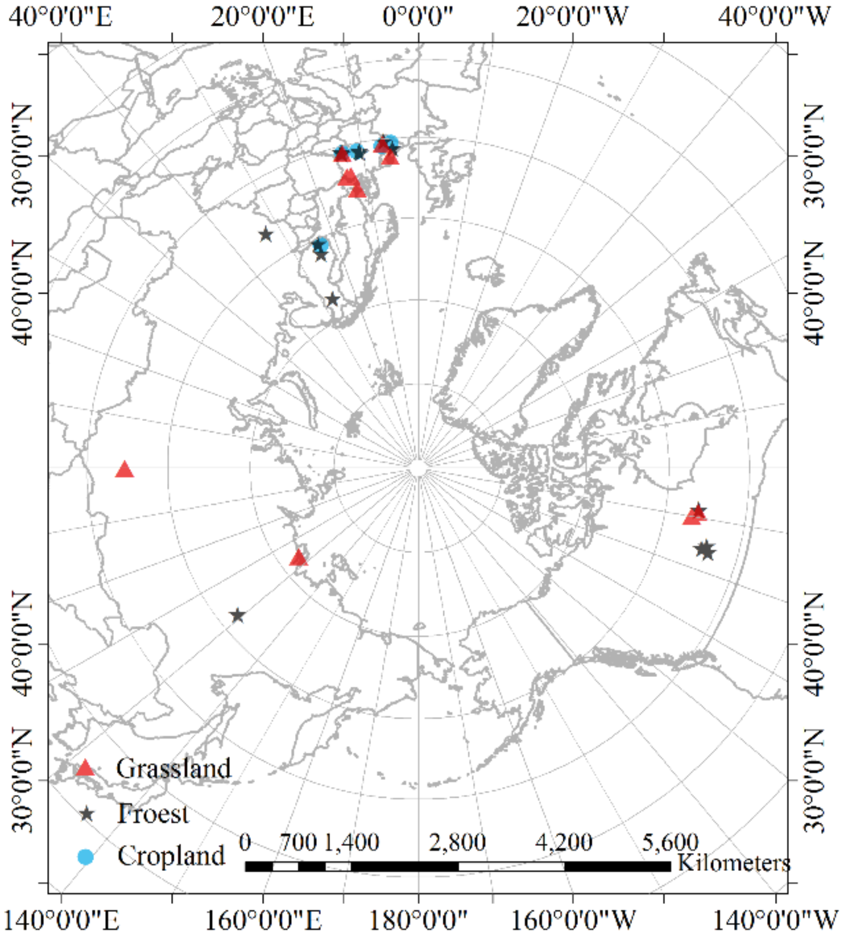
4. Data and Methods

site observation data



BE-BRA	CA-NS3	CA-OBS	DE-KLI	DE-THA	FI-SOD
BE-LON	CA-NS4	CA-SF1	DE-LNF	DE-ZRK	NL-HOR
BE-VIE	CA-NS5	DE-AKM	DE-OBE	DK-ENG	RU-FYO
CA-MAN	CA-NS6	DE-GEB	DE-RUR	FI-HYY	RU-HA1
CA-NS1	CA-NS7	DE-GRI	DE-RUS	FI-JOK	RU-SAM
CA-NS2	CA-OAS	DE-HAI	DE-SEH	FI-LET	RU-SKP

www.fluxnet.fluxdata.org/data/



Data processing

- ✓ Select original temperature and respiration data
- ✓ Average the original data if the number of effective data larger than 5
- ✓ decomposition the data into high and low frequency if the length of effective day was larger than 100

4. Data and Methods

Spatial grid dataset

atmospheric inversion data

based on the Monitoring Atmospheric Composition and Climate (MACC-Ⅲ) inversion system version 13.1

spatial resolution: 3.75° ×1.75°

temporal resolution: 3 hours

data from the 00:00, 03:00 and 21:00 of each day were aggregated into the daily mean respiration

ERA_interim reanalysis temperature data

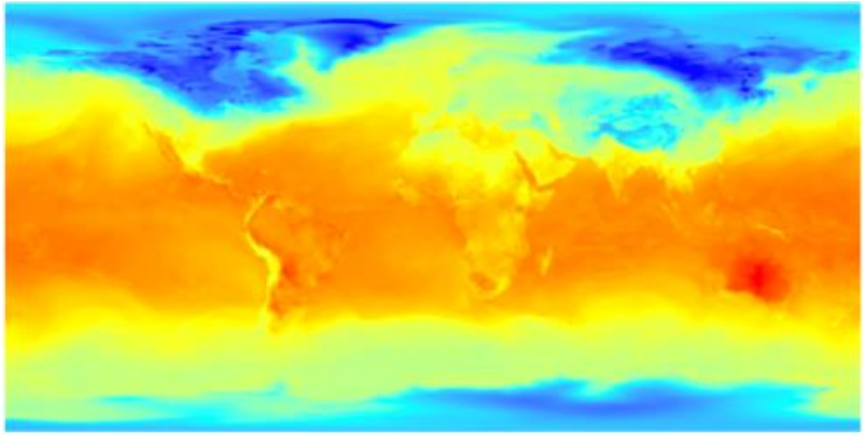
based on the comprehensive prediction system version 31r2, with the original spatial resolution being a simplified gaussian grid spaced approximately 79km apart.

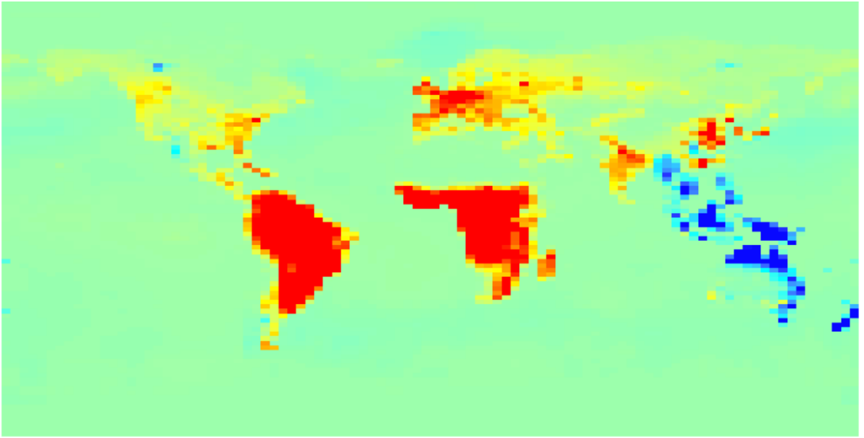
spatial resolution: 0.5° ×0.5° (resample to 3.75° ×1.75°)

temporal resolution: 3 hours

data from the 00:00, 03:00 and 21:00 of each day were aggregated into the daily mean temperature

atmospheric inversion data

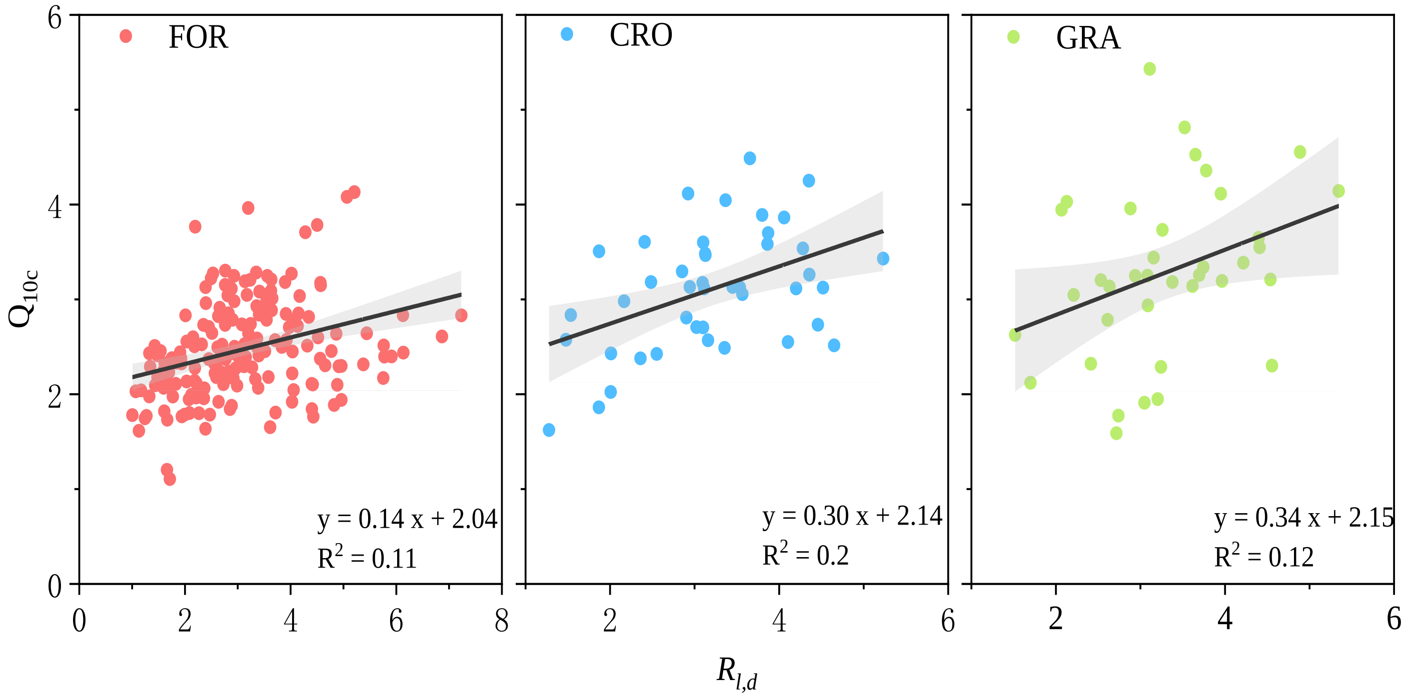




Spatial grid dataset

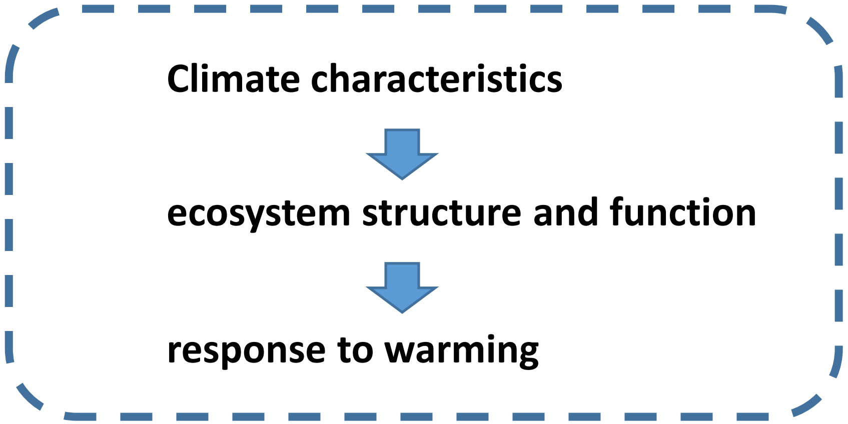
5. Results

Evaluating the confounding effects of three ecosystems type



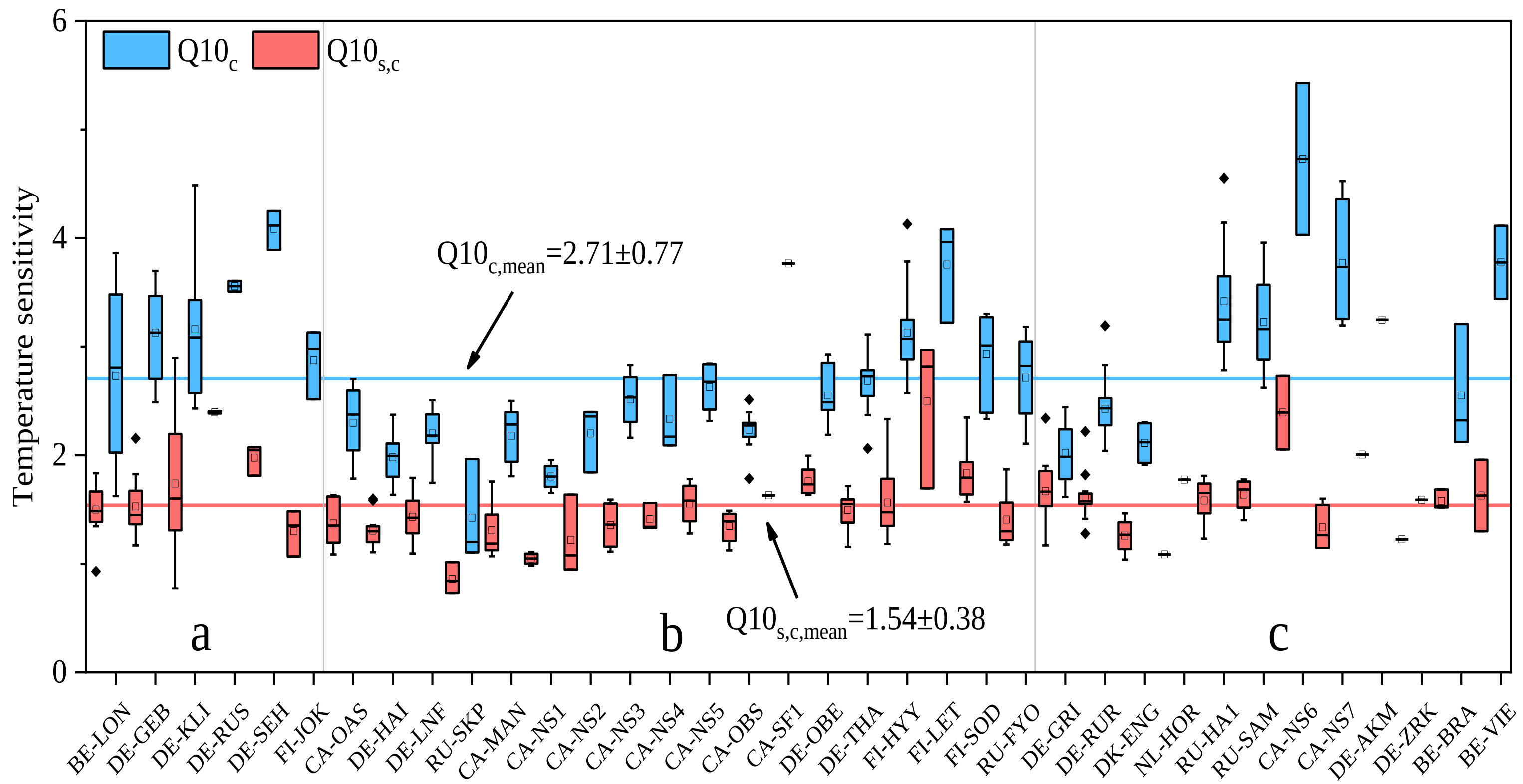
Relationship between low frequency difference and Q10c of three ecosystem types in the NHL.

✓ Three types were effected by confounding factors. The fitting slope of forest, cropland and grassland were increased



5. Results

Evaluating the apparent and intrinsic Q10 among 36 sites



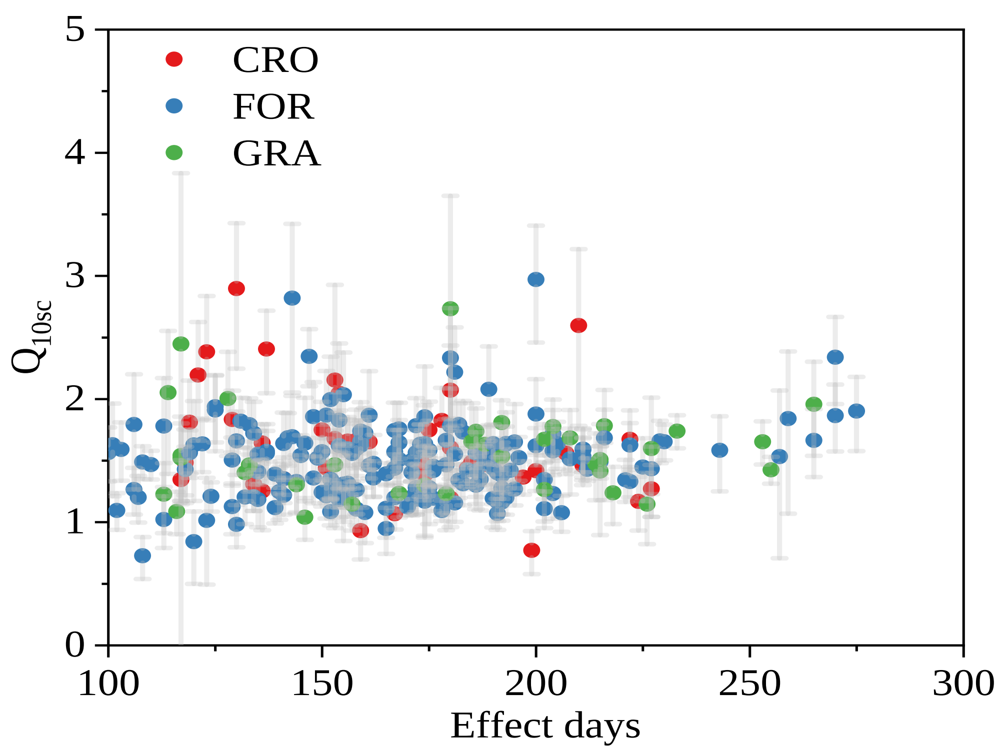
Multiple years of apparent Q10c and intrinsic Q10sc estimated in 36 sites in the NHL.

filter threshold: >100 effective days

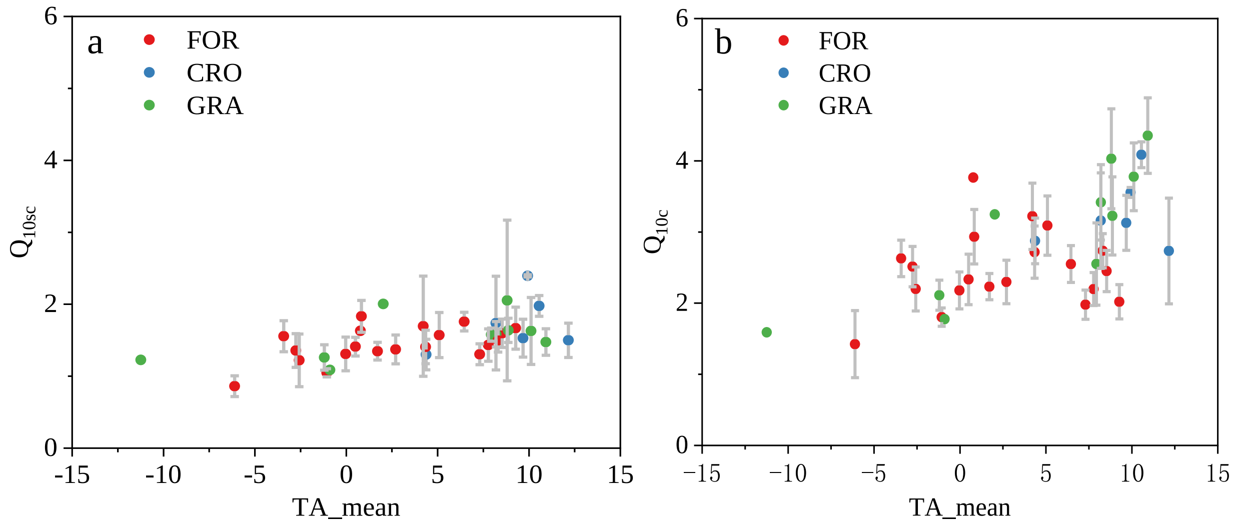
- ✓ intrinsic Q10sc showed convergence
- ✓ mean Q10c was 2.71 (±0.77)
  mean Q10sc was 1.54 (±0.38)
- ✓ The mean Q10sc was larger than global mean 1.4 (±0.1), smaller than 2.1 conducted in the Tibetan Plateau

5. Results

Environmental control on the Q10



The relationship of effective days with intrinsic temperature sensitivity

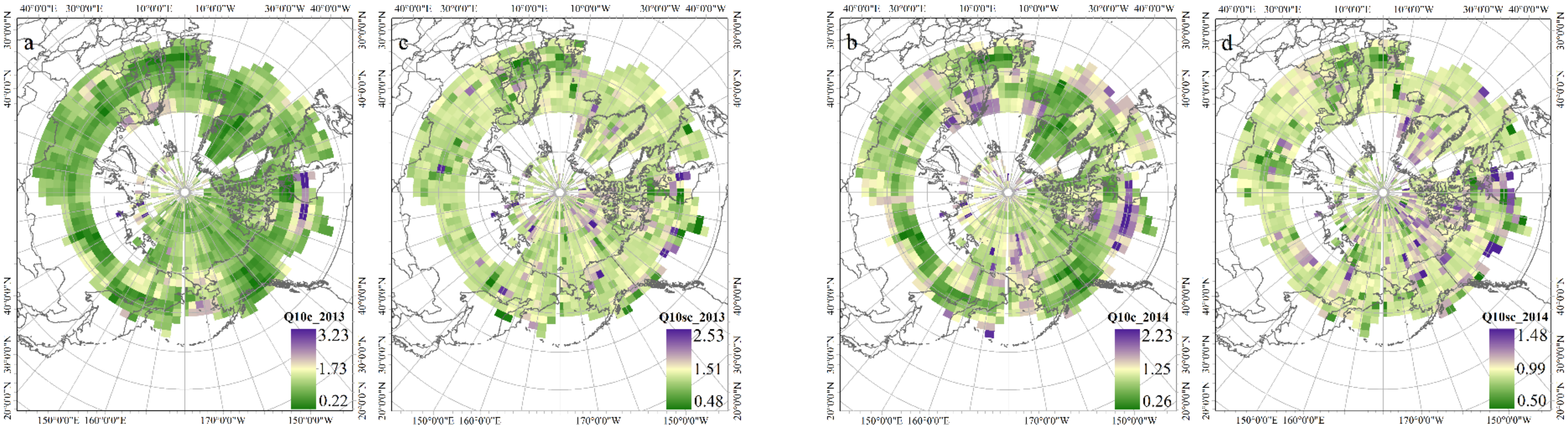


The relationship of mean annual temperature with apparent Q10c and intrinsic Q10sc

apparent Q10c increased with annual mean temperature, intrinsic Q10sc shown no variation with annual mean temperature

5. Results

Distribution of Q_{10c} and Q_{10sc} on the spatial scale

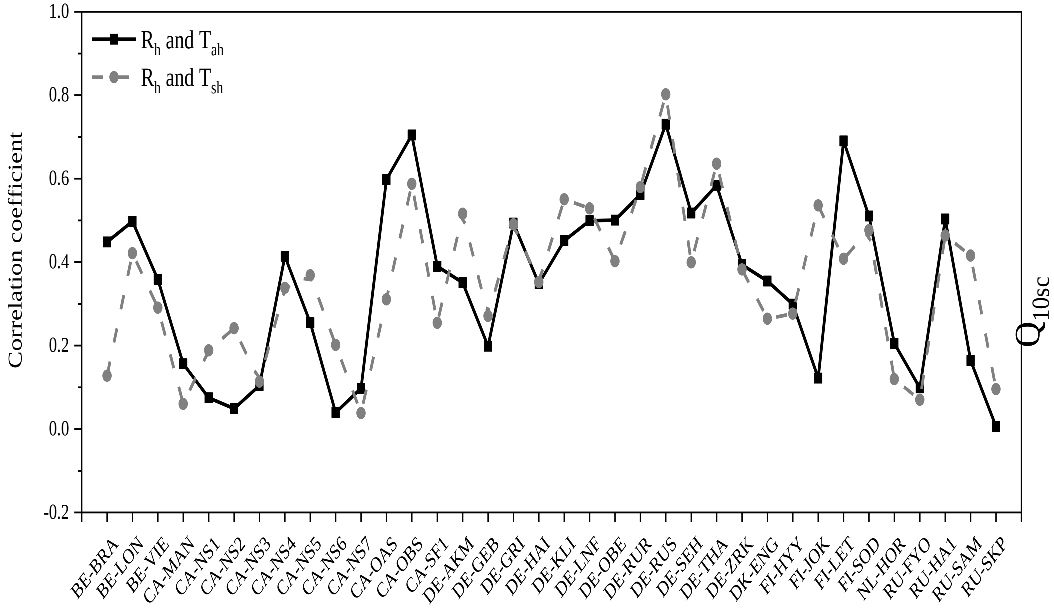


- ✓ The internal temperature sensitivity ranges from 0.48 to 2.53, and the apparent temperature sensitivity ranges from 0.22 to 3.23.
- ✓ the region with high apparent temperature sensitivity has low intrinsic temperature sensitivity, while the apparent temperature sensitivity is low, the intrinsic temperature sensitivity is high.

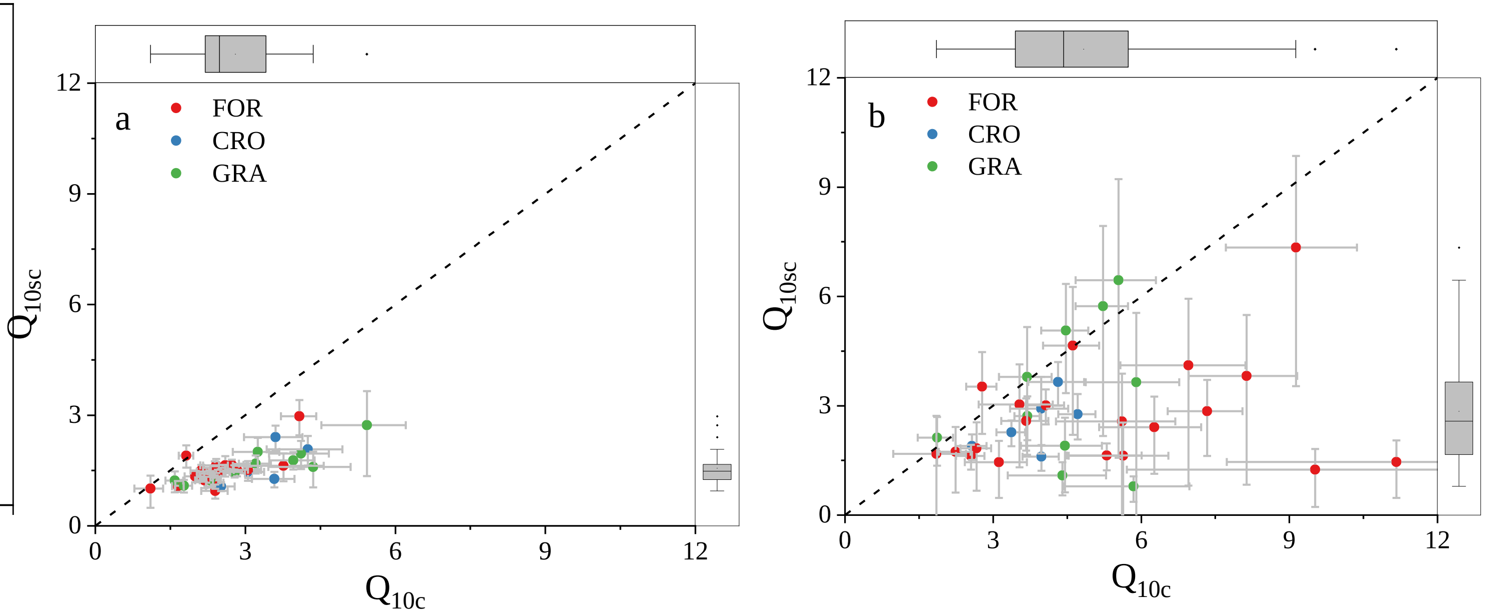
6. Discussion

Evaluating the difference of soil temperature and air temperature

Correlation between high frequency ecosystem respiration and high frequency air temperature and high frequency soil temperature.



Estimation of multi-site temperature sensitivity based on air temperature and soil temperature



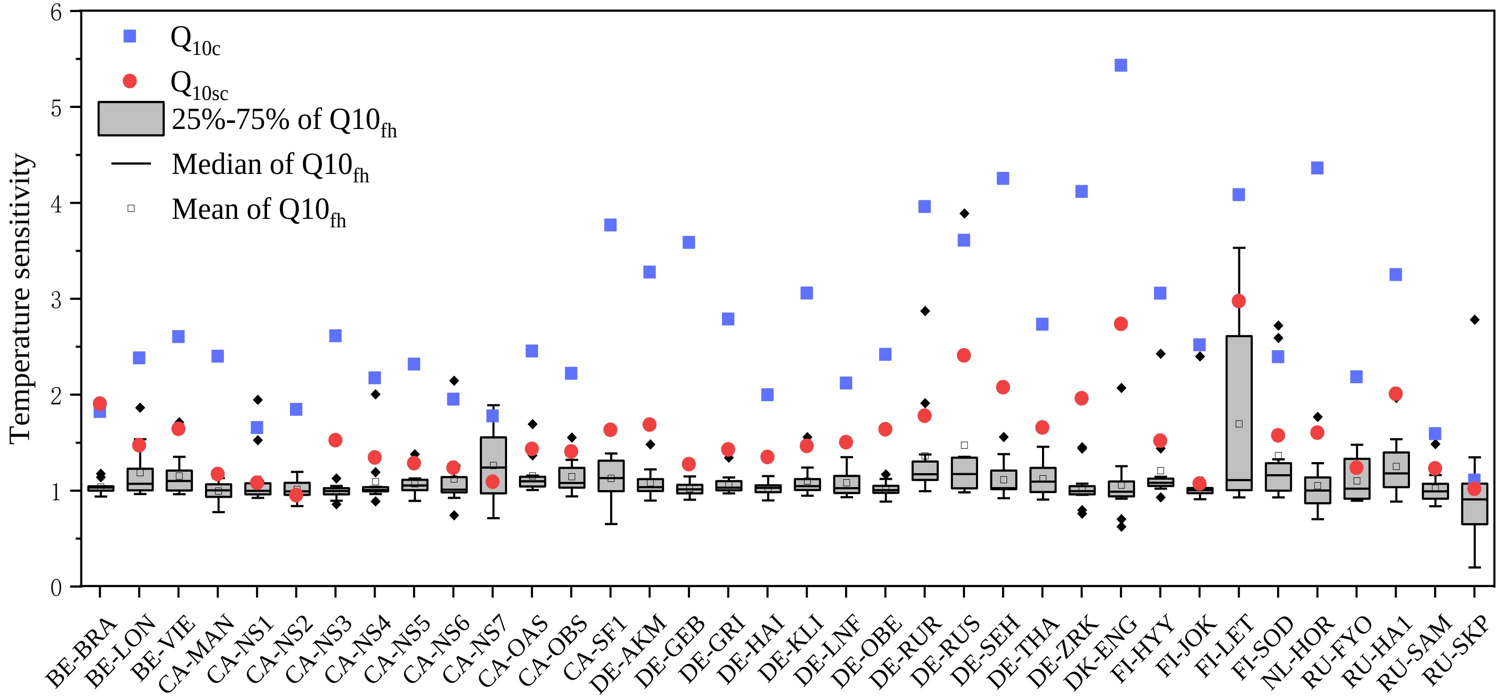
✓ The correlation analysis results indicate that the hysteresis effect of soil respiration was not obvious

✓ the calculated values of air temperature showed convergence, and there were more abnormal values of soil temperature, which may be due to the large observation error of soil temperature under freezing-thawing action.

6. Discussion

Evaluating the difference of SCAPE and SCAPE-M

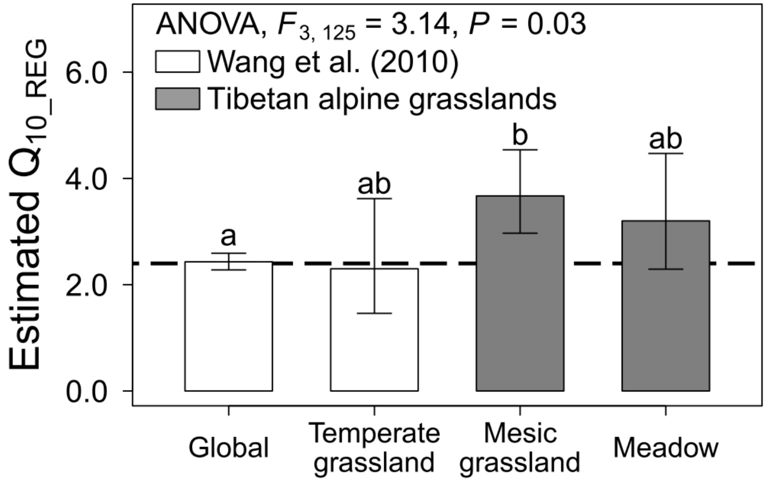
Effect of singular spectral decomposition on temperature sensitivity

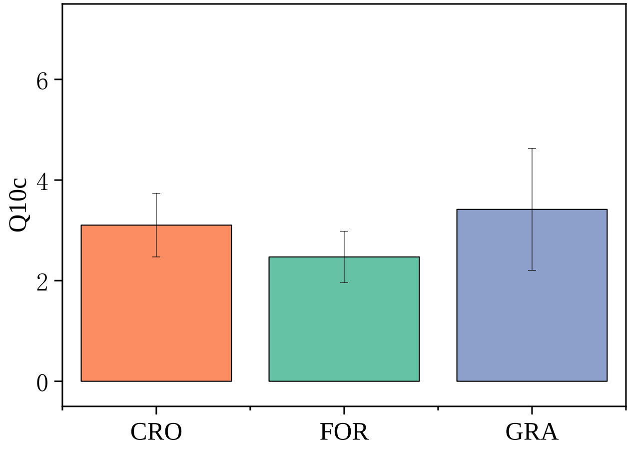


Selecting a high frequency using the SCAPE method results in information loss, resulting in lower results.
The SCAPE-M method improves the estimation of intrinsic temperature sensitivity

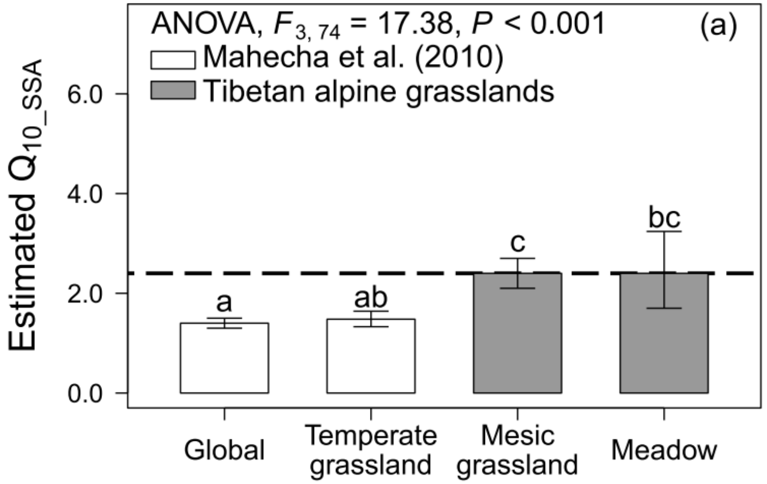
6. Discussion

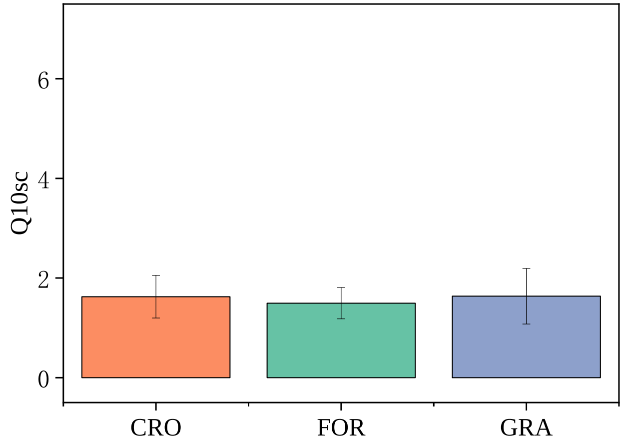
Comparison with other experiment results





The apparent Q10c of CRO and GRA in the NHL is higher than the global average, while the FOR is lower than the global average. All three ecosystems were lower than the alpine meadow vegetation of the Tibetan plateau.





The intrinsic Q10sc of CRO and GRA in the NHL is higher than the global average. All three ecosystems were lower than the alpine meadow vegetation of the Tibetan plateau.

7. Conclusion

- The intrinsic temperature sensitivity without confounding effects in the NHL was 1.54 (±0.38). Most land surface process model overestimate carbon emissions at high latitudes in the northern hemisphere
- The apparent temperature sensitivity in the NHL increased with the annual average temperature, but the intrinsic temperature sensitivity shown no significant variations
- The apparent temperature sensitivity is low, the intrinsic temperature sensitivity is high. Where the apparent temperature sensitivity is high, the temperature sensitivity is low.

Thanks for attention