延邊大學 연변대학
YANBIAN UNIVERSITY

Multiscale Response of Vegetation Growth to Climate Extremes

Duqi Liu[1,*], Guishan Cui[1,2,3], and Zhen Xu[1,2,3]

[1] College of Geography and Ocean Sciences, Yanbian University, Yanji, China

[2] Tumen River Basin Wetland Ecosystem Field Scientific Research and Observation Station, Yanbian University, Yanji, China

[3] Jilin Provincial International Joint Research Center of Tumen River Basin Wetland and Ecology, Yanbian University, Yanji, China

*** E-mail:** 2023010776@ybu.edu.cn / duqi_liu@outlook.com

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ABSTRACT

1. Regional Scale

A Case in Northeast Aisa

Motivation 1: Current studies mainly focus on the negative impacts of climate extremes on vegetation. However, **the effects of climate extremes on vegetation are diverse** and not all climate extremes have negative impacts on vegetation.

Motivation 2: There is **a limited focus on the discrete nature of extreme events over long time-series**, where extreme events only occur when values are above (or below) the threshold upper (or lower) limits.

Question: **Do climate extremes have negative or positive effects on vegetation growth in Northeast Asia?**

The Positive Impact of Extreme Heat on Vegetation Growth in Northeast Aisa

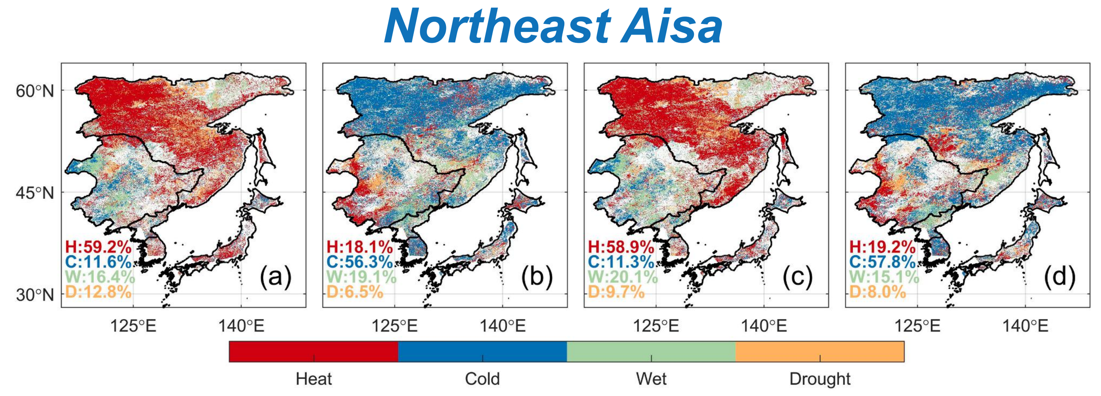

Fig. 1. Distribution of the highest coincidence rates between abnormal vegetation growth and different climate extremes (extreme heat, extreme cold, extreme wet, and extreme drought). *(a) Vegetation high-growth expressed by the NDVI, (b) vegetation low-growth expressed by the NDVI, (c) vegetation high-growth expressed by the EVI, and (d) vegetation low-growth expressed by the EVI. The red H indicates extreme heat, blue C is extreme cold, cyan W represents extreme wet, and yellow D indicates extreme drought.*

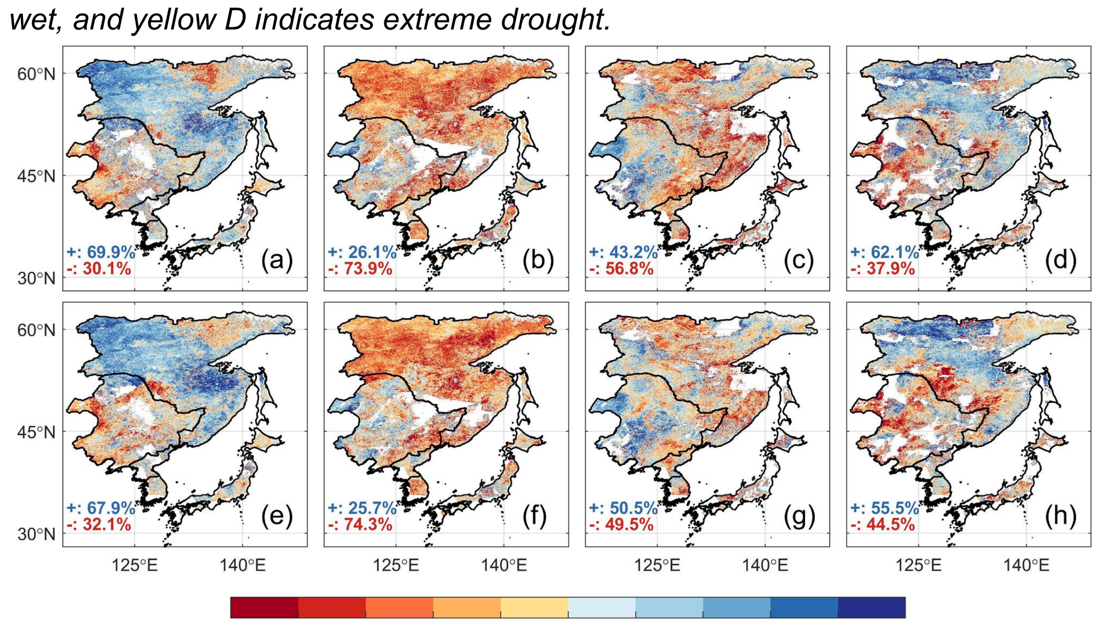

Fig. 2. Spatial patterns of the sensitivity of vegetation growth to climate extremes. *Sensitivity of the NDVI to (a) extreme heat, (b) extreme cold, (c) extreme humidity, and (d) extreme drought. Sensitivity of the EVI to (e) extreme heat, (f) extreme cold, (g) extreme wet, and (h) extreme drought. The blue + indicates positive sensitivity while the red - indicates negative sensitivity*

Influence of Local Climatic Conditions on Extreme Heat Promoting Vegetation Growth

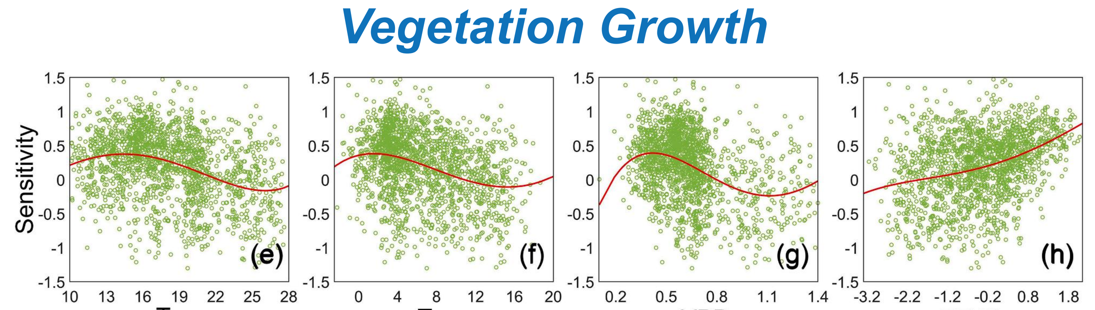

Fig. 3. Sensitivity of vegetation growth to extreme heat influenced by local hydrothermal conditions. *Scatter plots of the (e) maximum temperature (℃), (f) minimum temperature (℃), (g) VPD (kPa), and (h) PDSI plotted with respect to the sensitivity of vegetation high-growth to extreme heat, where the red line is the fourth-degree polynomial fitting curve.*

Conclusions

Conclusion 1: **Vegetation high-growth occurred more under extreme heat.**

Conclusion 2: **Promotion of vegetation growth under extreme heat weakened with an increasing temperature gradient, but strengthened along the humidity gradient.**

2. Land Scale

A Summary of Terrestrial Ecosystem

Motivation 1: A growing number of studies, **predominantly at the local and regional scales**, have suggested that climate extremes may potentially drive these observed vegetation growth extremes, leading to the impairment of ecosystem functions.

Motivation 2: Evaluating the influence of climatic extremes on the vegetation growth extremes across broad scales may **reveal the trajectories of coupled climates and ecosystems**, especially in terms of feedback loops within climate systems.

Question: **What are the spatial patterns of vegetation sensitivity to climate extremes in the Northern Hemisphere?**

Spatial Distribution of the Sensitivity of Vegetation Growth to Climate Extremes in the Northern Hemisphere

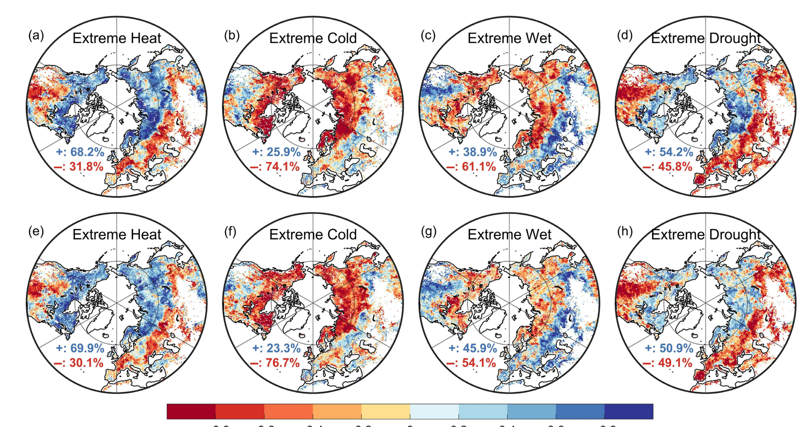

Fig. 4. Sensitivity of vegetation growth to climate extremes in the Northern Hemisphere. *The sensitivities of vegetation growth based on SIF to (a) extreme heat, (b) extreme cold, (c) extreme wet and (d) extreme drought. The sensitivities of vegetation growth based on NDVI to (e) extreme heat, (f) extreme cold, (g) extreme wet and (h) extreme drought. The values in blue and red indicate positive and negative sensitivities, respectively.*

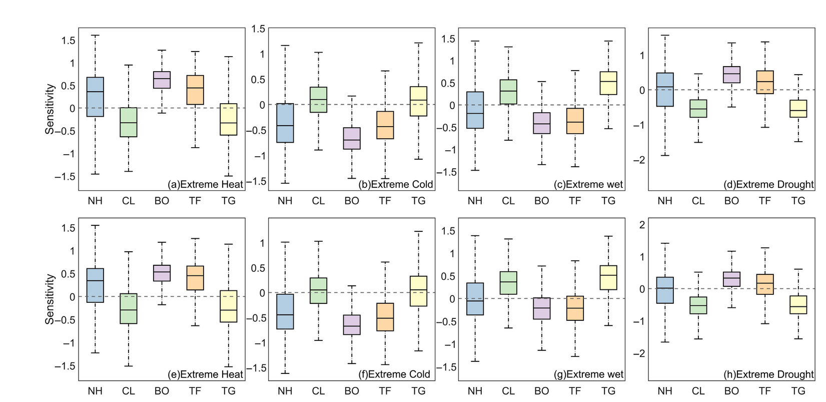

Fig. 5. Sensitivity of vegetation growth to climate extremes in different biomes. *The sensitivity of vegetation growth based on SIF to (a) extreme heat, (b) extreme cold, (c) extreme wet and (d) extreme drought is shown. The sensitivity of vegetation growth based on NDVI to (e) extreme heat, (f) extreme cold, (g) extreme wet and (h) extreme drought is shown. NH is the Northern Hemisphere's overall situation, CL is the cropland biome, BO is the boreal biome, TF is the forest biome and TG is the grassland biome.*

Hydrothermal Conditions Modulate the Impact of Climate Extremes on Vegetation Growth in the Northern Hemisphere

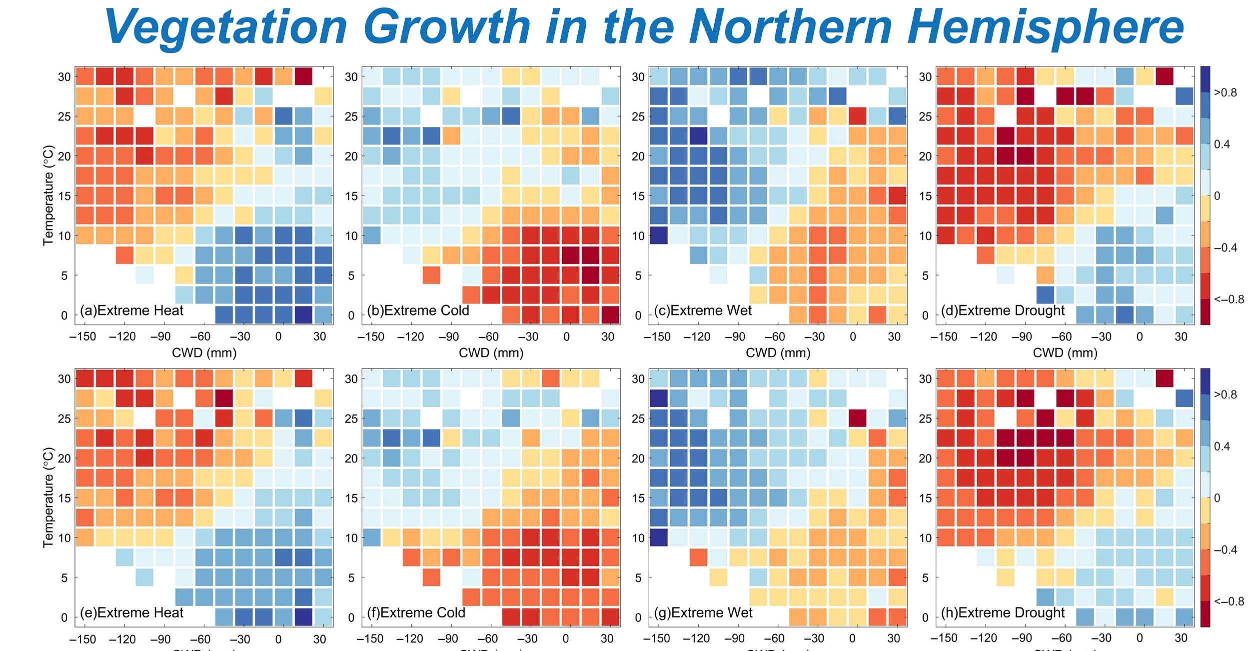

Fig. 6. Sensitivity of vegetation growth to climate extremes under different hydrothermal conditions in the Northern Hemisphere. *The sensitivity of vegetation growth based on SIF to (a) extreme heat, (b) extreme cold, (c) extreme wet and (d) extreme drought is shown. The sensitivity of vegetation growth based on NDVI to (e) extreme heat, (f) extreme cold, (g) extreme wet and (h) extreme drought is shown. The horizontal axis represents the local CWD (mm), the vertical axis represents the local temperature (℃) and the grid colours represent the sensitivity of vegetation growth to climate extremes along hydrothermal gradients.*

Conclusions

Conclusion 1: **Extreme heat promotes vegetation growth, while extreme cold has a detrimental effect on vegetation growth.**

Conclusion 2: **Extreme heat and drought were more conducive to positive vegetation growth in cold or humid regions, respectively, whereas extreme cold and wet were more conducive to negative vegetation growth, respectively.**

3. Land-Ocean Scale

An Interest in the Coastal Vegetation

Motivation 1: The simultaneous occurrence of terrestrial and marine climate extremes represents a new type of compound risk, **whose impacts on vegetation productivity go beyond the additive effects of individual extreme events.**

Motivation 2: The response of vegetation productivity to climate extremes shows **a marked dependence on temporal scale.**

Question: **How do the impacts of extreme heat-surge on coastal vegetation productivity differ across temporal scales?**

Differences in the Impacts of Extreme Heat-Surge on Coastal Vegetation Productivity across Temporal Scales

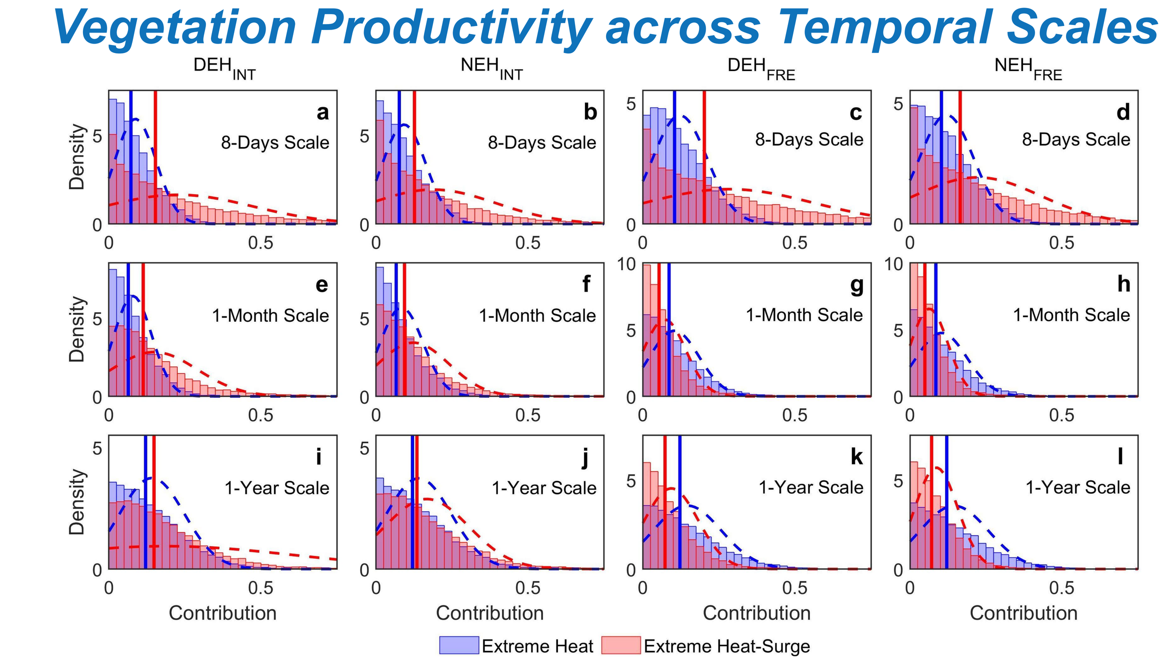

Fig. 7. The impacts of individual or compound extreme heat on coastal vegetation productivity across different temporal scales. *(a) to (d) represent the relative contributions at an 8-days scale of individual or compound daytime extreme heat intensity (DEH_{INT}), nighttime extreme heat intensity (NEH_{INT}), daytime extreme heat frequency (DEH_{FRE}), and nighttime extreme heat frequency (NEH_{FRE}) to changes in coastal vegetation productivity, respectively. (e) to (h) represent the relative contributions at an 1-month scale of individual or compound DEH_{INT}, NEH_{INT}, DEH_{FRE}, and NEH_{FRE} to changes in coastal vegetation productivity, respectively. (i) to (l) represent the relative contributions at an 1-year scale of individual or compound DEH_{INT}, NEH_{INT}, DEH_{FRE}, and NEH_{FRE} to changes in coastal vegetation productivity, respectively. Dashed lines denote the fitted probability density function curves, and solid lines indicate the medians.*

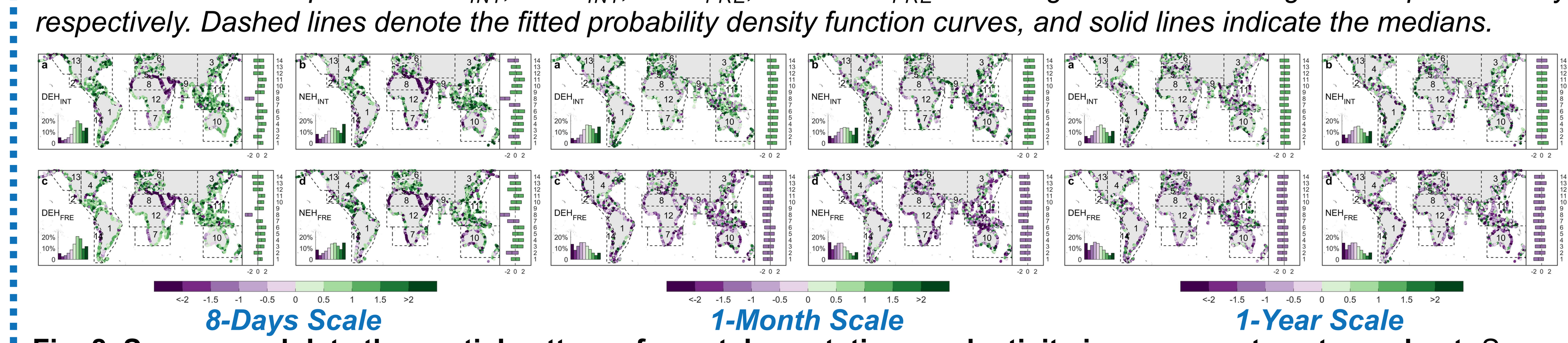

Fig. 8. Surges modulate the spatial pattern of coastal vegetation productivity in response to extreme heat. *Surges influence the impact of (a) daytime extreme heat intensity, (b) nighttime extreme heat intensity, (c) daytime extreme heat frequency, and (d) nighttime extreme heat frequency on coastal vegetation productivity, respectively. The subfigure histograms show the probability distributions with colors consistent with the legend. The subfigure box plots depict the modulation effects of surges across different regions, with purple indicating a negative median and green indicating a positive median.*

Furture Compound Extreme Heat-Surge across Temporal Scales

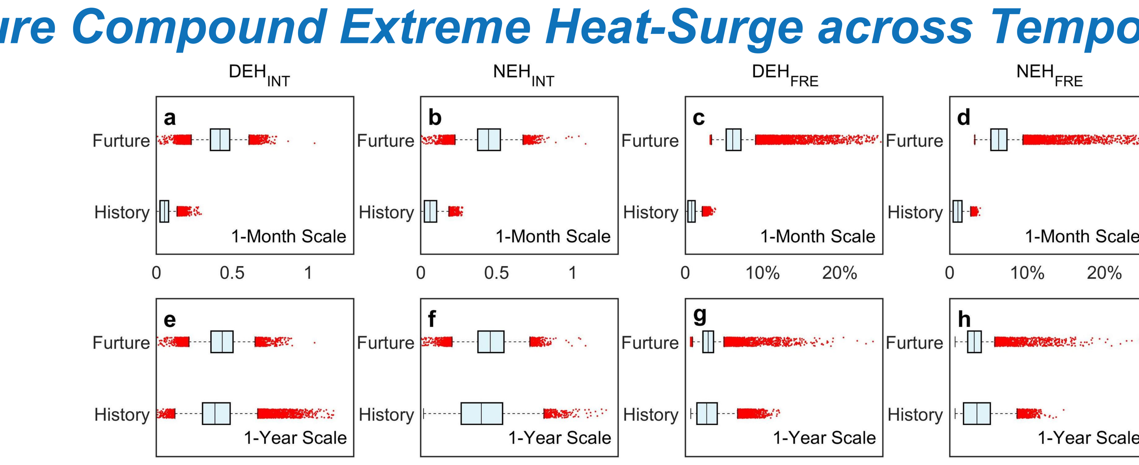

Fig. 9. Furture and historical compound extreme heat-surge across different temporal scales.

Conclusions

Conclusion 1: **Both past and future results show that shorter temporal scales better reveal the impact of extreme heat–surge on coastal vegetation. Finer temporal resolution ecosystem models are urgently needed.**

References:

1. **Liu, D.**, ..., Cui, G.* (2024). ***Agricultural and Forest Meteorology***
2. Xu, Z.*, **Liu, D.**, ... (2024). ***Global Ecology and Biogeography***

ResearchGate: