

Spatiotemporal change in ecological patterns across the late Quaternary

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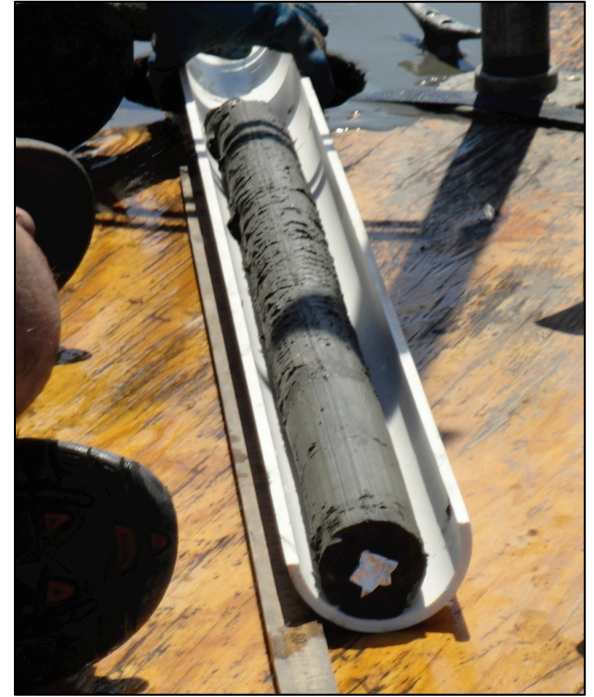
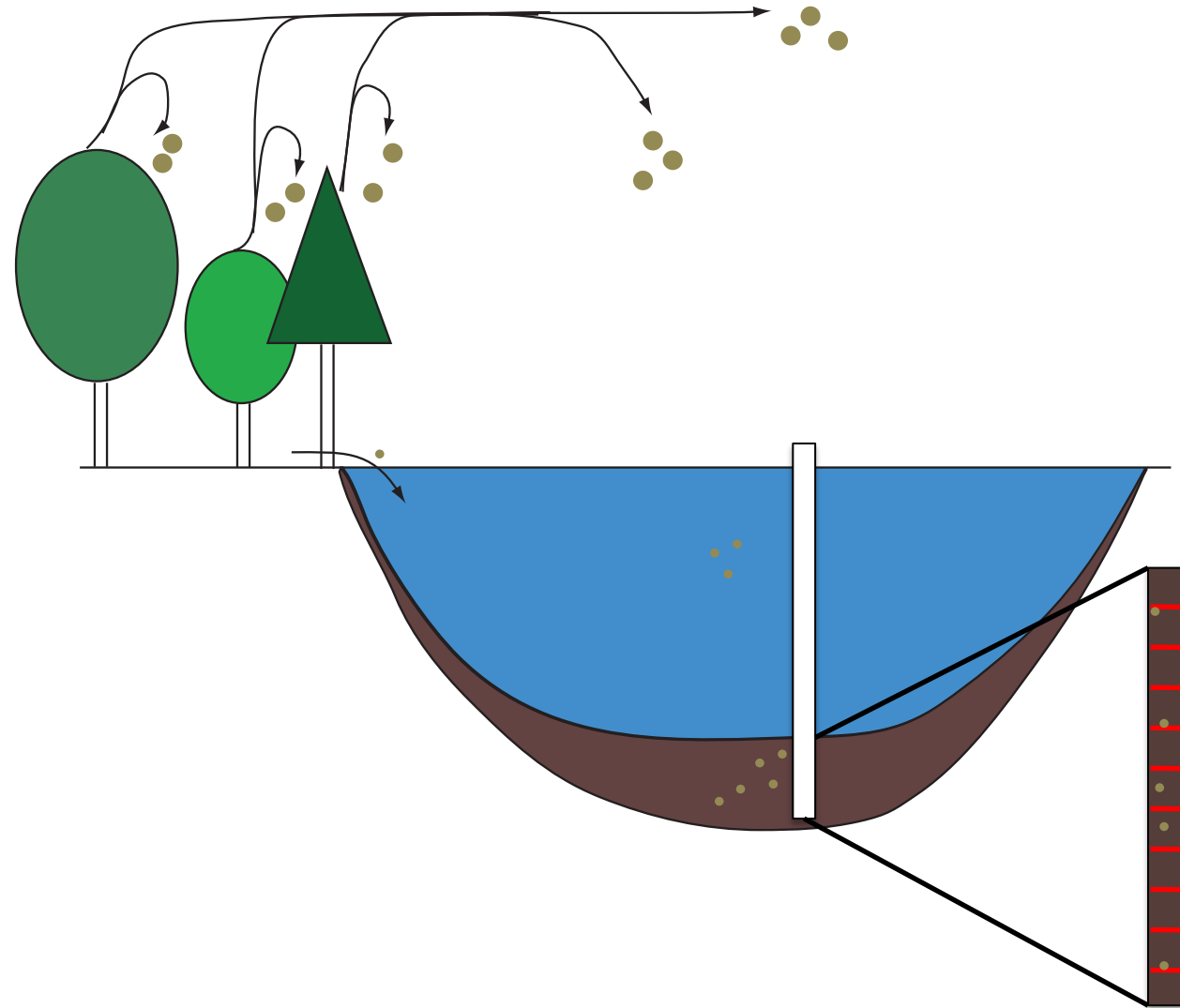
Providing a long-term context for recent and future biodiversity change

- ▮ Influence of climate on vegetation assemblages
- ▮ How does the past inform our predictions of the future?

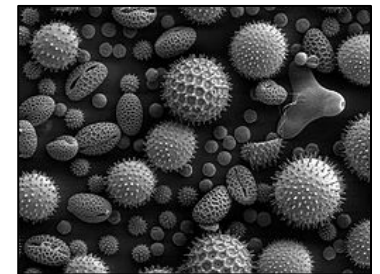
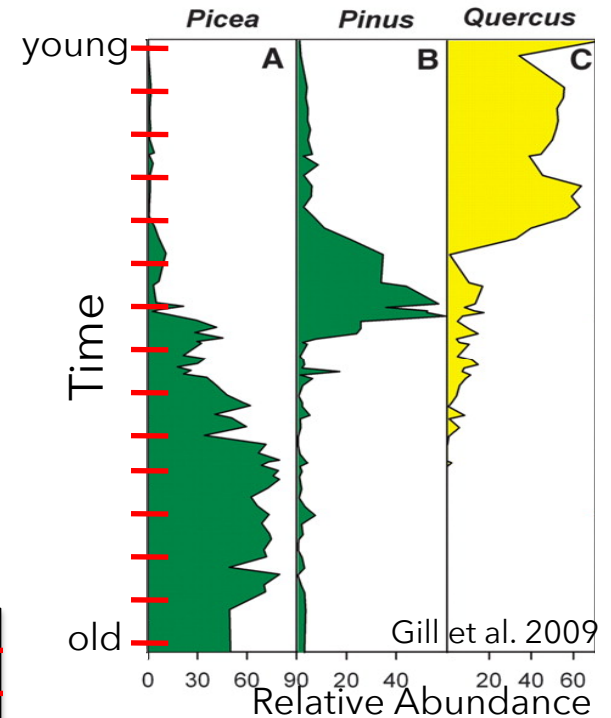
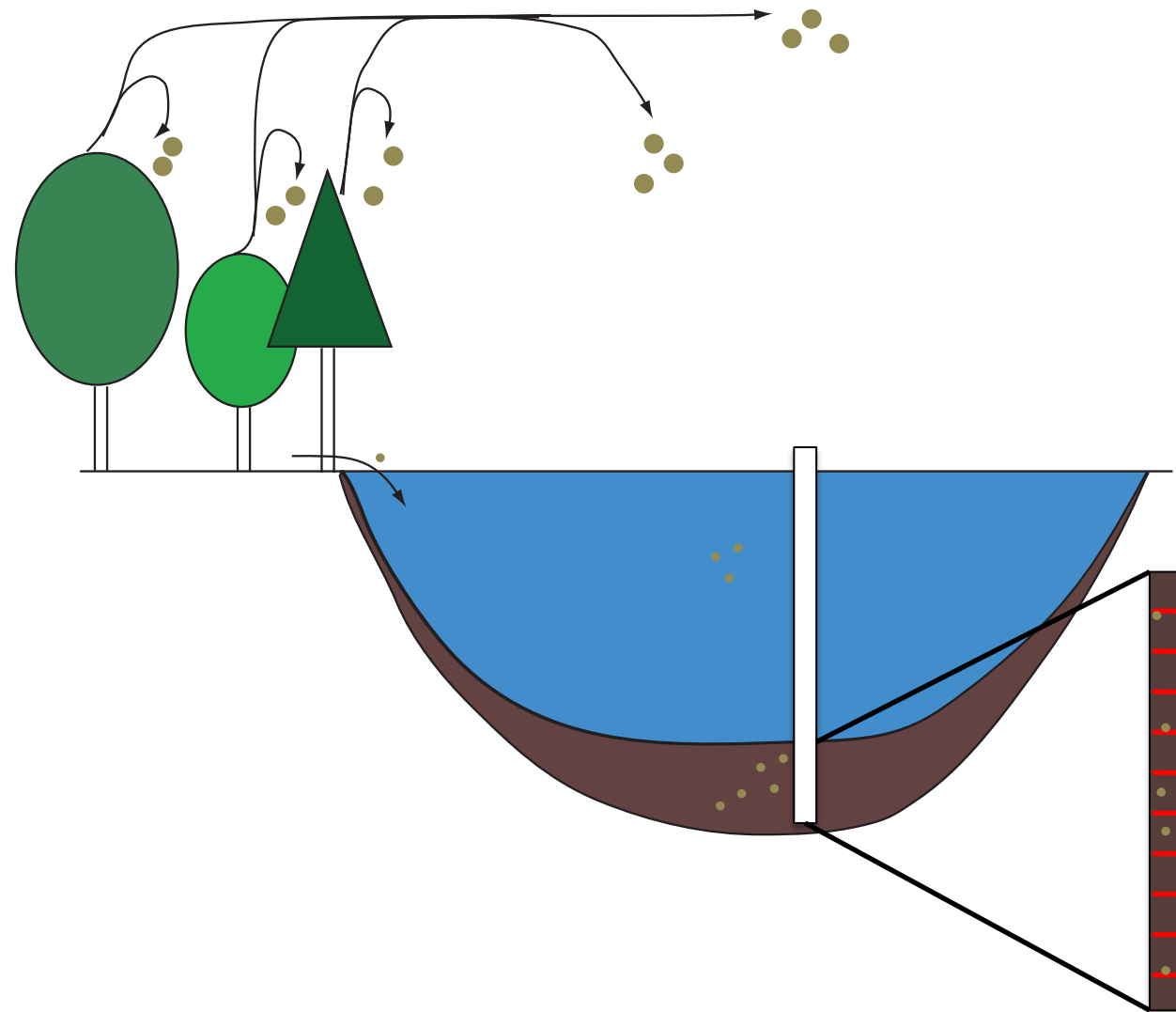
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Study system: Fossil pollen from lake sediments captures a diverse plant community



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Fossil pollen: proxy for vegetation of eastern North America over the past 21,000 years



Alnus
(alder)



Quercus
(oak)



Ulmus
(elm)



Picea
(spruce)

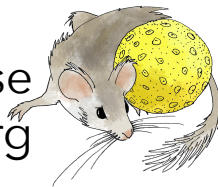
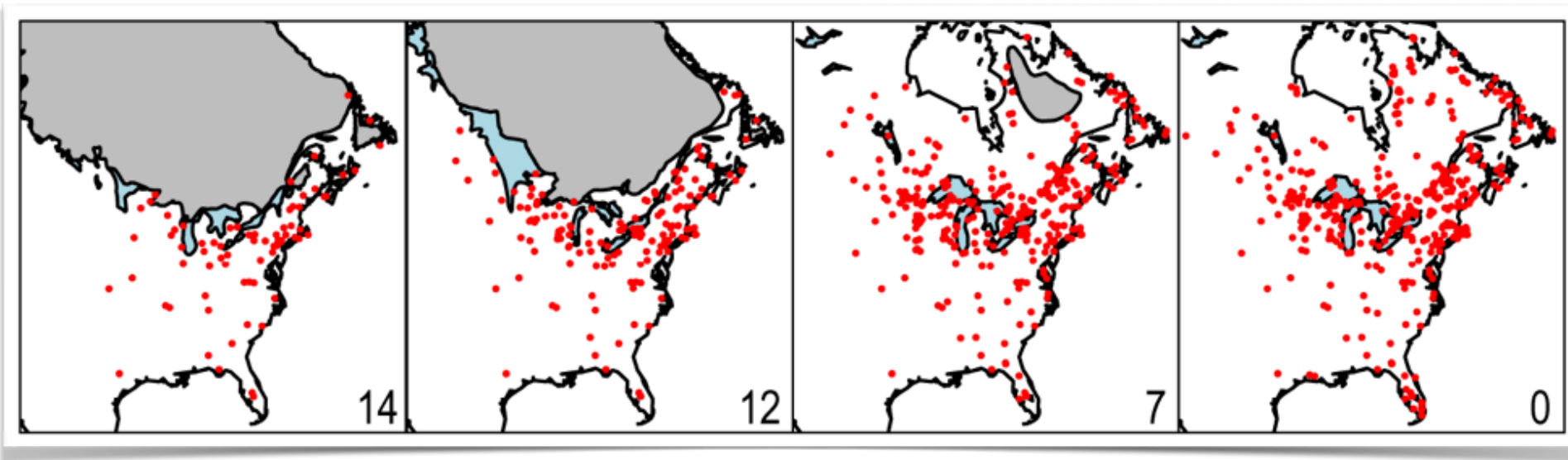


Pinus
(pine)

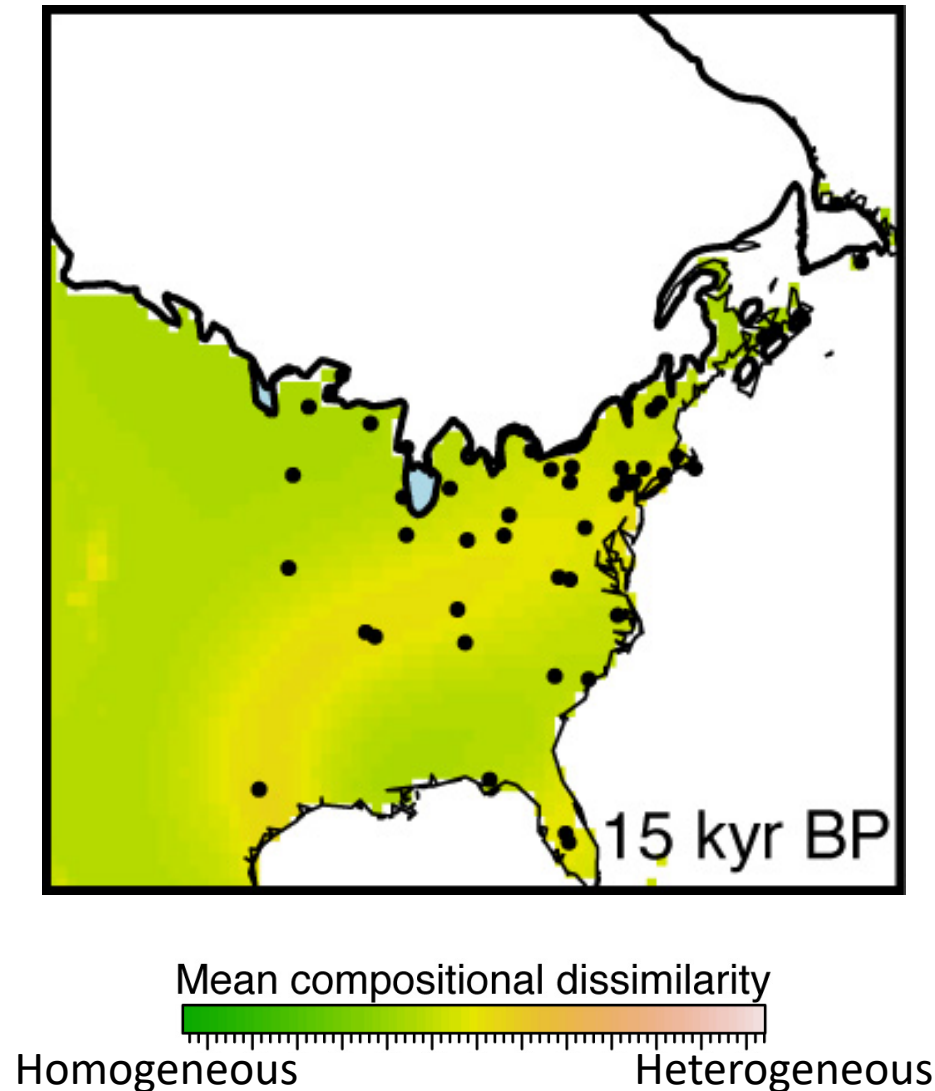


Fraxinus
(ash)

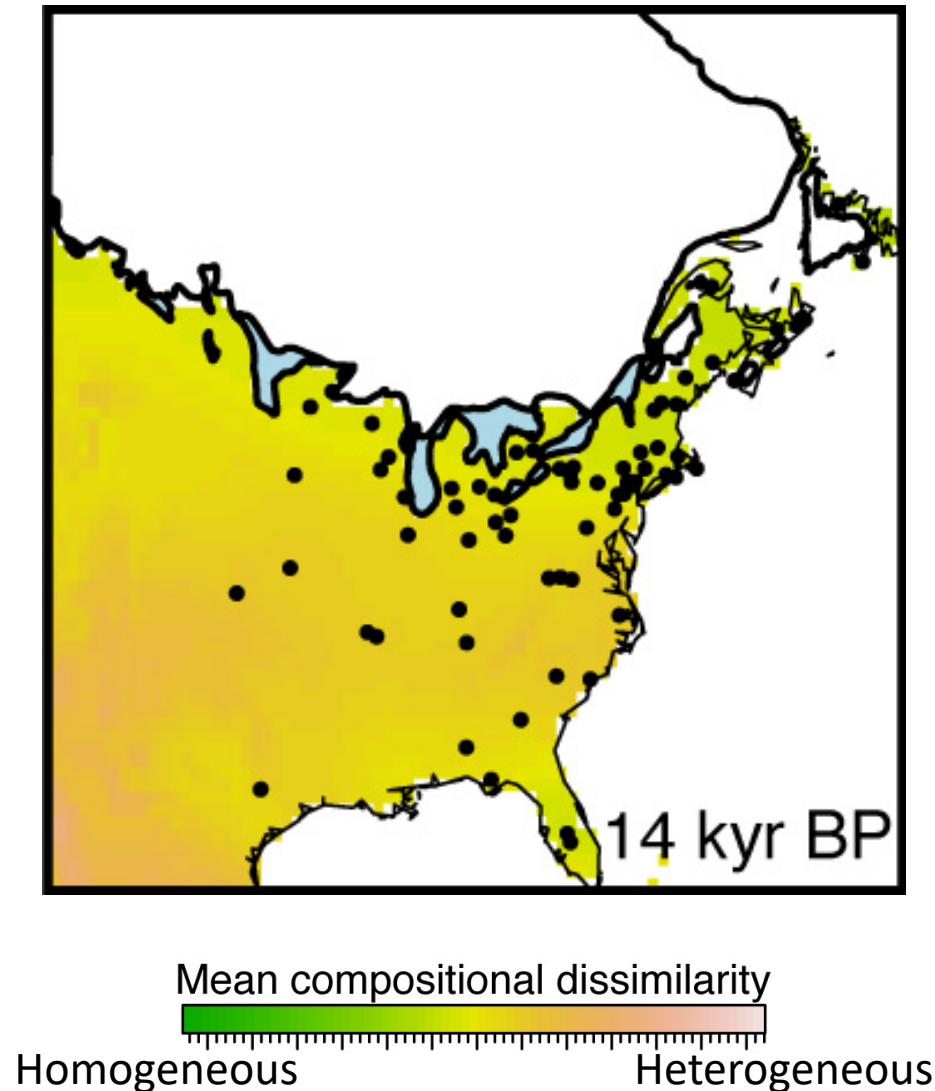
Fossil pollen: proxy for vegetation of eastern North America over the past 21,000 years



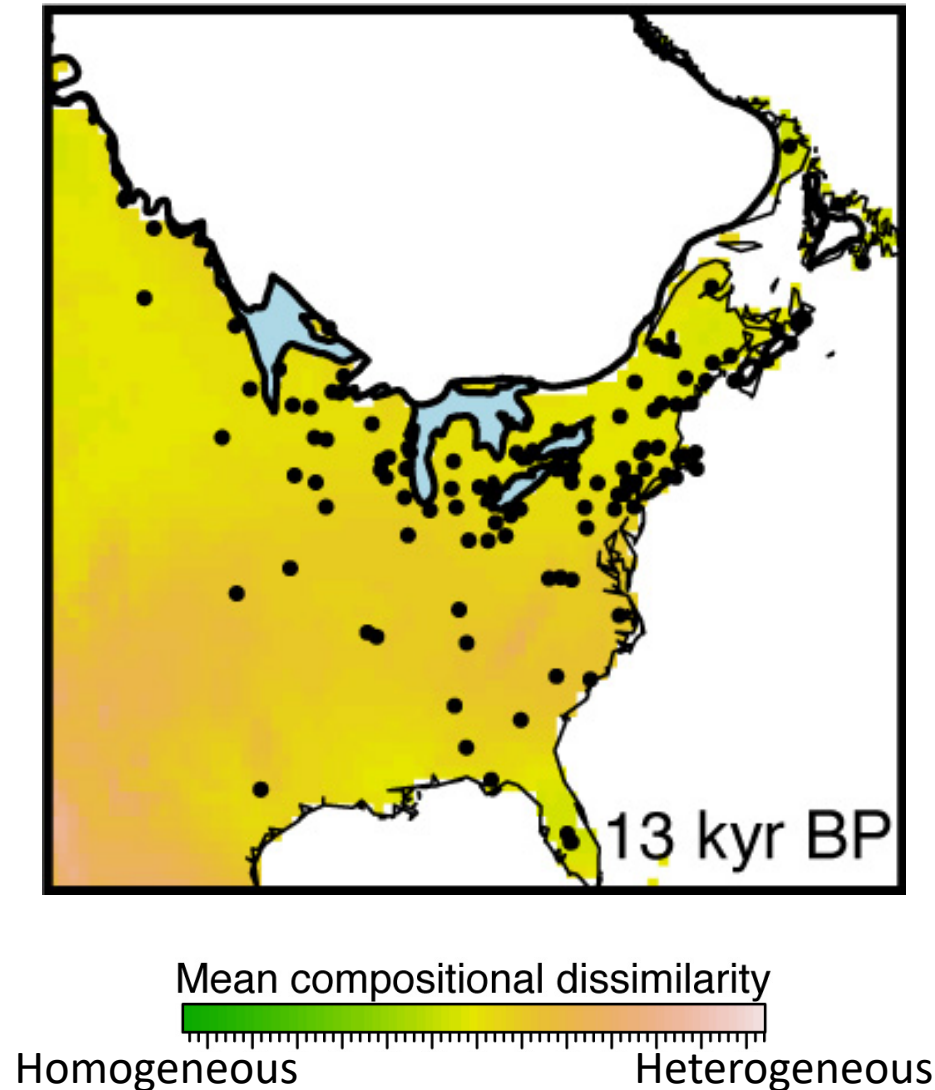
Community dissimilarity has changed dramatically over past 15,000 years



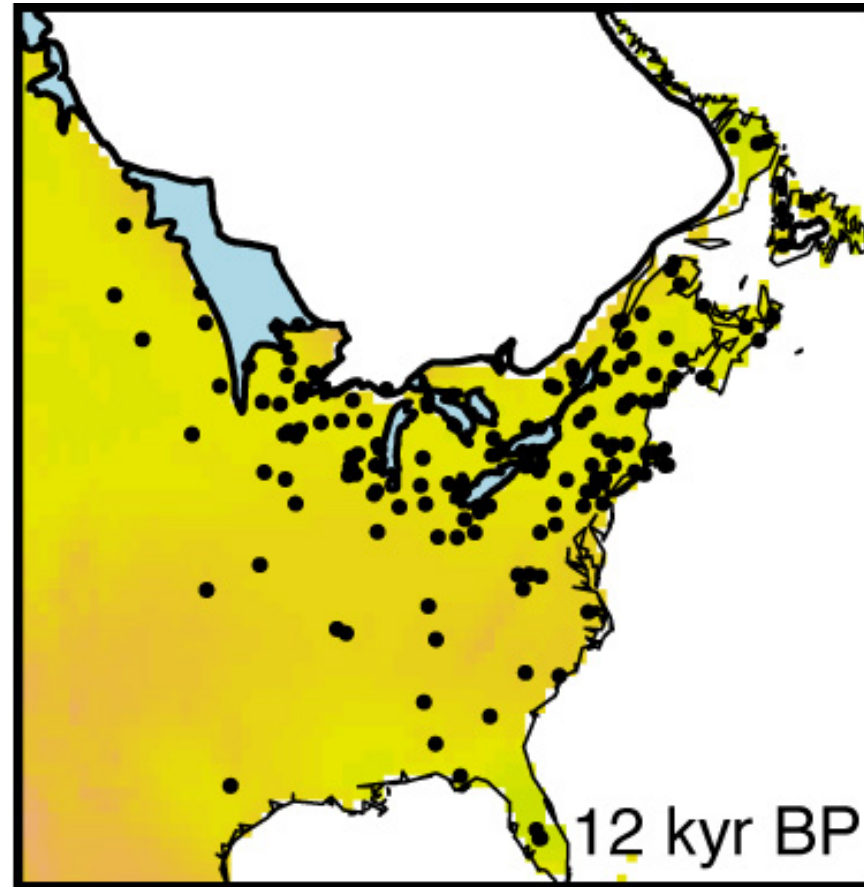
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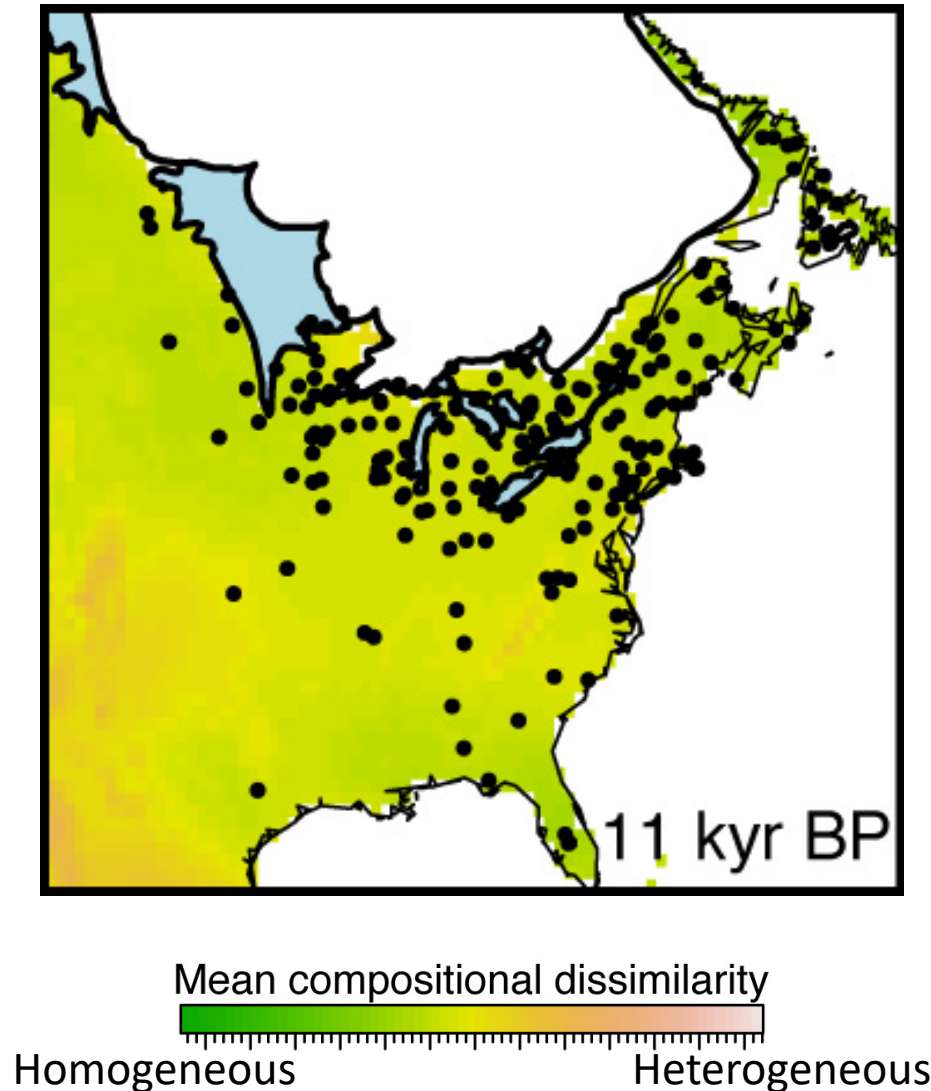


Mean compositional dissimilarity

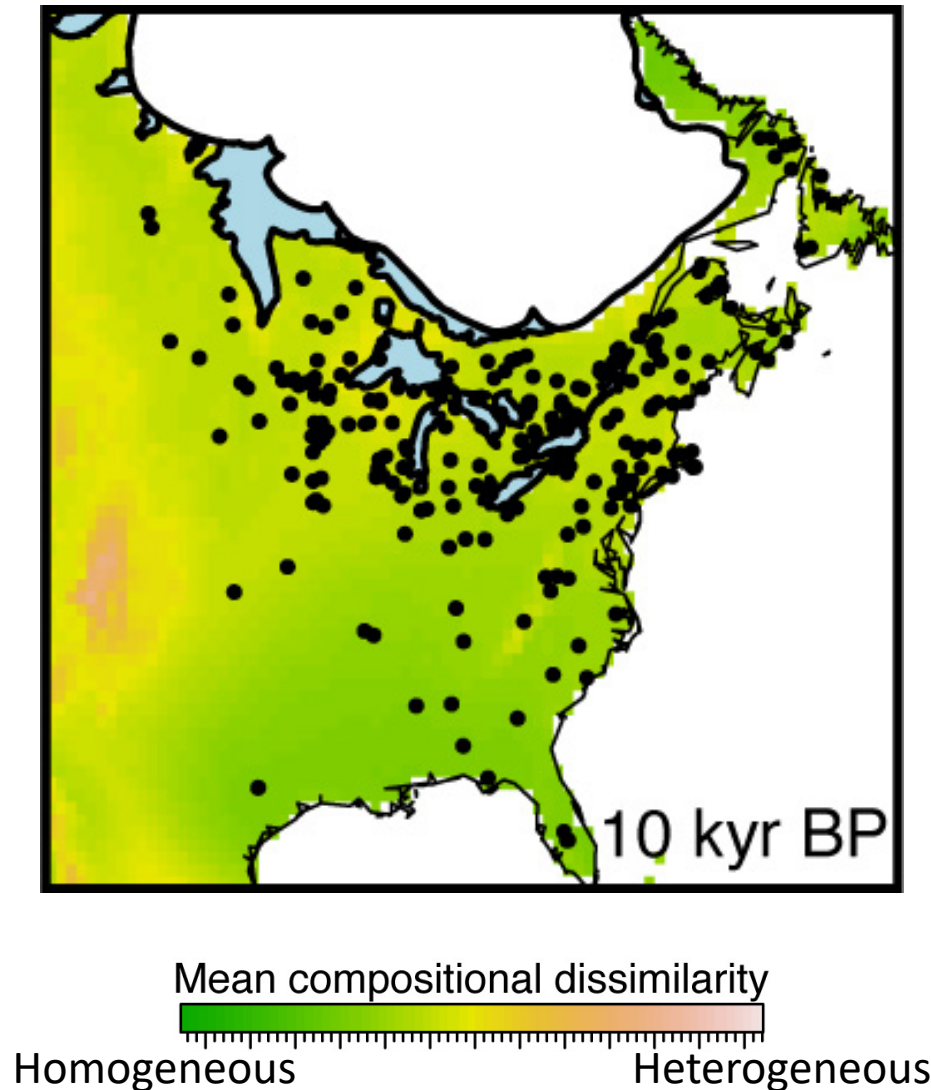
Homogeneous Heterogeneous

A horizontal color scale bar with a gradient from green on the left to red on the right. Below the bar is a series of vertical tick marks of varying lengths, creating a scale from 0 to 100.

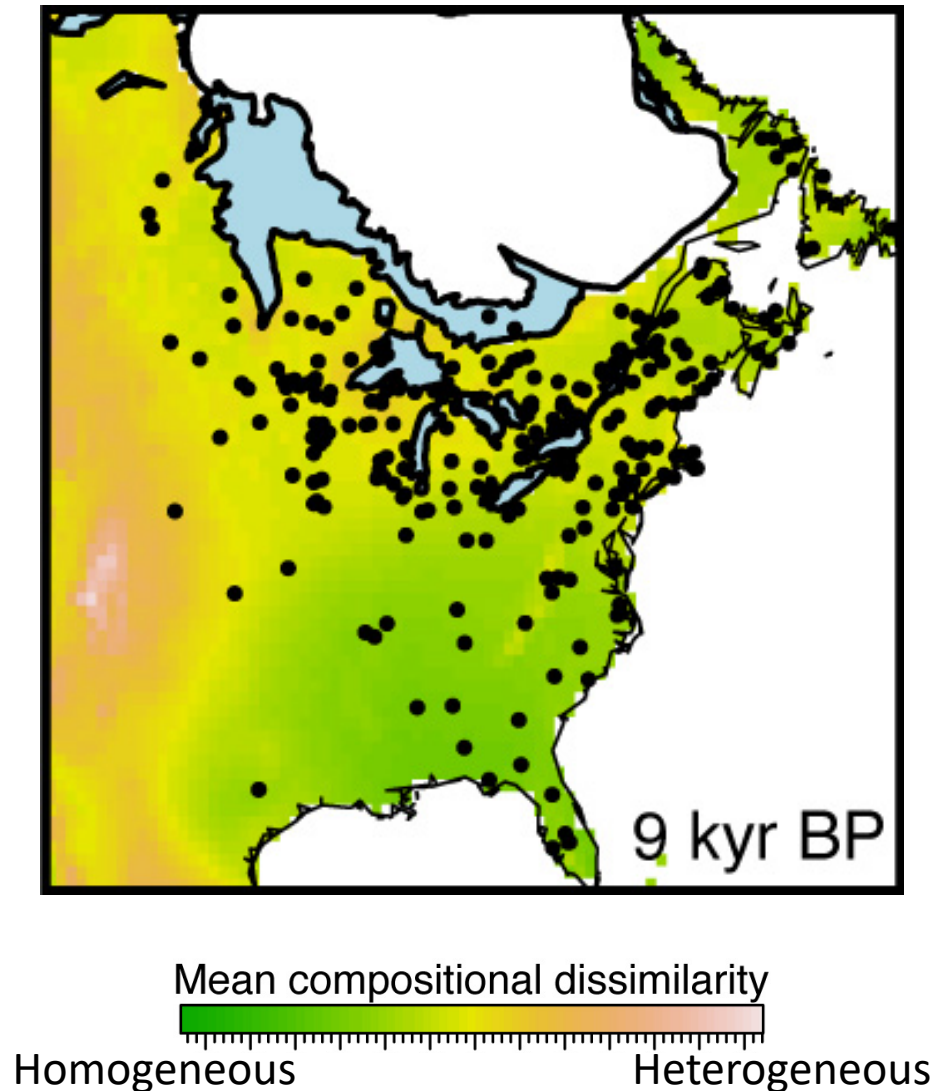
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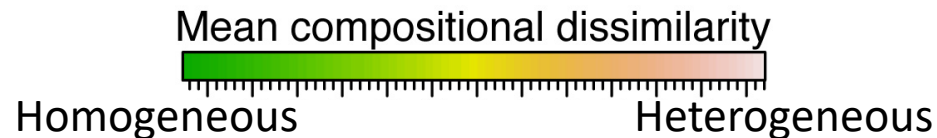
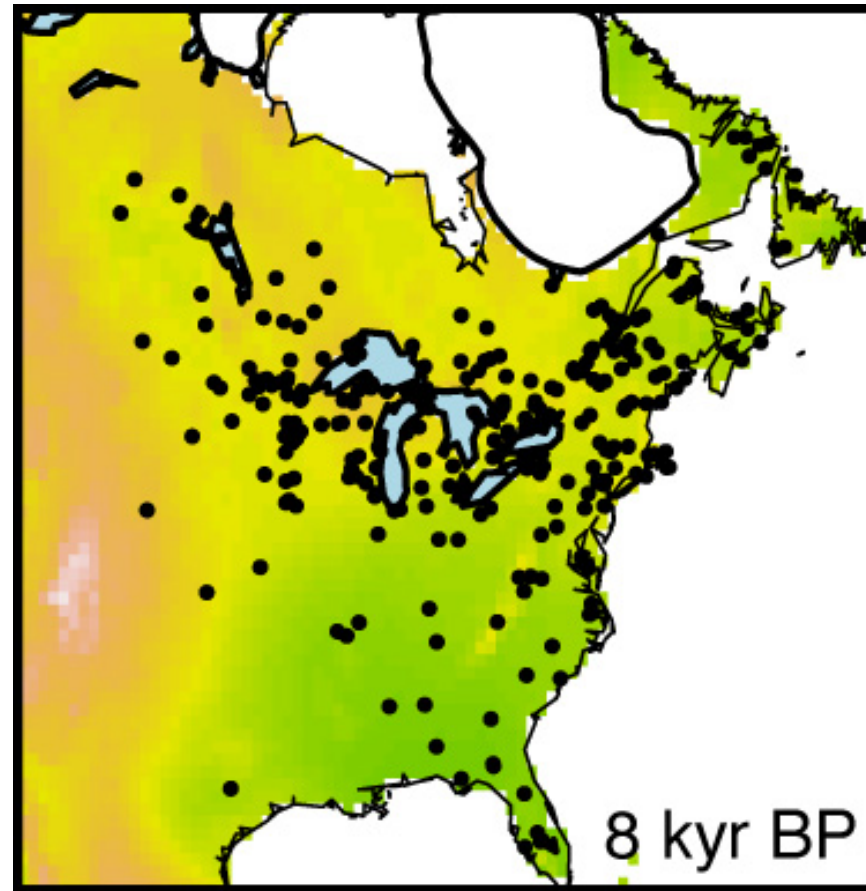
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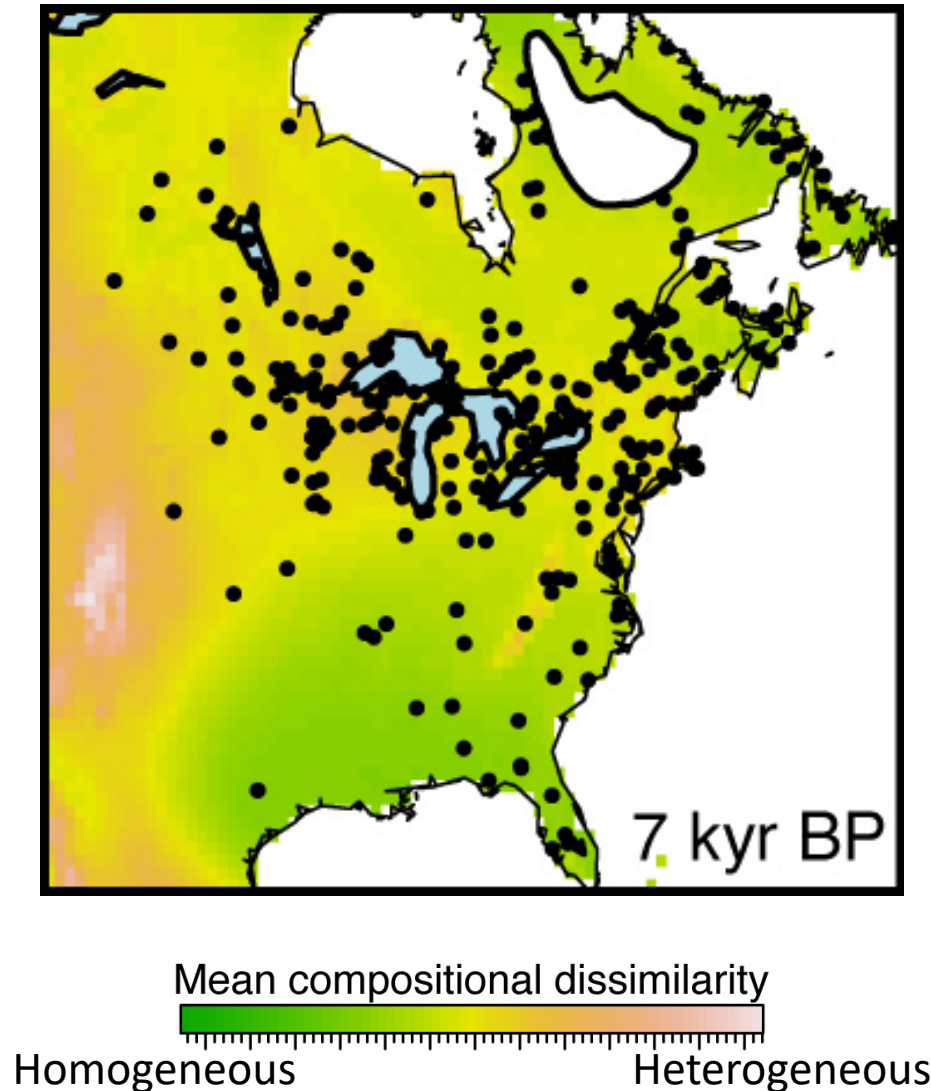
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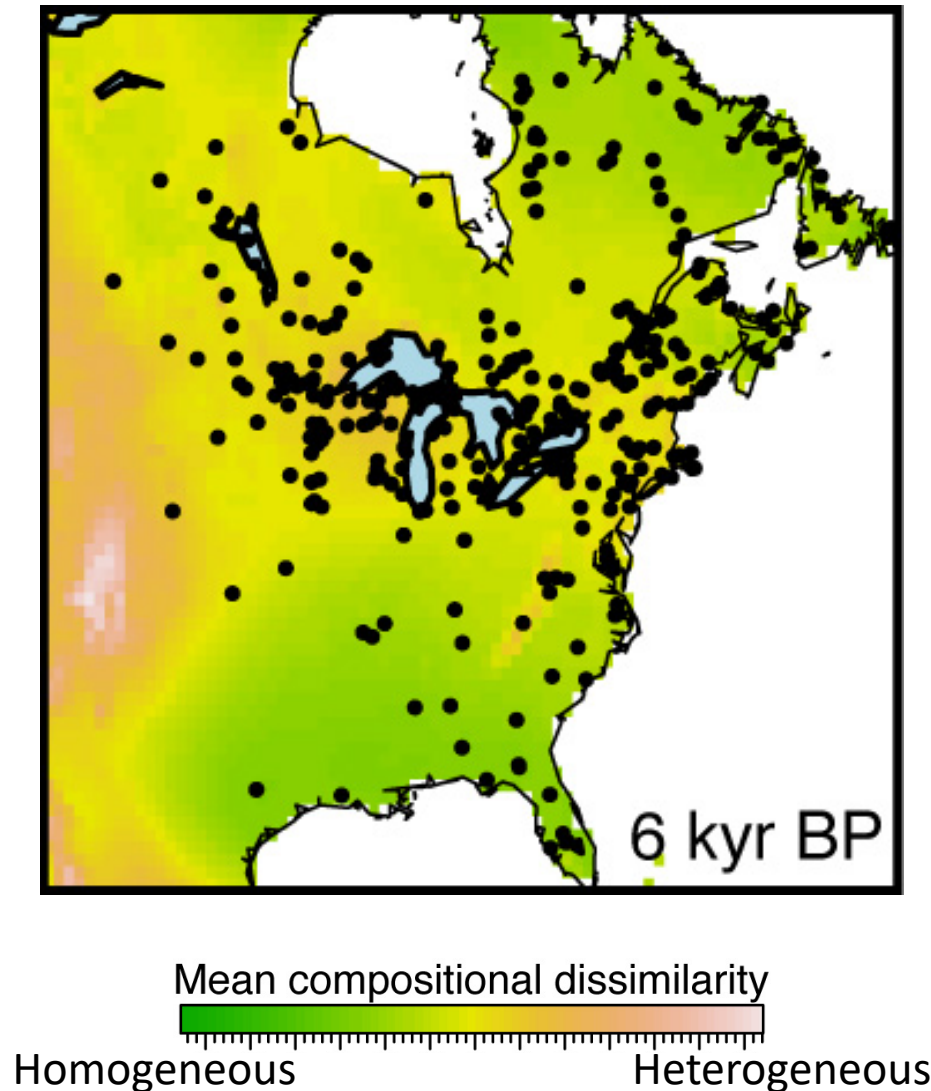
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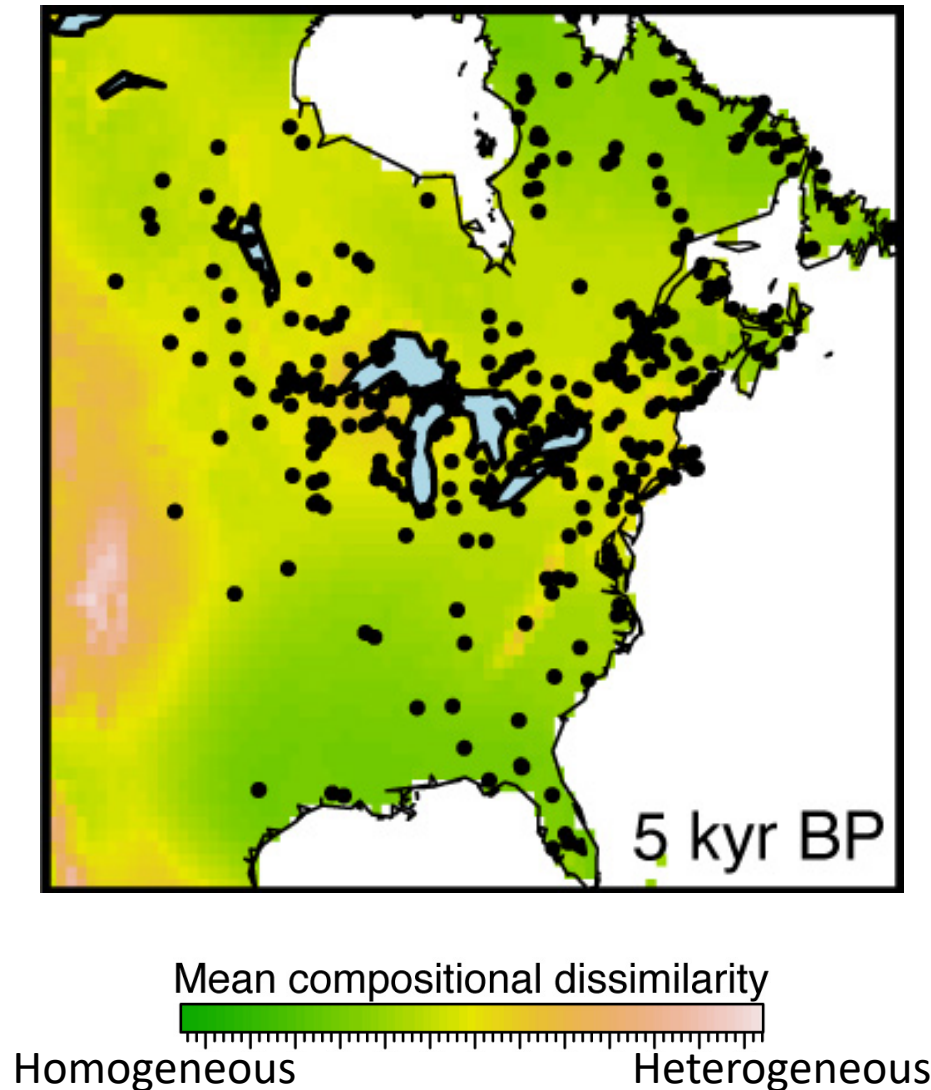
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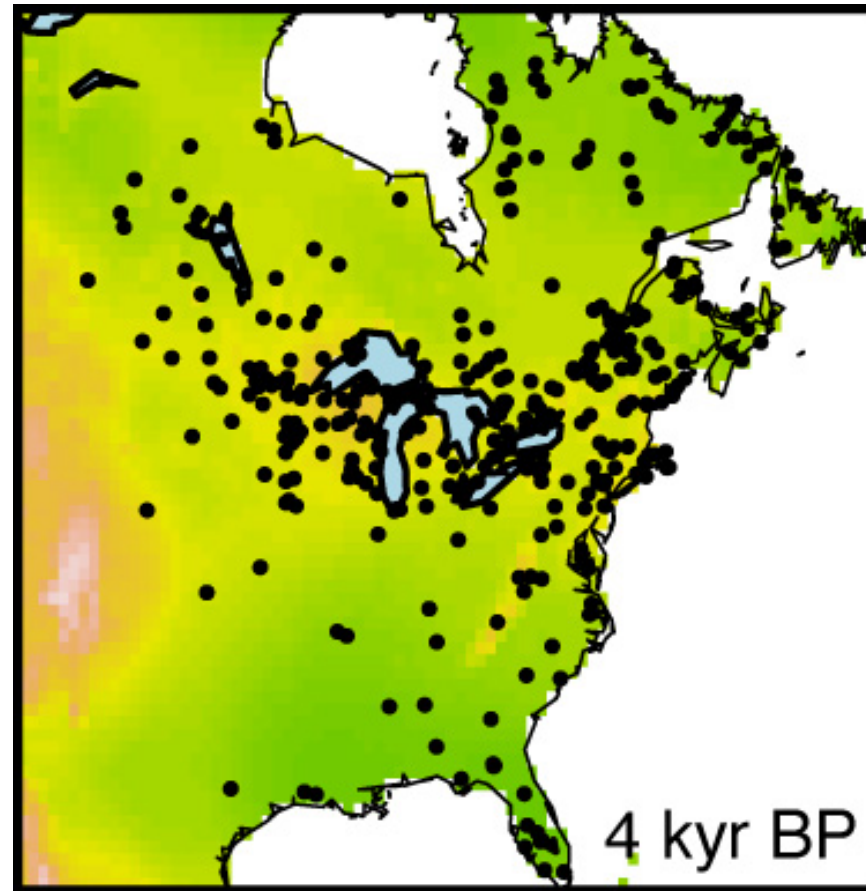
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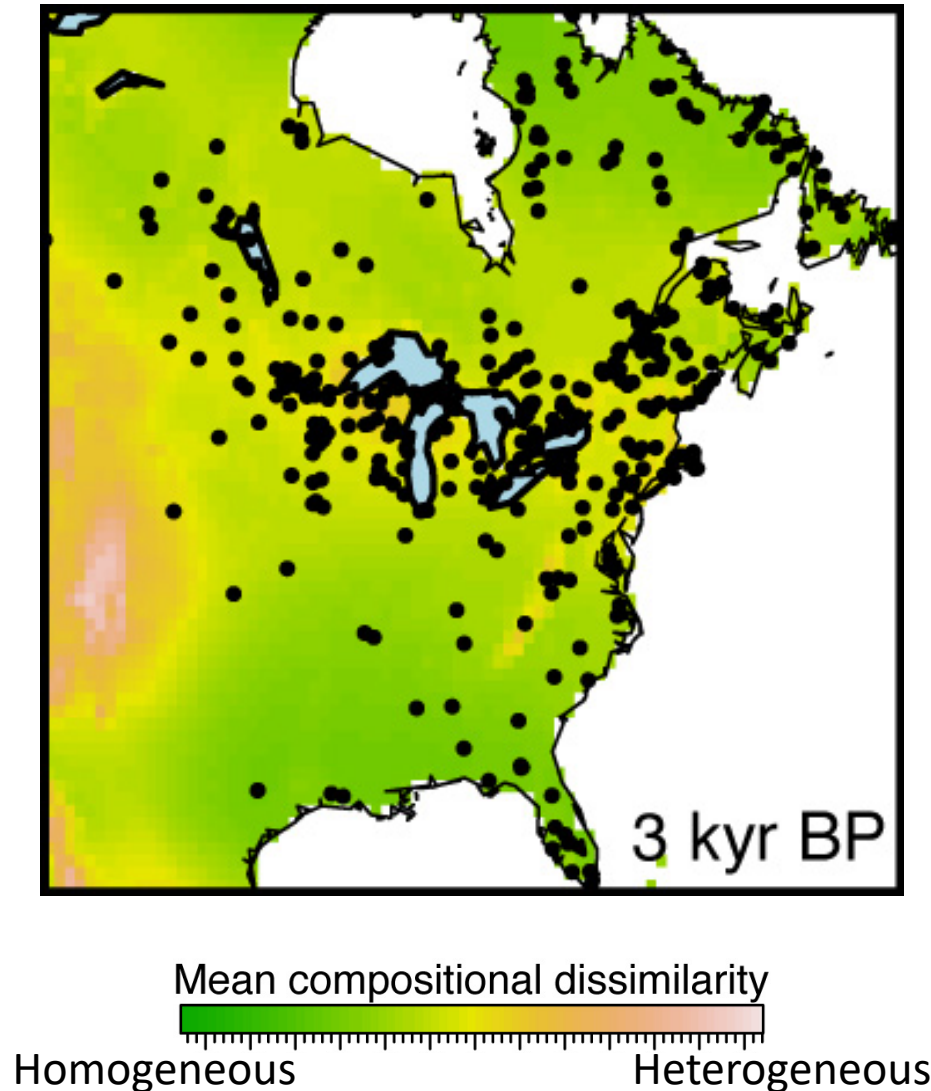
Community dissimilarity has changed dramatically over past 15,000 years



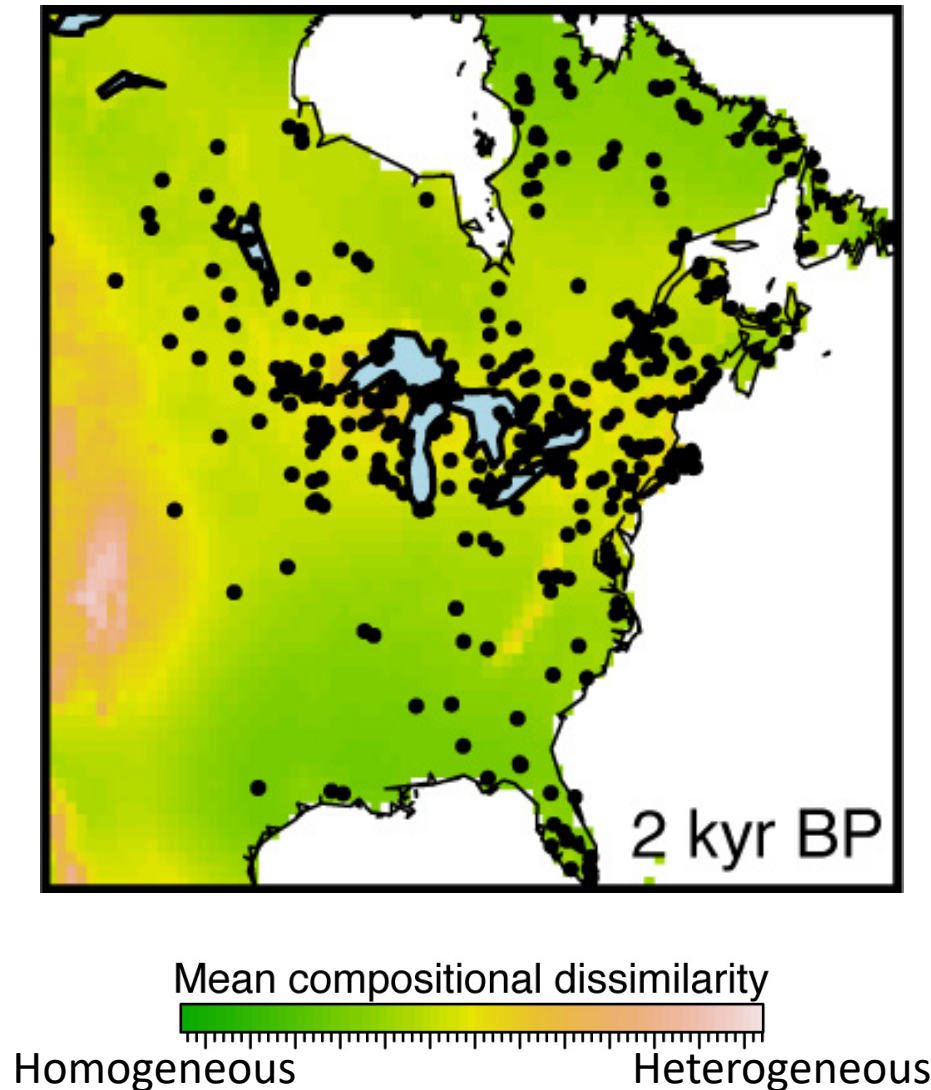
Community dissimilarity has changed dramatically over past 15,000 years



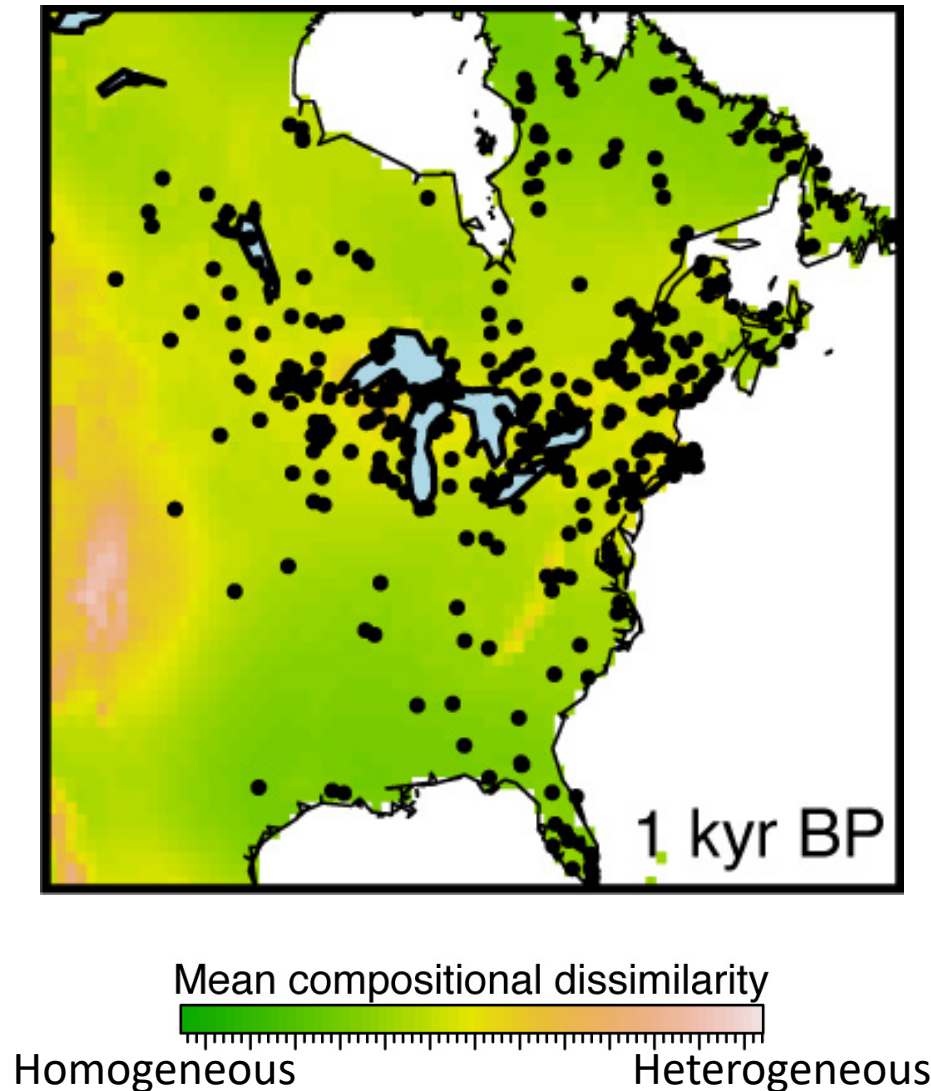
Community dissimilarity has changed dramatically over past 15,000 years



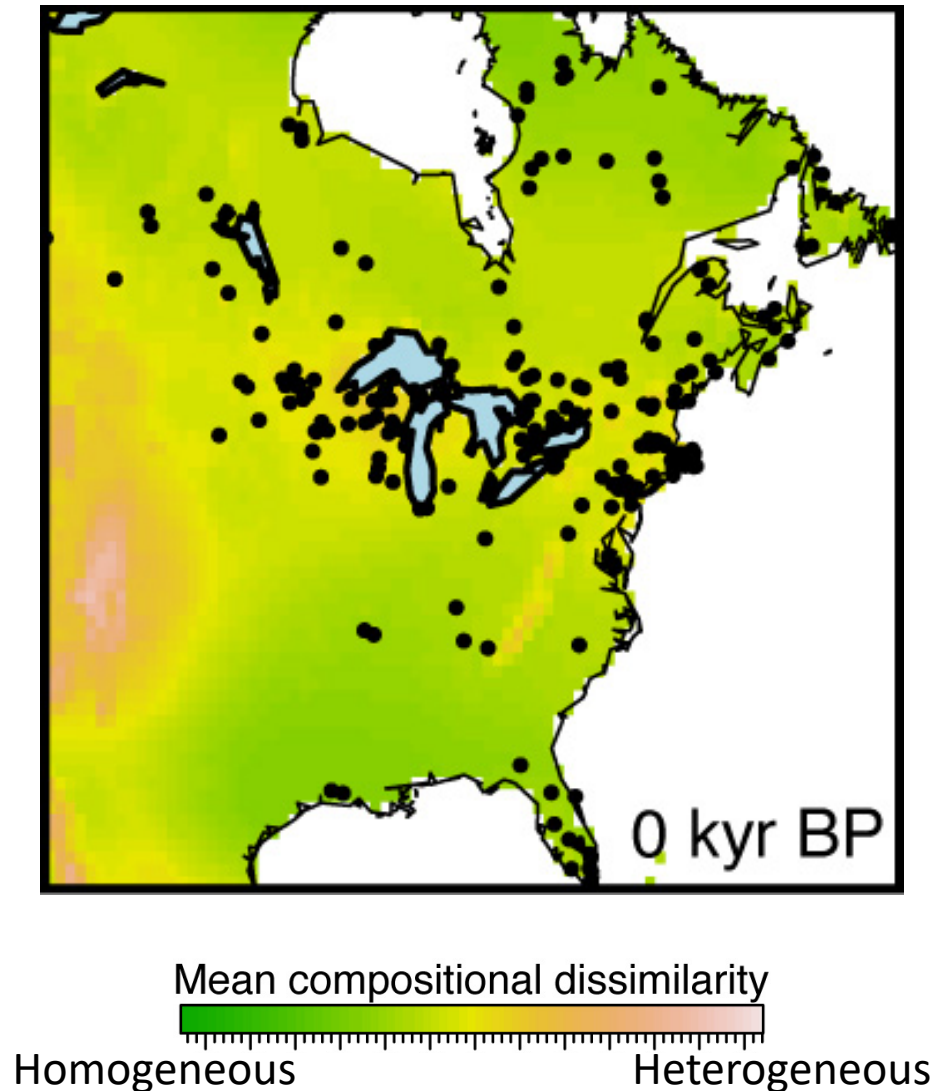
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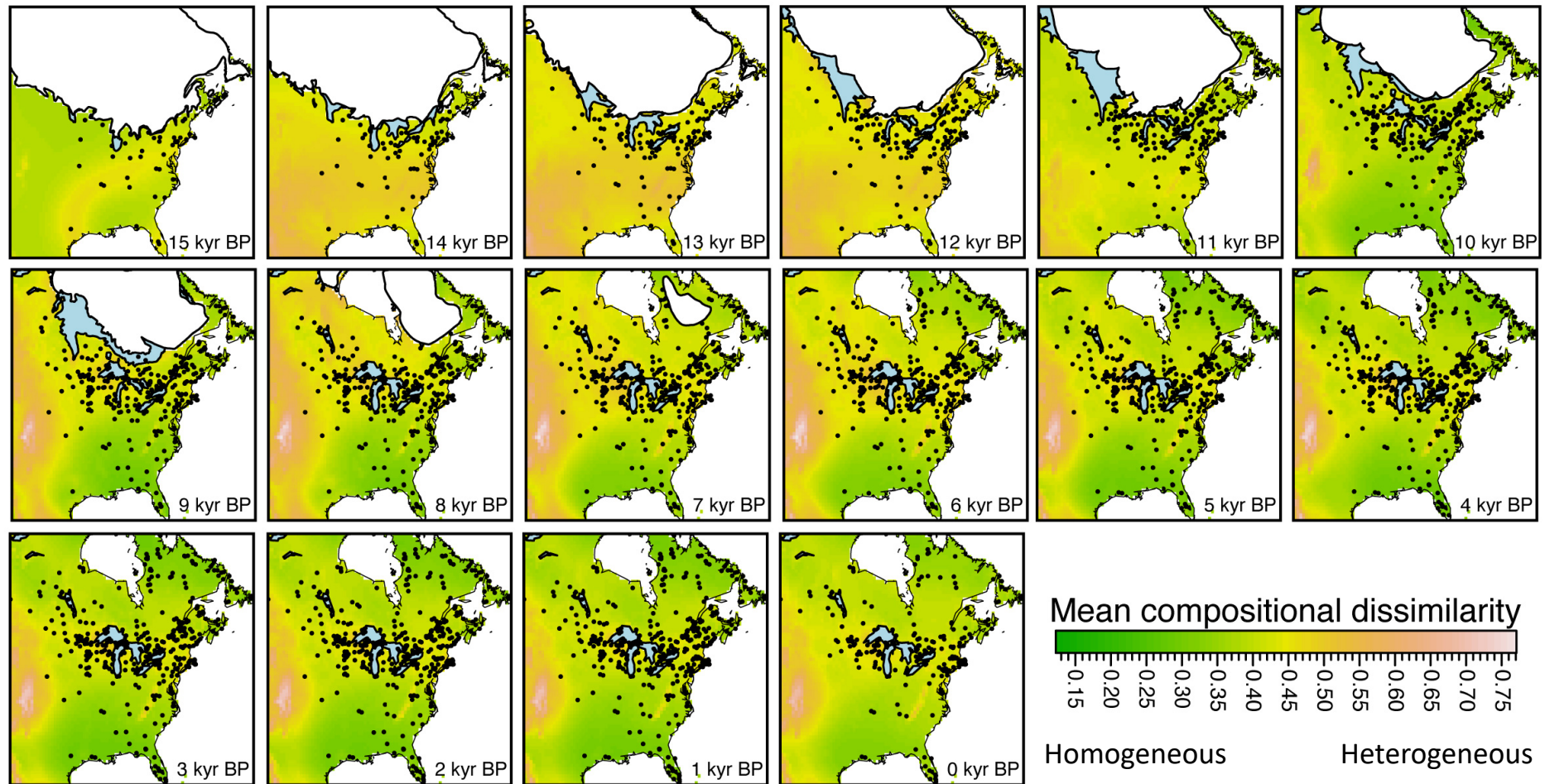
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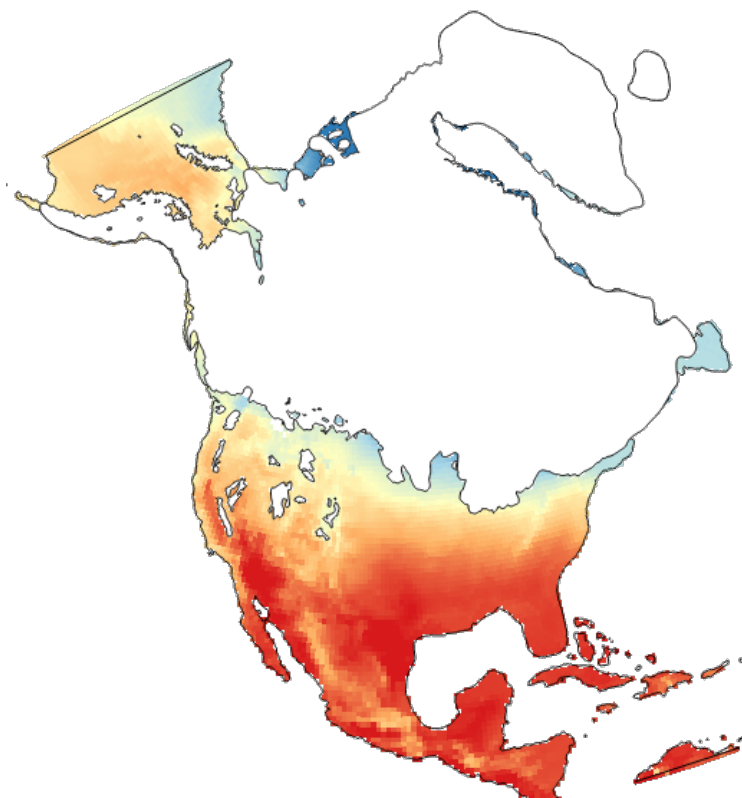


Are these changes linked to climate?



Climate simulations

CCSM: Over the last 21 kyr



TMAX during the LGM (21 kyr)

CLIMATIC VARIABLES

- **TMAX:** Max. Quarter Temperature
- **WDEI:** Annual Water Deficit
- **PMIN:** Min. Quarter Precipitation
- **PMAX:** Max. Quarter Precipitation
- **ETR:** Ann. Evapotranspiration Ratio
- **AET:** Ann. Actual Evapotranspiration



- Spearman < 0.7
- (plus many other variables)

What is the influence of climate on community turnover across space and time?

- ▮ For a single time slice, build a model that relates community turnover across space to climatic turnover across space
- ▮ Repeat this for multiple time slices over the past 14,000 years
- ▮ Examine how climate, as a whole and for individual variables, influences community turnover

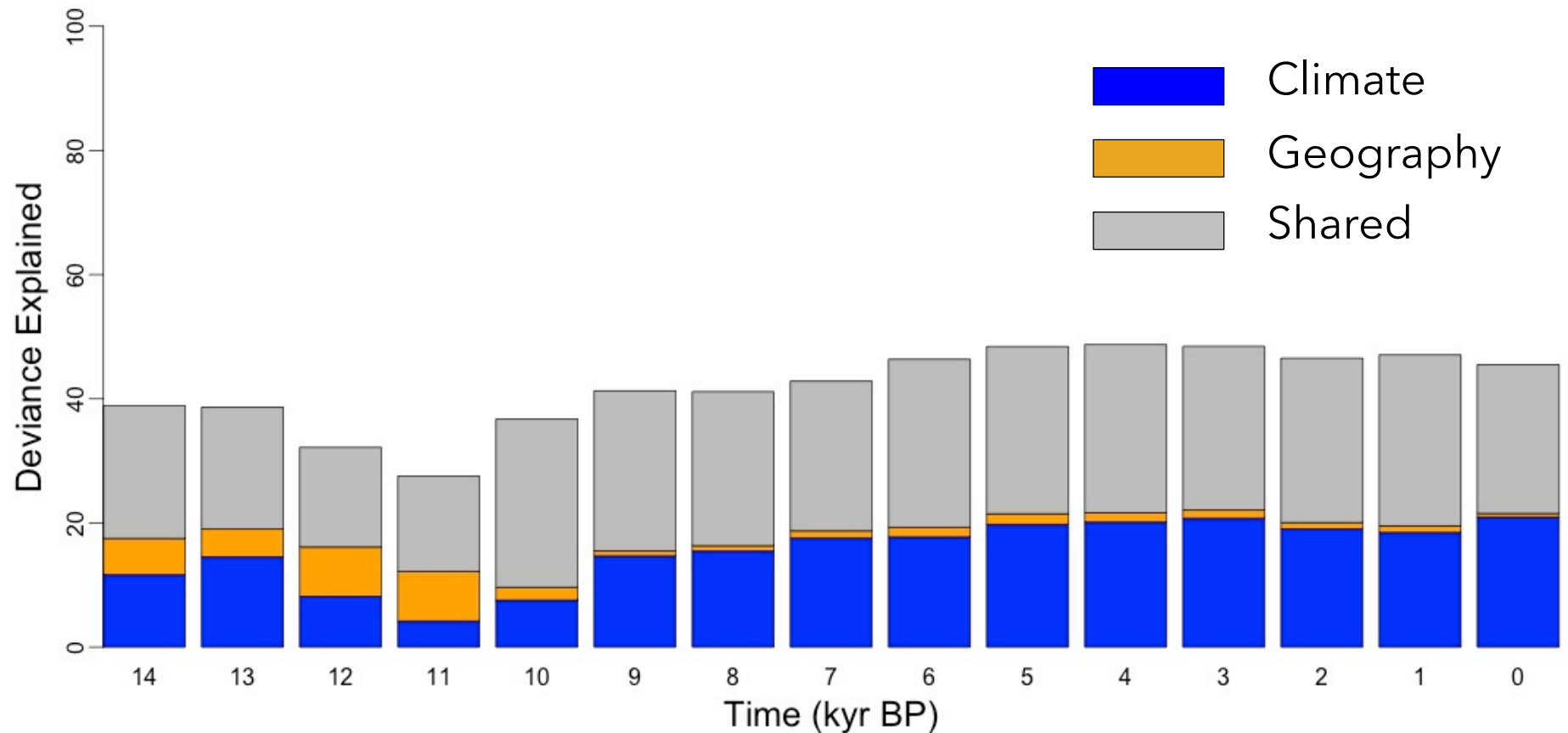


Generalized dissimilarity modeling

GDM:

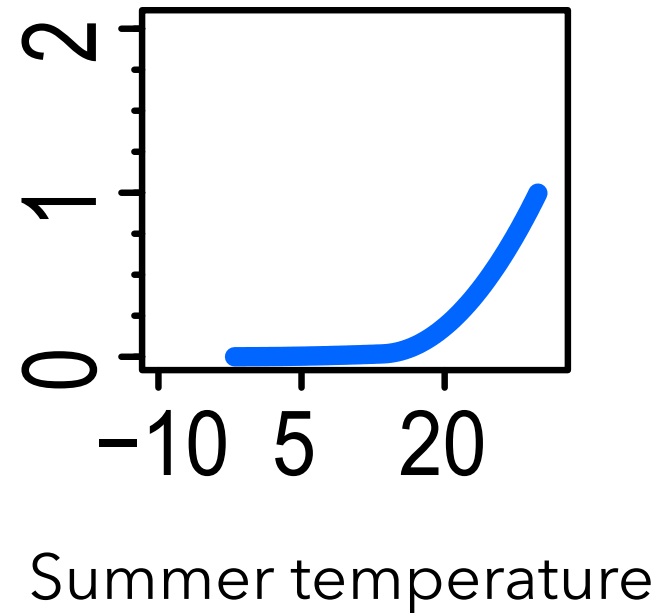
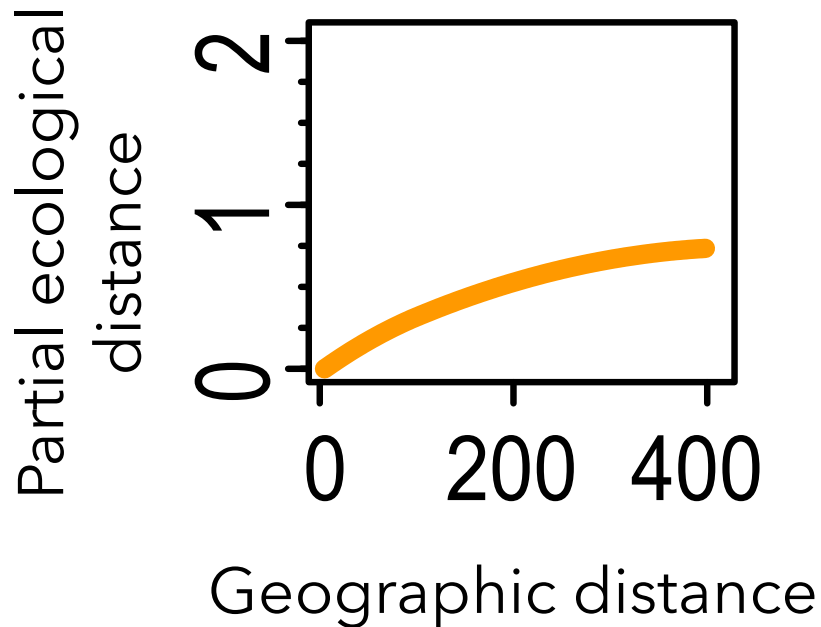
"...an extension of matrix regression, designed specifically to accommodate two types of nonlinearity commonly encountered in large-scaled ecological data sets: (1) the curvilinear relationship between increasing ecological distance, and observed compositional dissimilarity, between sites; and (2) the variation in the rate of compositional turnover at different positions along environmental gradients."

Is the influence of climate (or other factors) stable through time?



- ▮ Climate influences community turnover at all times over the past 14,000 years
- ▮ Climate is not evenly influential through time

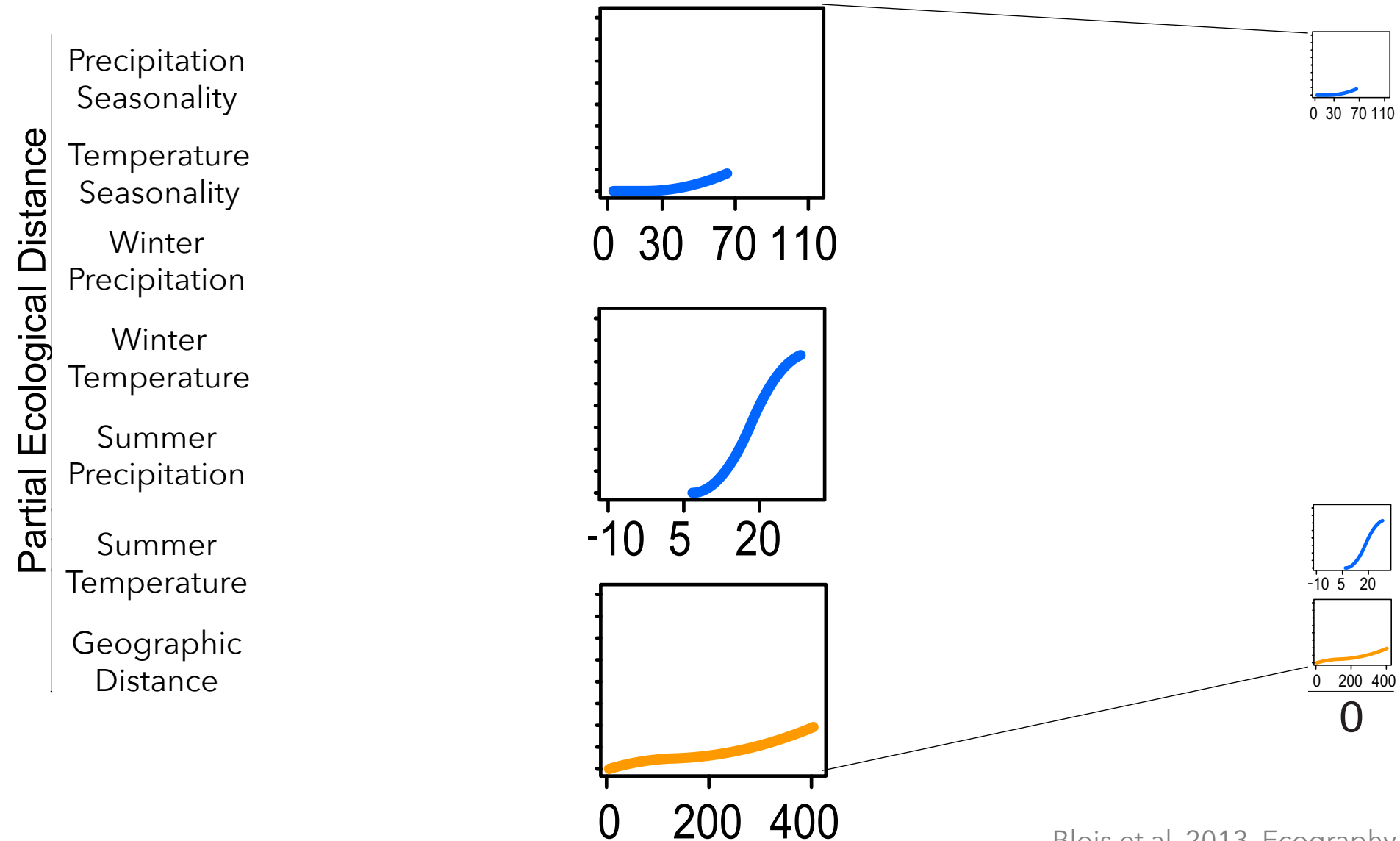
Fitted climate-turnover relationships



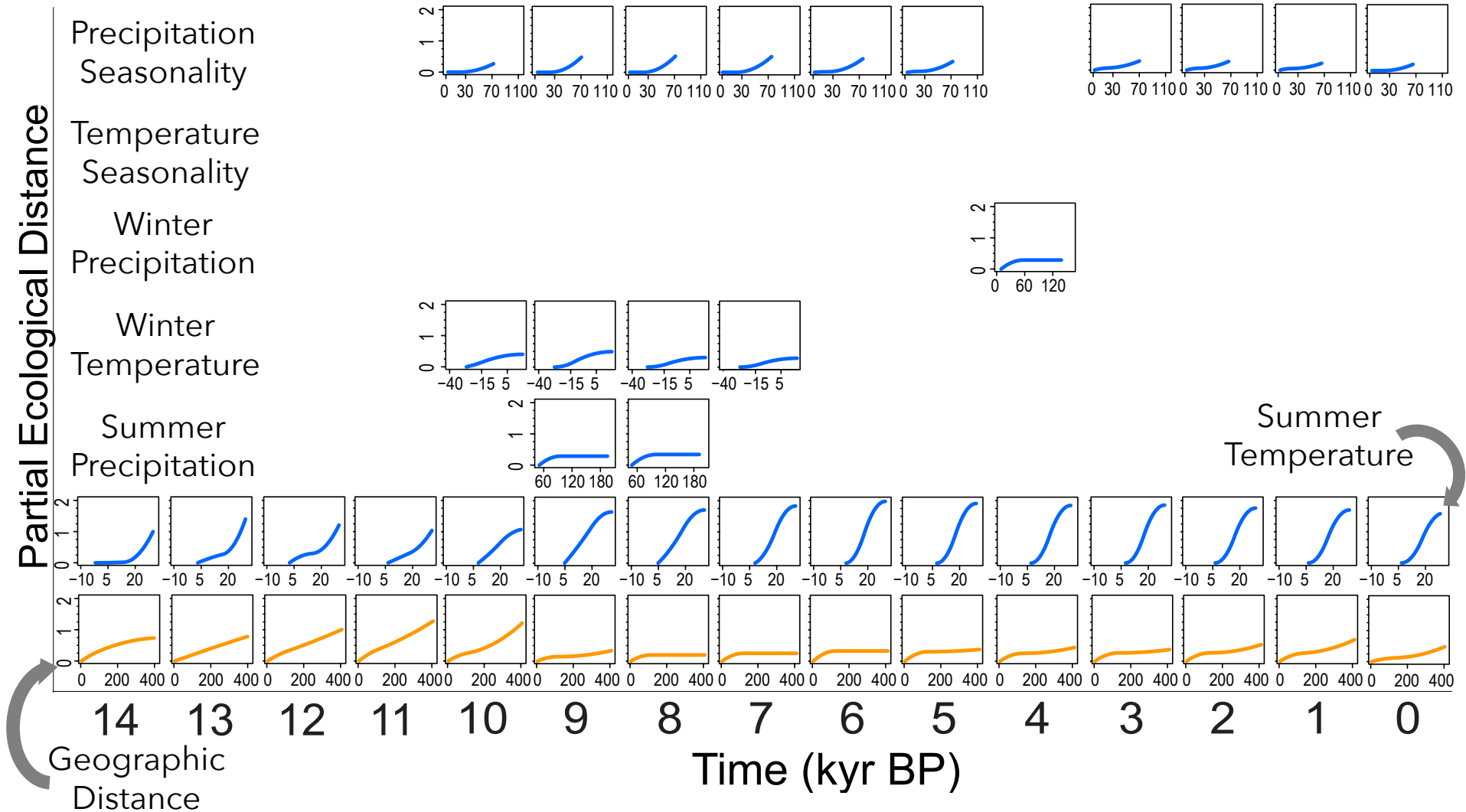
Fitted relationships for individual climate variables changes through time



Fitted relationships for individual climate variables changes through time



Fitted relationships for individual climate variables changes through time



What is the influence of climate on community turnover across space and time?

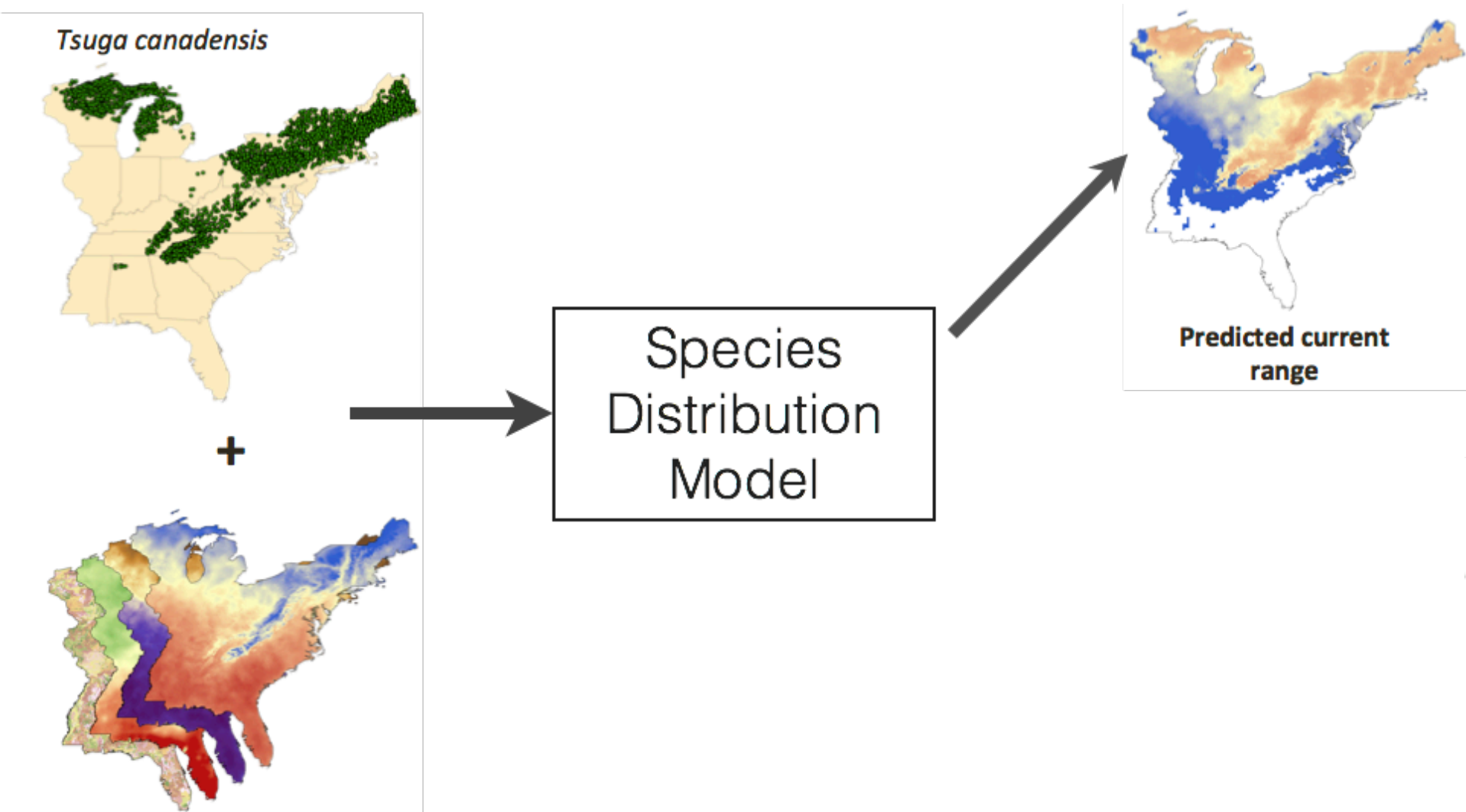
- ▮ Present-day correlates of vegetation turnover are not the same as those of the past
 - ▮ Variation unexplained by climate is higher in past than present
 - ▮ Fitted relationships of individual climate variables changes through time



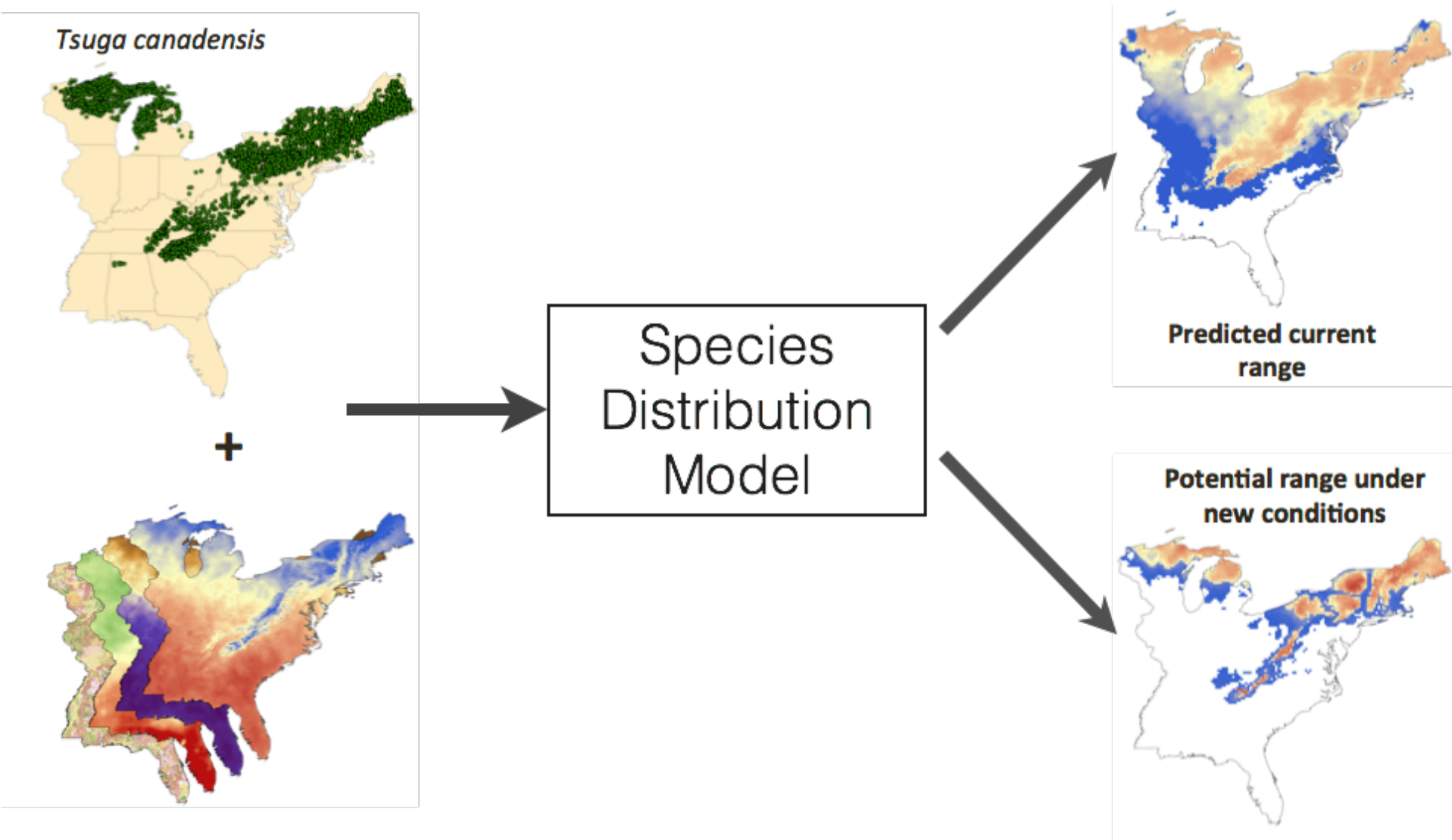
Providing a long-term context for recent and future biodiversity change

- ▮ Influence of climate on vegetation assemblages
- ▮ How does the past inform our predictions of the future?

Approaches for projecting across space or time



Approaches for projecting across space or time



Species-level modeling

$$\begin{bmatrix} & Spp_1 \\ Site_1 & 0 \\ Site_2 & 1 \\ Site_3 & 1 \\ \dots & \dots \\ Site_j & 1 \end{bmatrix} = f \left\{ \begin{bmatrix} & Env_1 & Env_2 & Env_3 & \dots & Env_k \\ Site_1 & 23.4 & 545.5 & 0.64 & \dots & 4.1 \\ Site_2 & 22.1 & 89.0 & 0.22 & \dots & 8.0 \\ Site_3 & 24.9 & 439.5 & 0.61 & \dots & 3.4 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ Site_j & 25.3 & 321.7 & 0.88 & \dots & 3.9 \end{bmatrix} \right\}$$

Community-level modeling

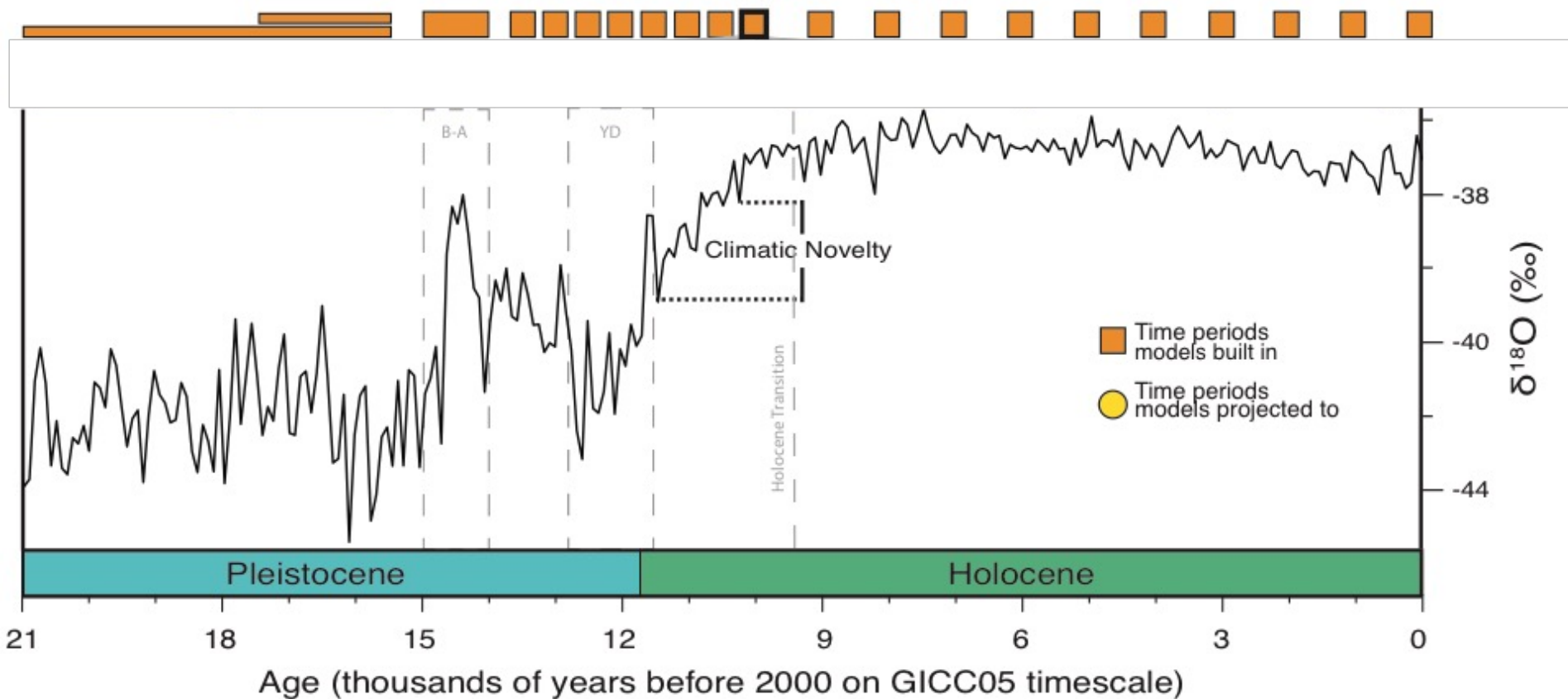
$$\begin{bmatrix} & Spp_1 & Spp_2 & Spp_3 & \dots & Spp_n \\ Site_1 & 0 & 1 & 0 & \dots & 0 \\ Site_2 & 1 & 1 & 1 & \dots & 0 \\ Site_3 & 1 & 0 & 0 & \dots & 1 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ Site_j & 1 & 0 & 0 & \dots & 1 \end{bmatrix} = f \left\{ \begin{bmatrix} & Env_1 & Env_2 & Env_3 & \dots & Env_k \\ Site_1 & 23.4 & 545.5 & 0.64 & \dots & 4.1 \\ Site_2 & 22.1 & 89.0 & 0.22 & \dots & 8.0 \\ Site_3 & 24.9 & 439.5 & 0.61 & \dots & 3.4 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ Site_j & 25.3 & 321.7 & 0.88 & \dots & 3.9 \end{bmatrix} \right\}$$

Community-level modeling

$$\begin{bmatrix}
 & Spp_1 & Spp_2 & Spp_3 & \dots & Spp_n \\
 Site_1 & 0 & 1 & 0 & \dots & 0 \\
 Site_2 & 1 & 1 & 1 & \dots & 0 \\
 Site_3 & 1 & 0 & 0 & \dots & 1 \\
 \dots & \dots & \dots & \dots & \dots & \dots \\
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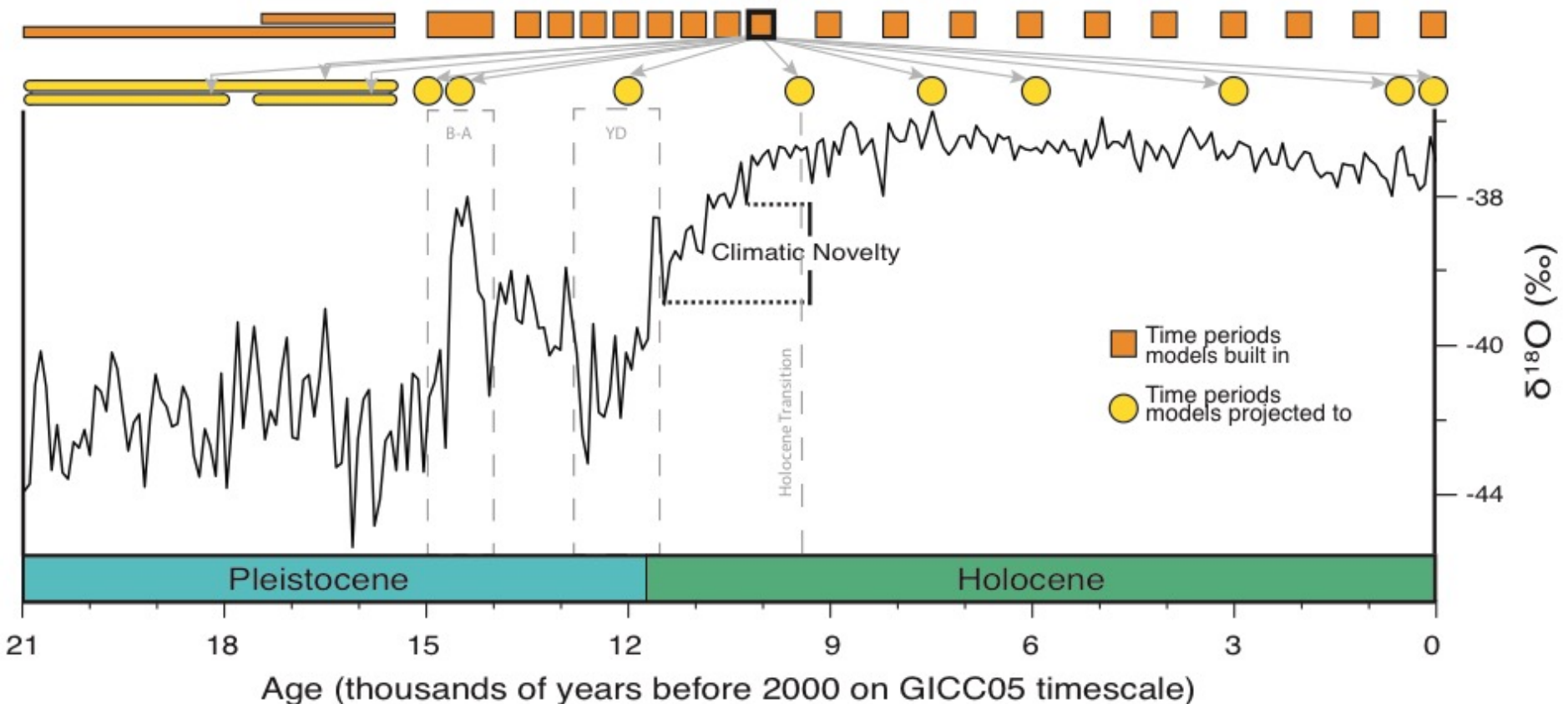
Comparing SDMs vs CLMs through time

1. Build SDMs
Build CLMs

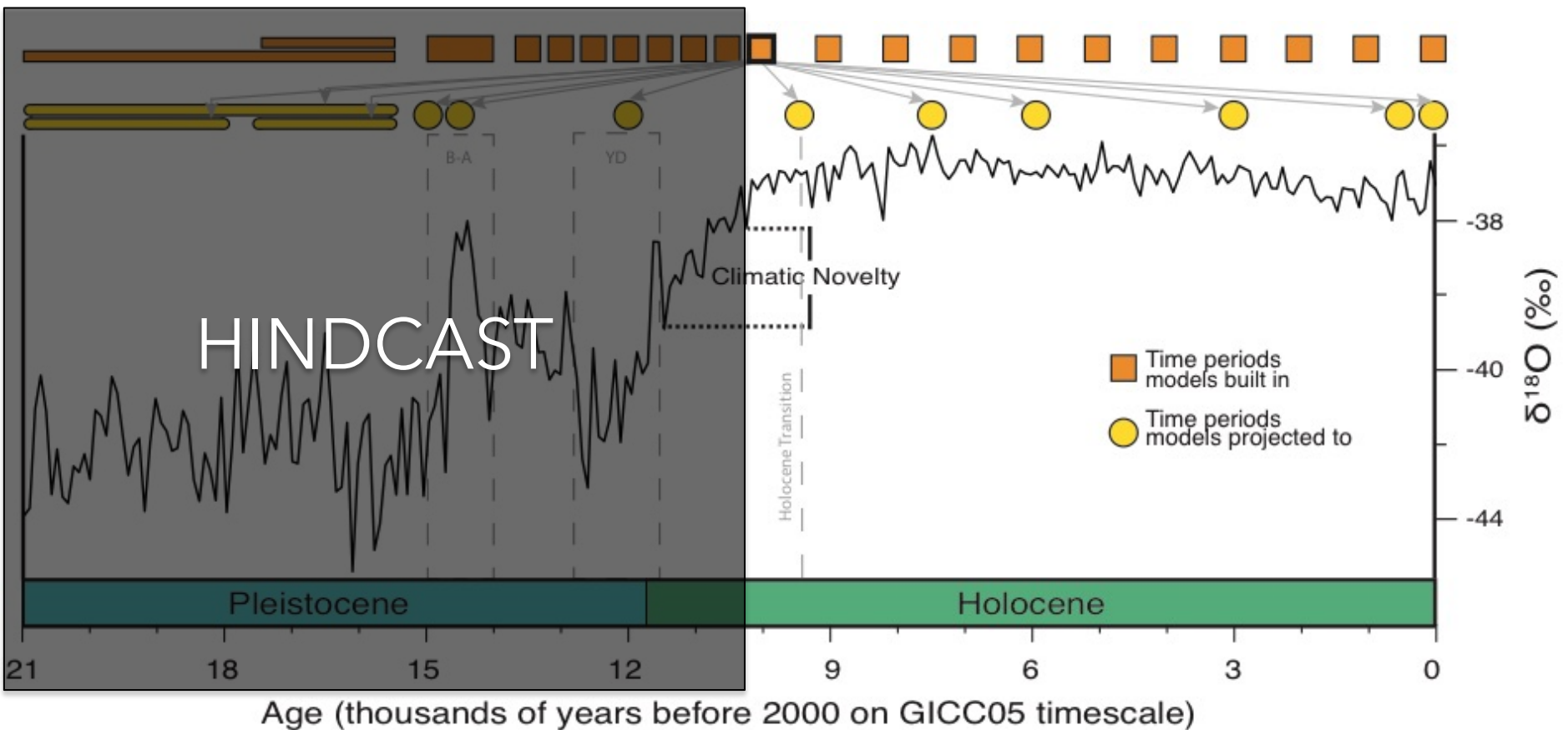


Comparing SDMs vs CLMs through time

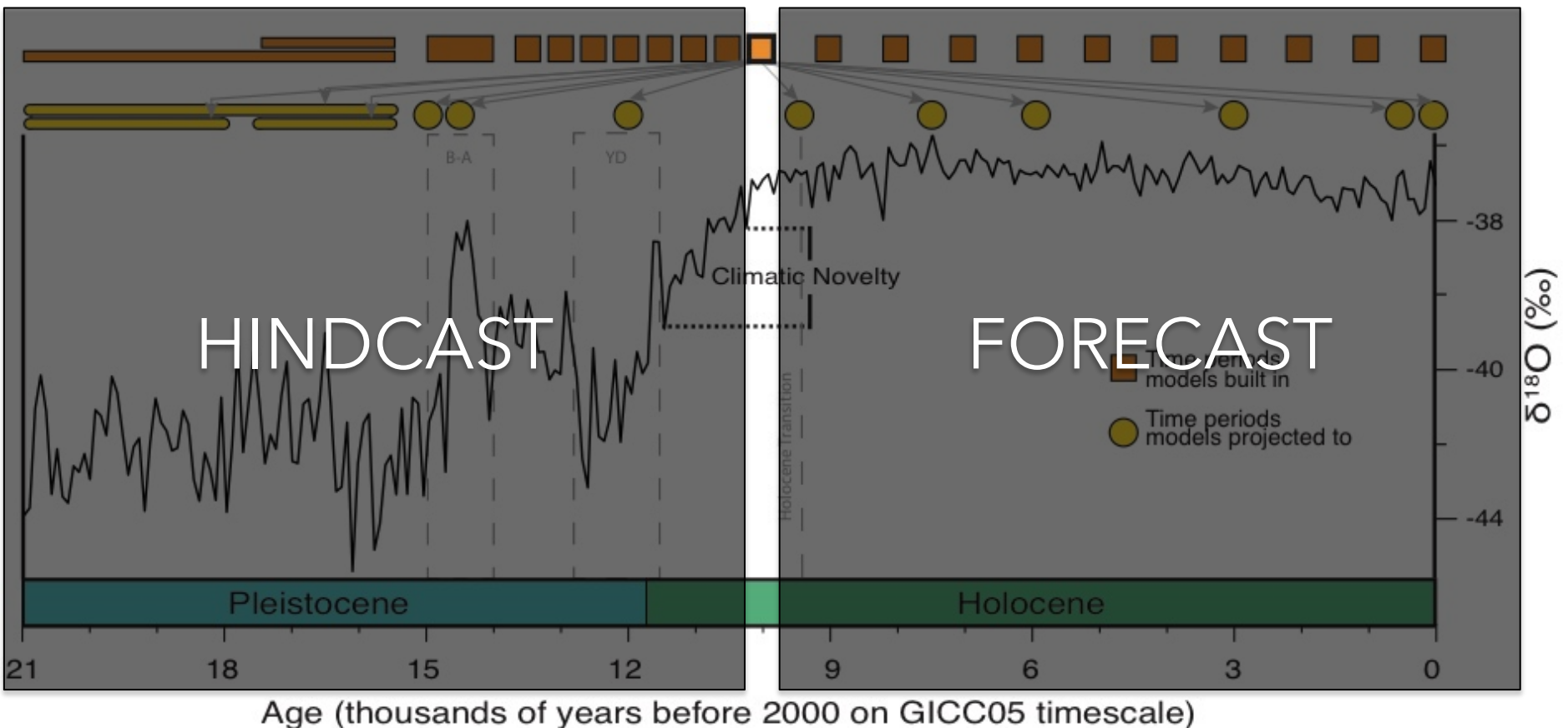
1. Build SDMs
Build CLMs → 2. Project to a different time → 3. Compare predictions vs. observations



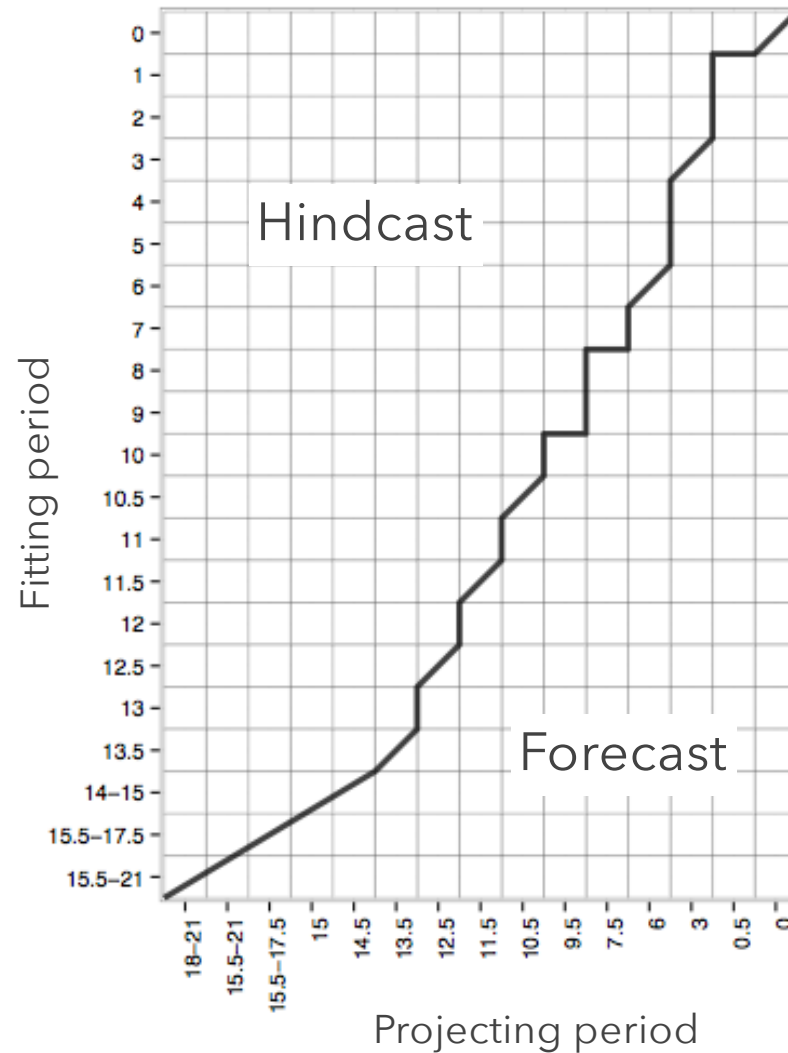
Comparing SDMs vs CLMs through time



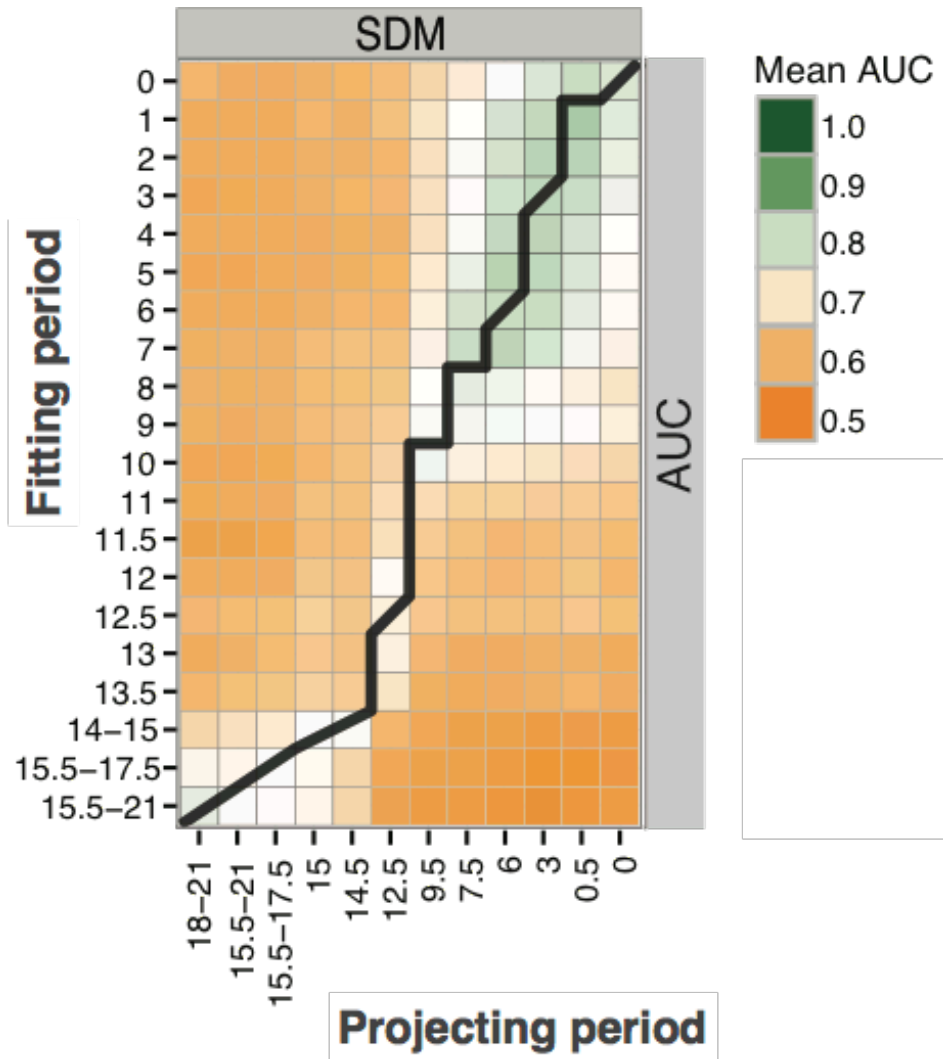
Comparing SDMs vs CLMs through time



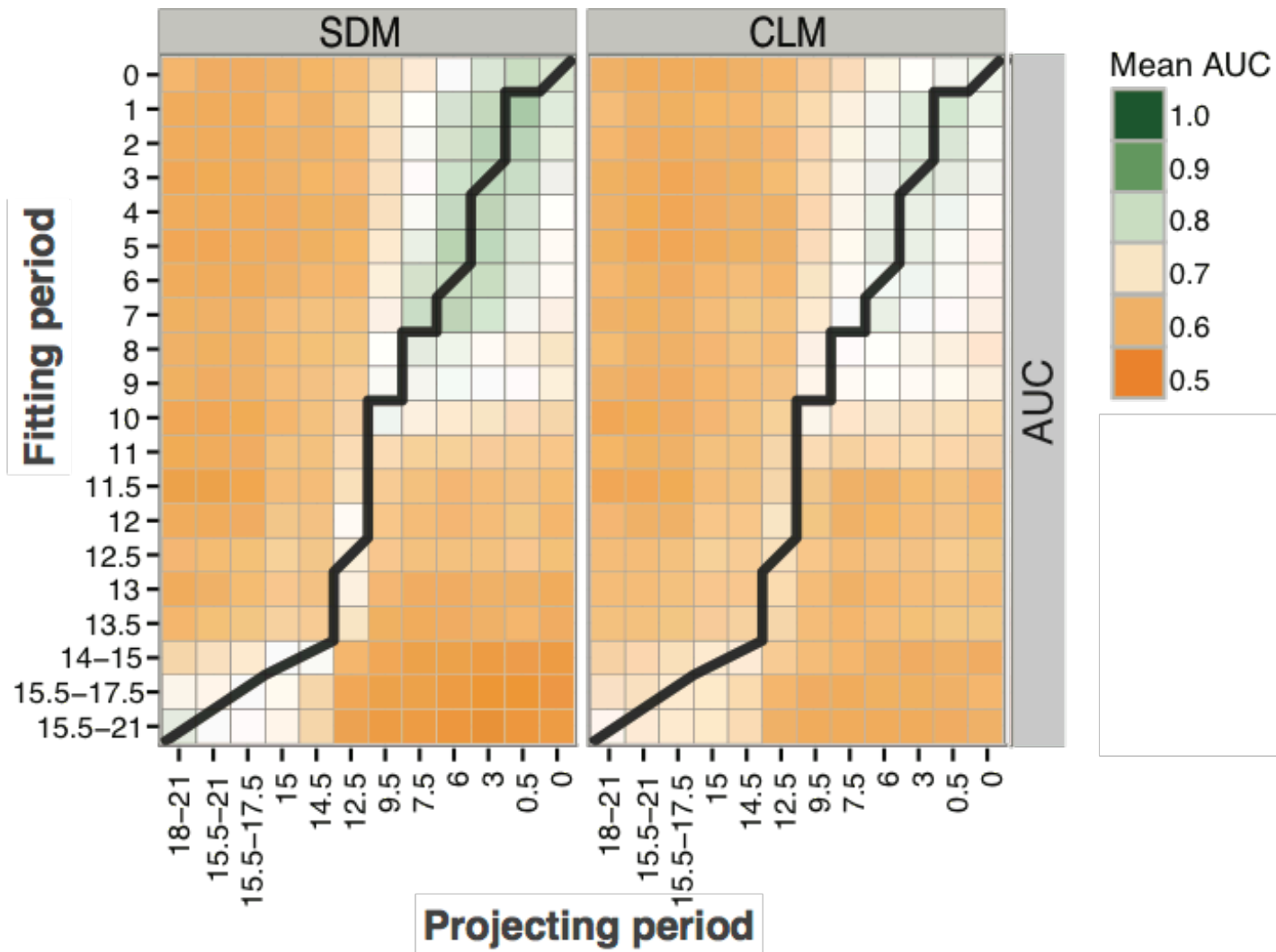
SDM-CLM comparison



Models perform poorly when projected to distant time periods

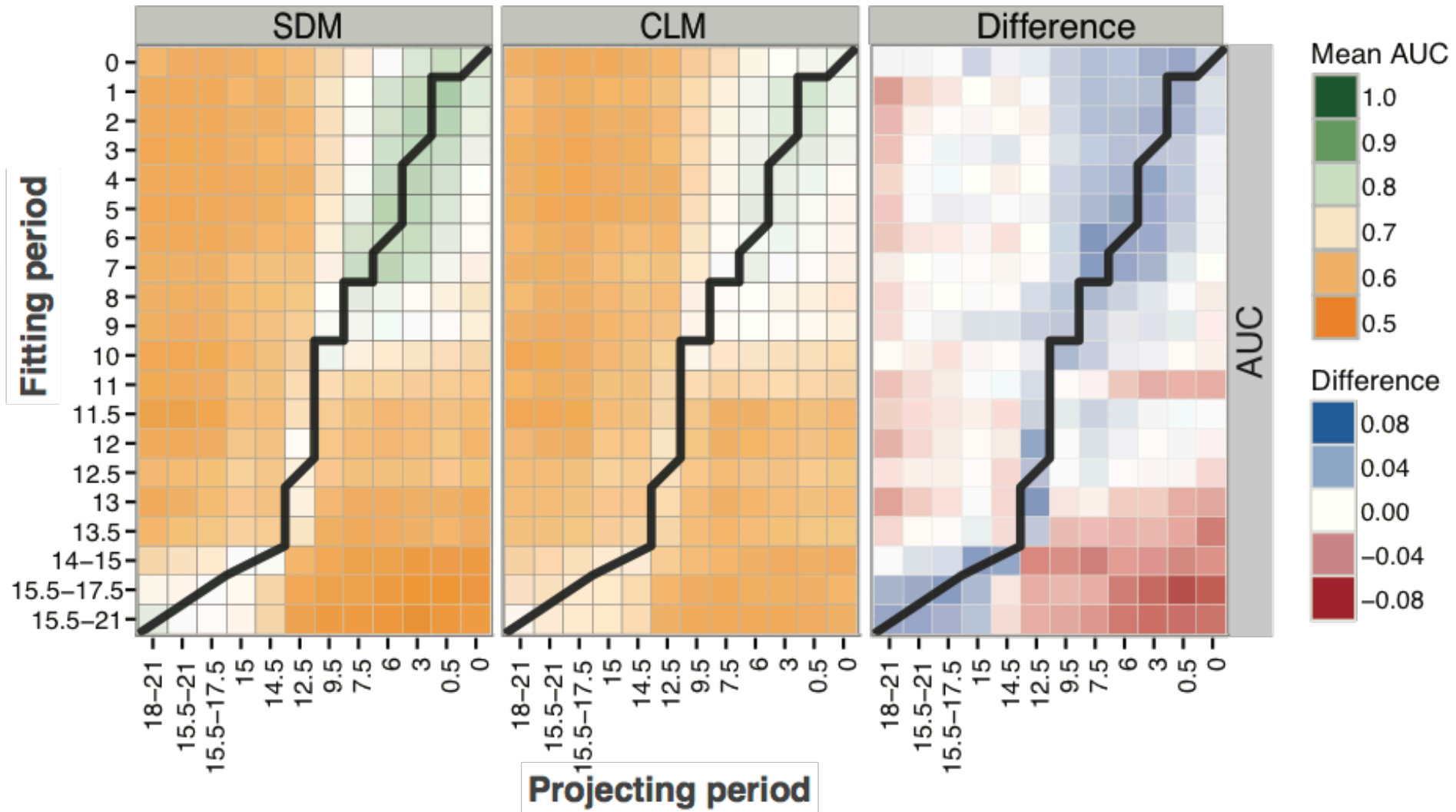


Models perform poorly when projected to distant time periods

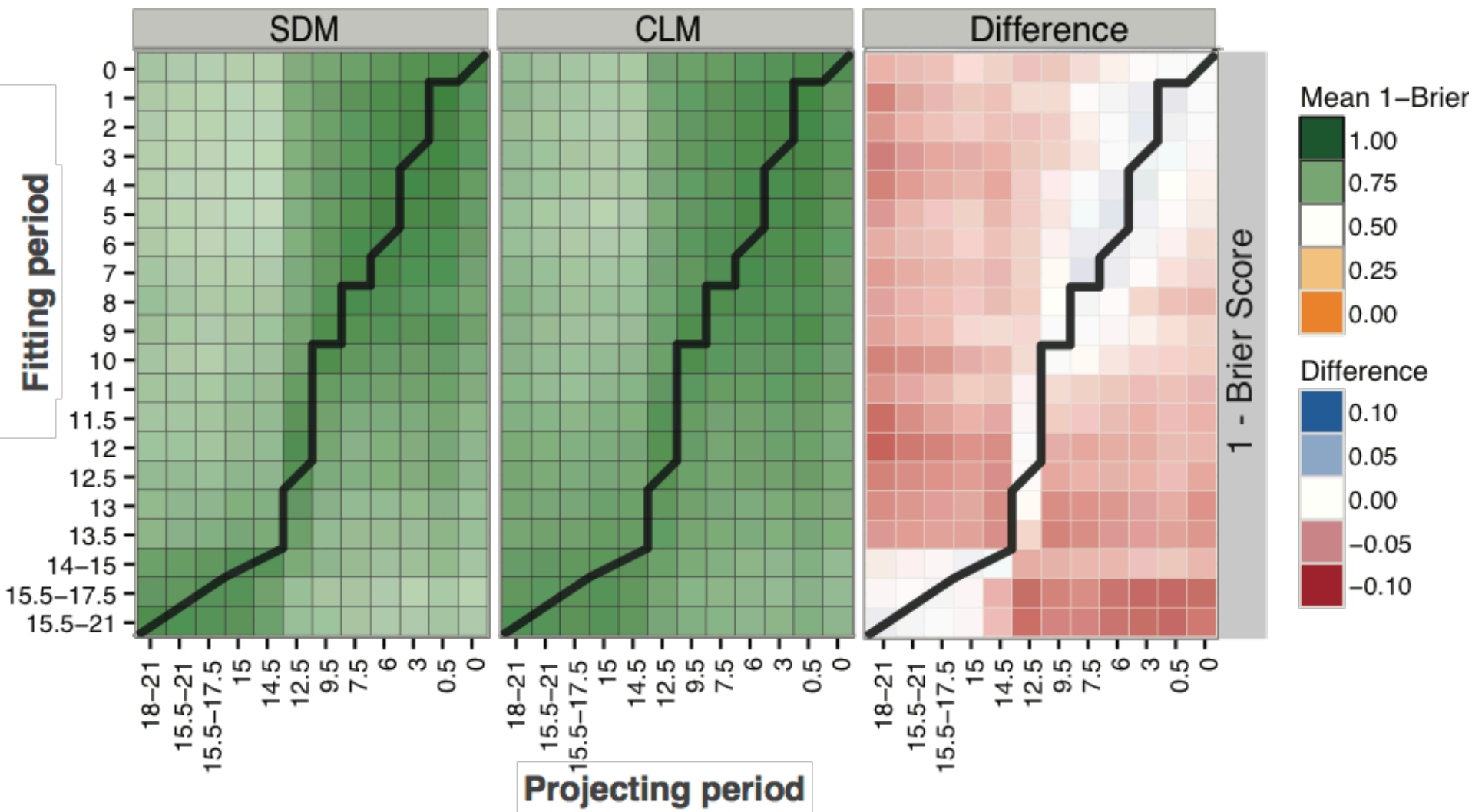


SDMs: relatively better for adjacent times

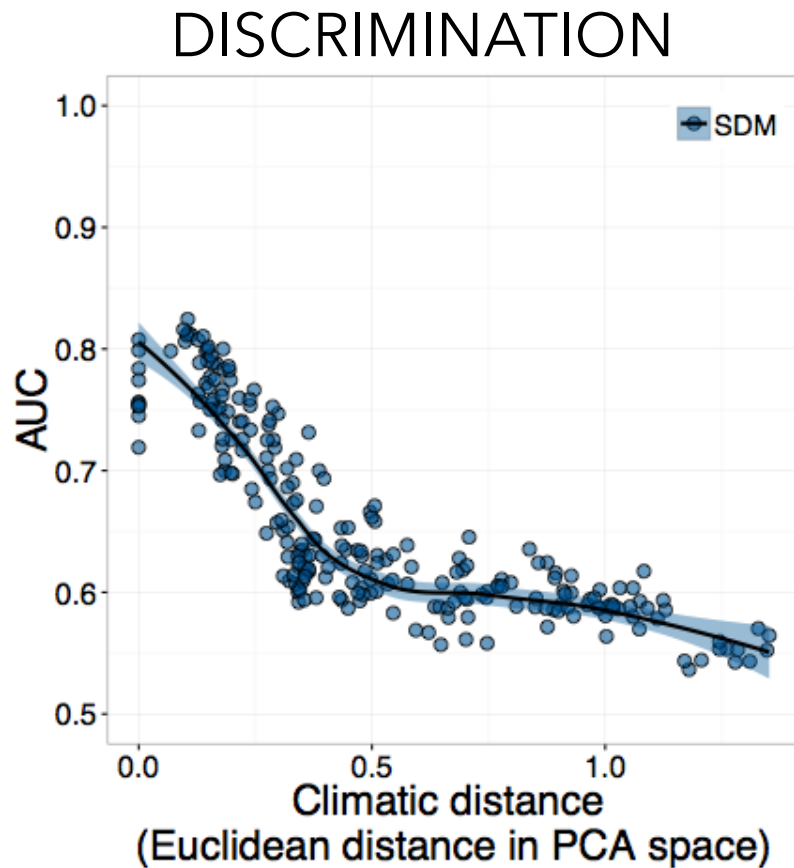
CLMs: relatively better for distant times



CLMs: better calibrated than SDMs

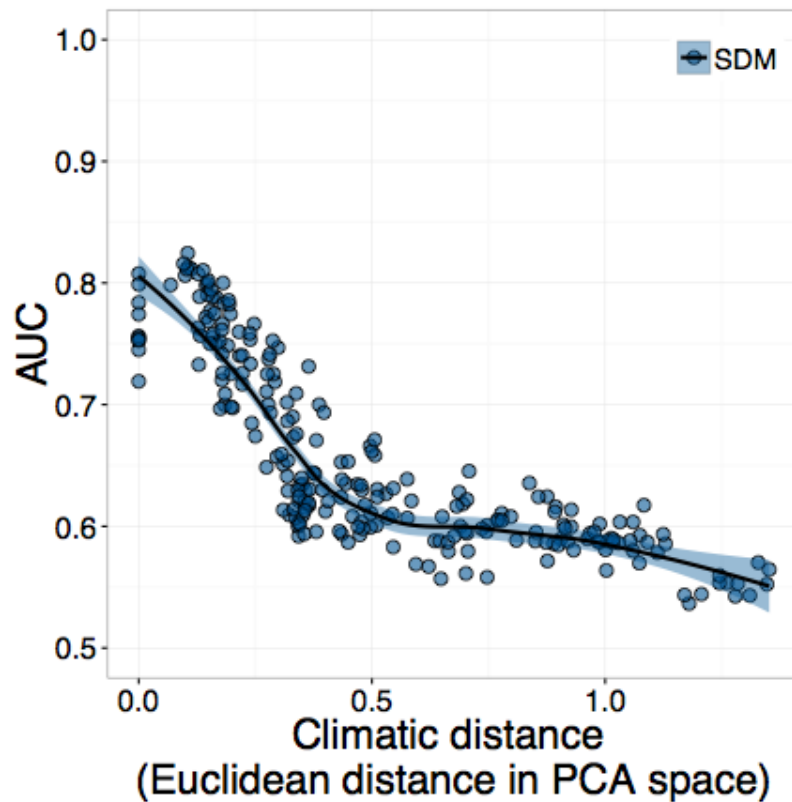


Model performance declines as climate novelty increases...

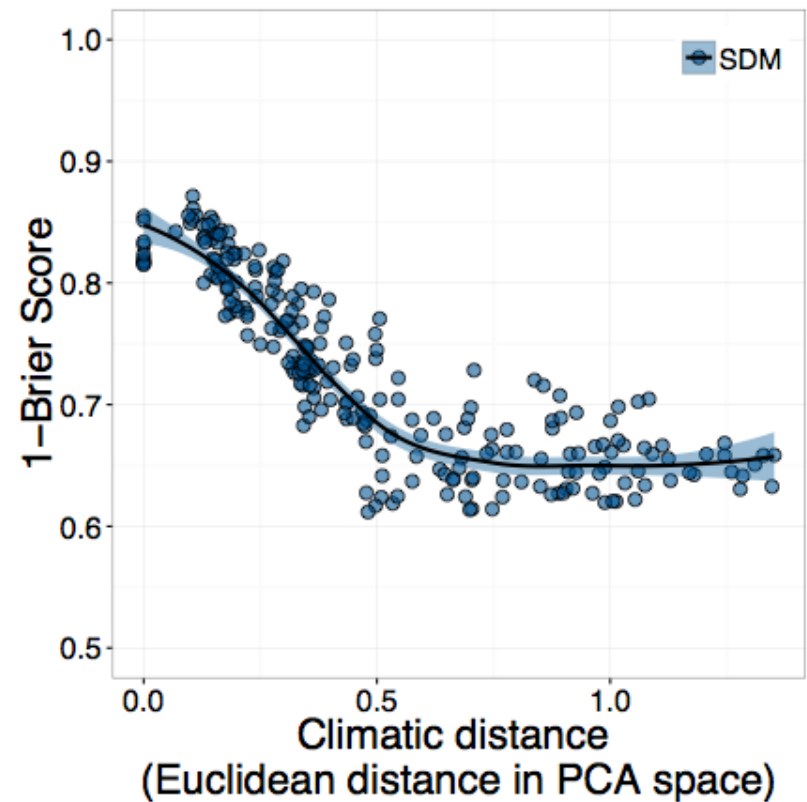


Model performance declines as climate novelty increases...

DISCRIMINATION

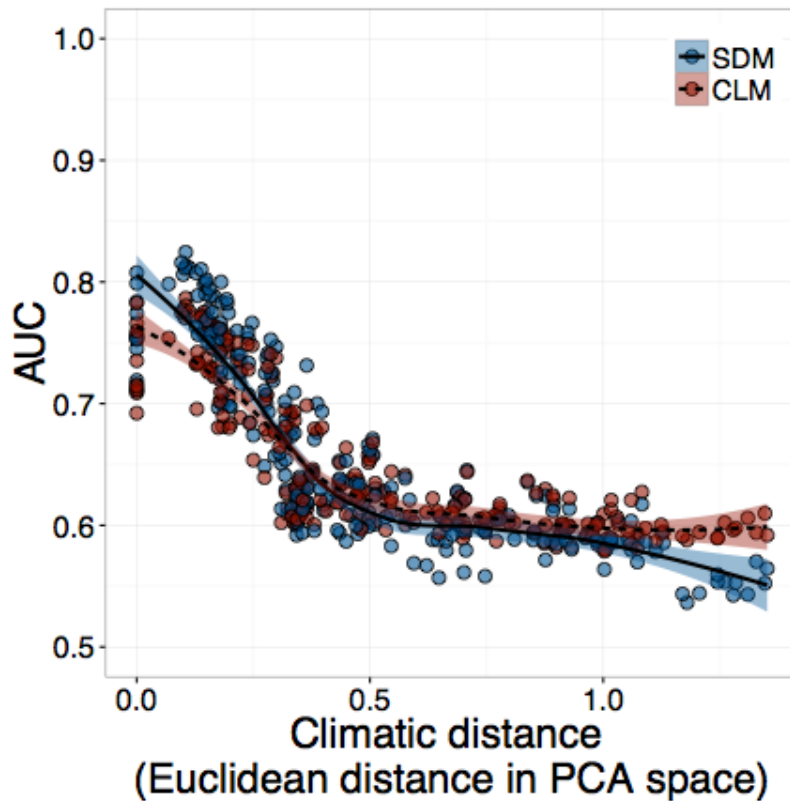


CALIBRATION

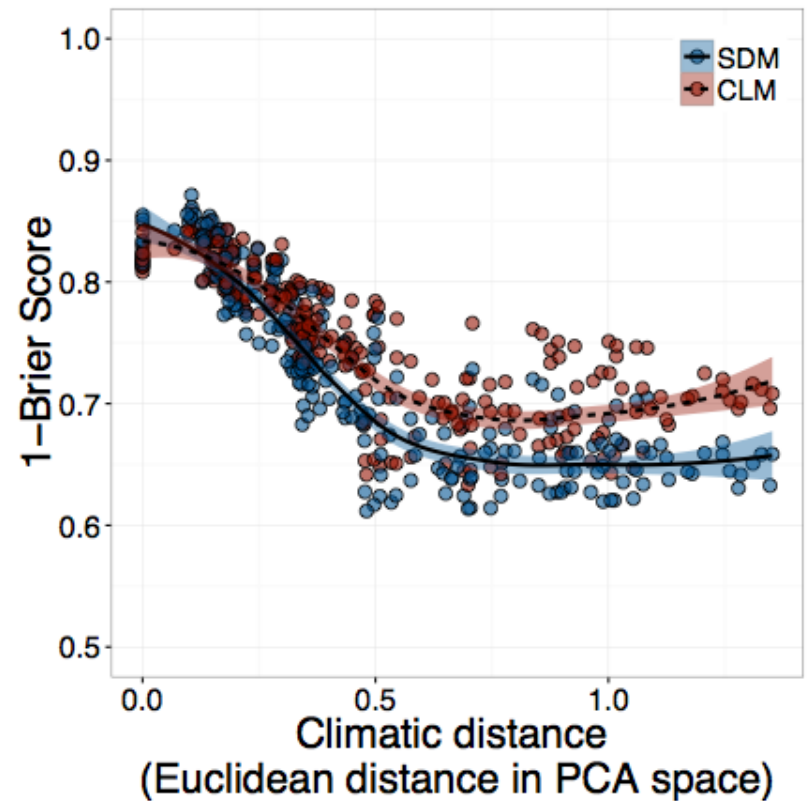


Model performance declines as climate novelty increases... LESS so for CLMS

DISCRIMINATION



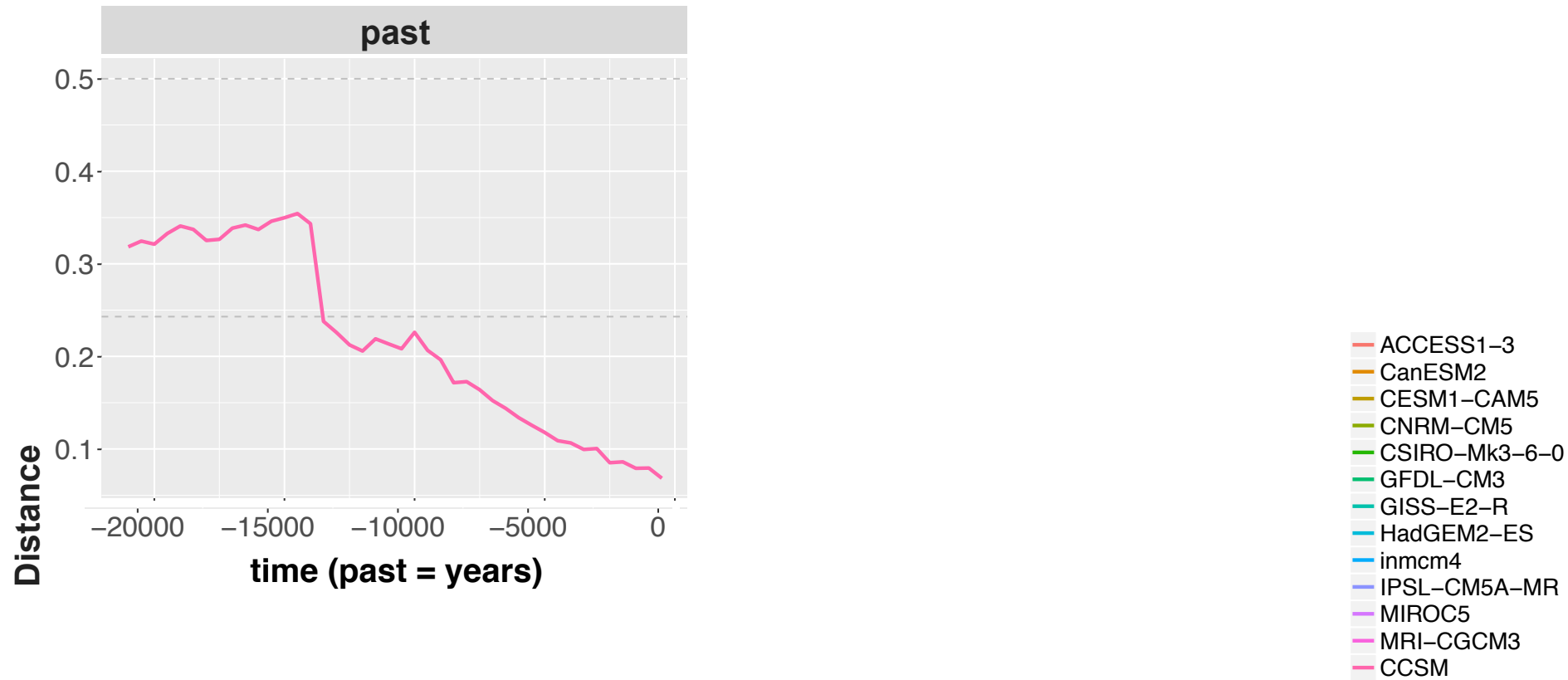
CALIBRATION



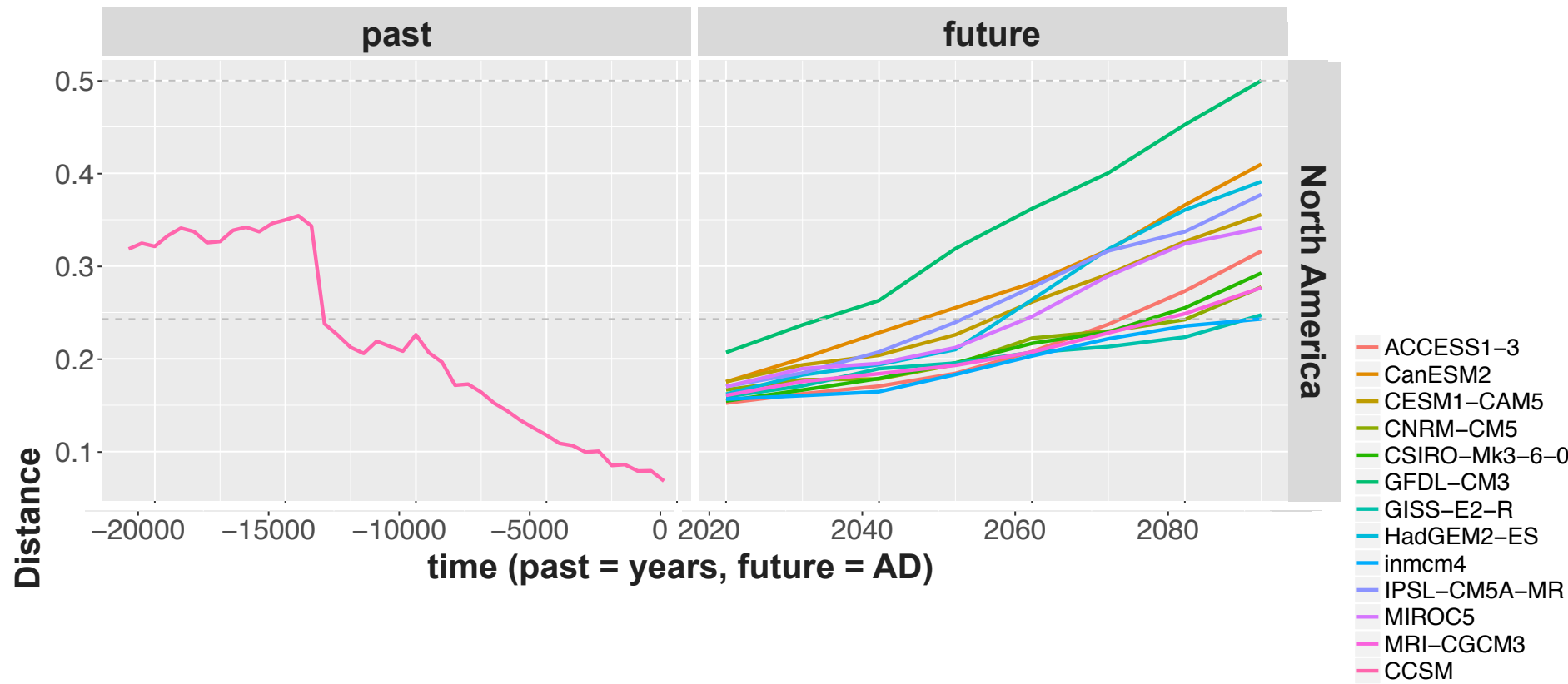
How might future climate novelty impact model performance?

- ▮ How does future climate novelty compare to past climate novelty?
- ▮ What is the expected robustness of different modeling approaches?

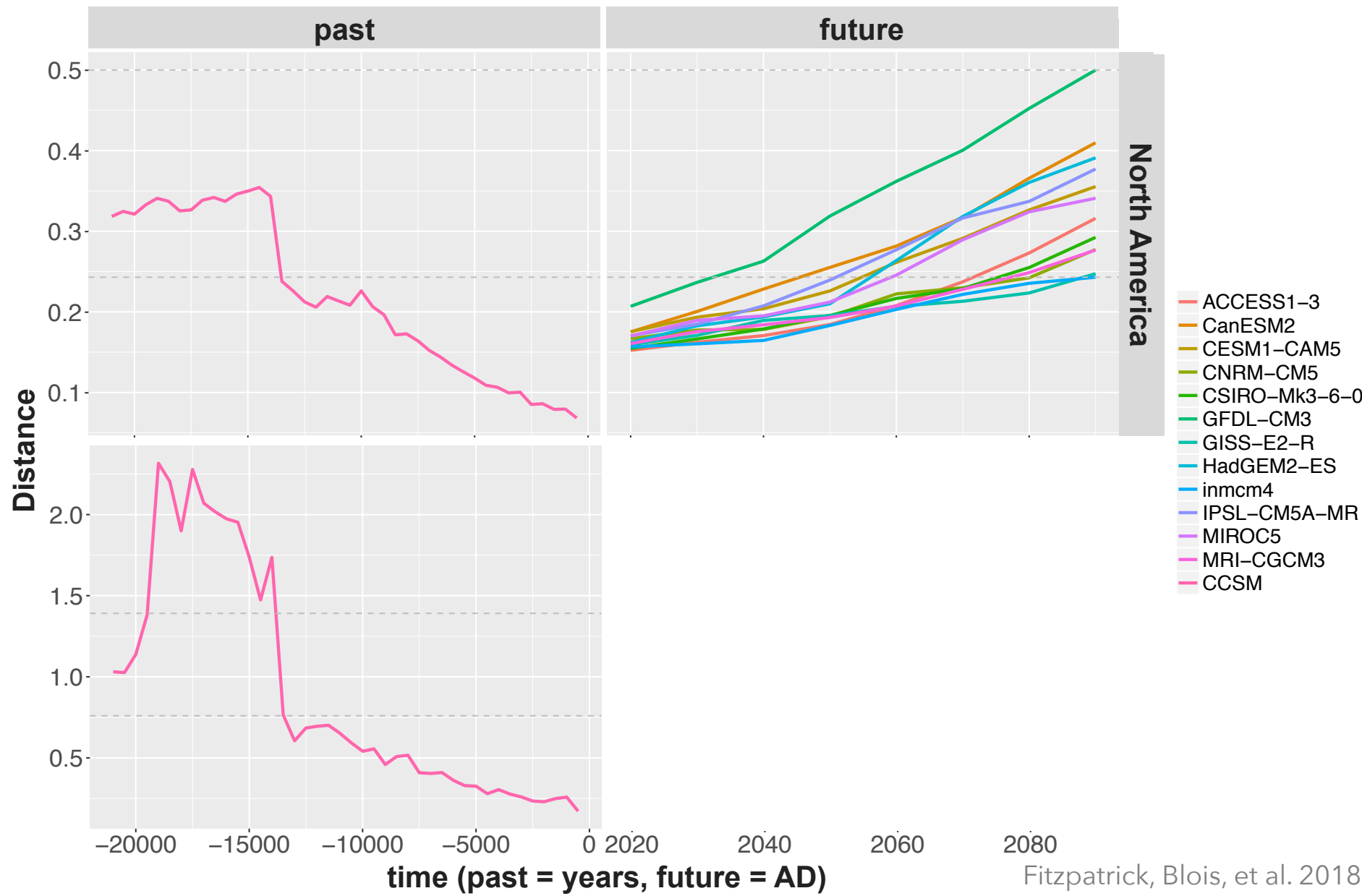
Climate novelty through time: all of North America



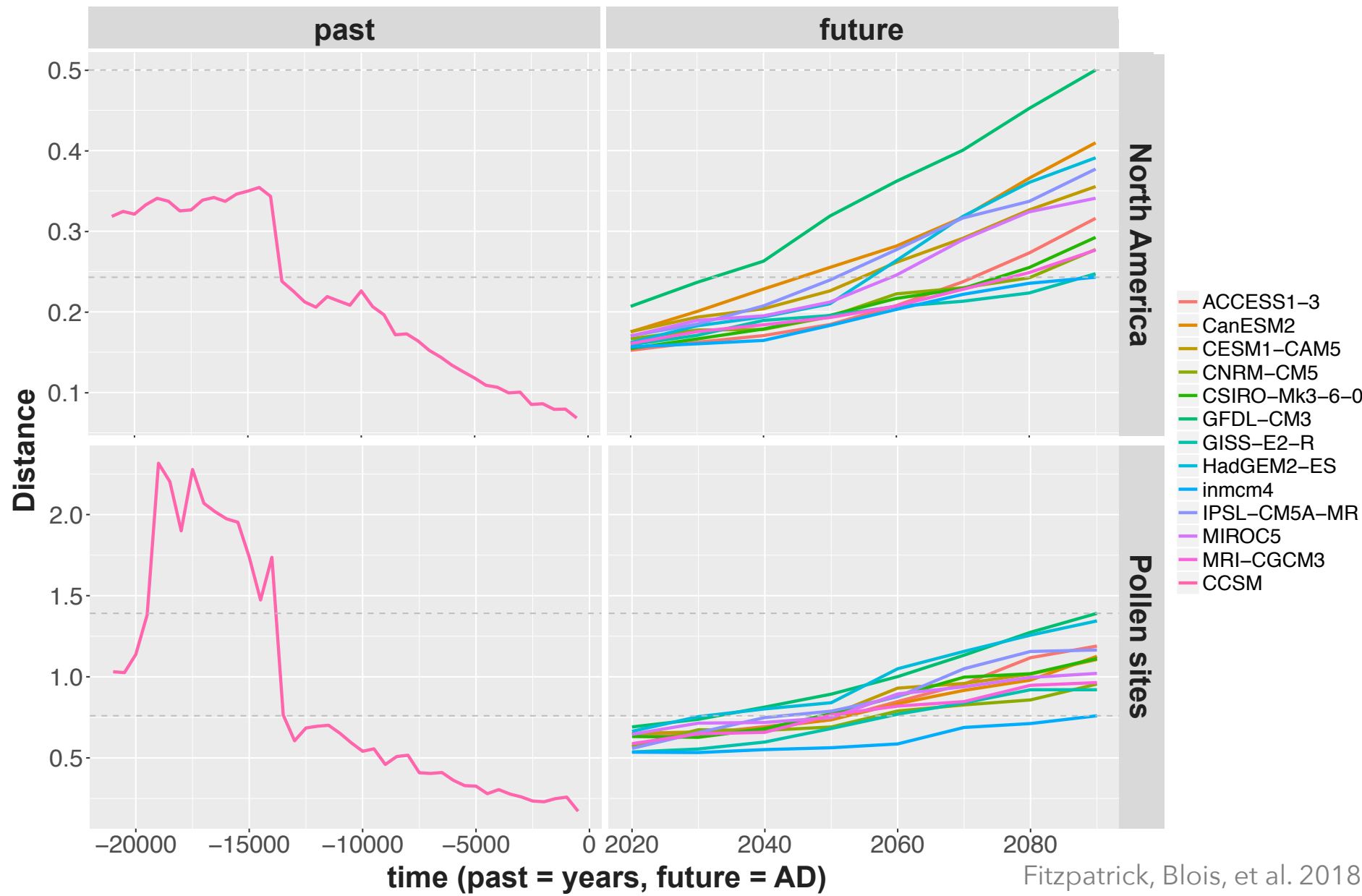
Climate novelty through time: all of North America



Climate novelty through time: eastern North America

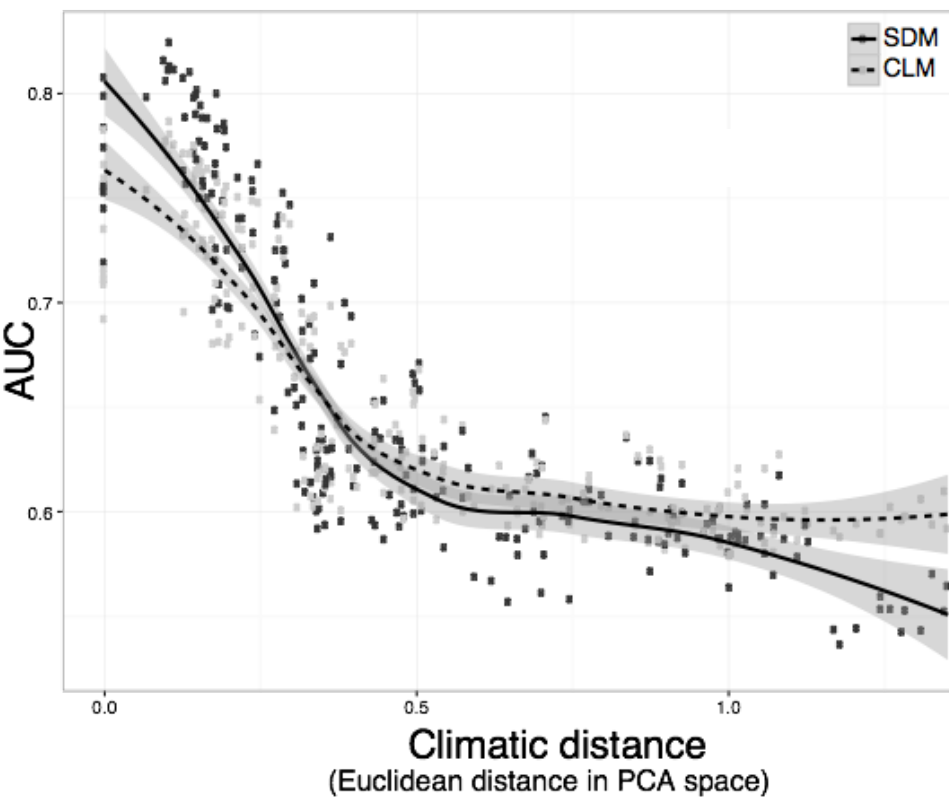


Climate novelty through time: eastern North America

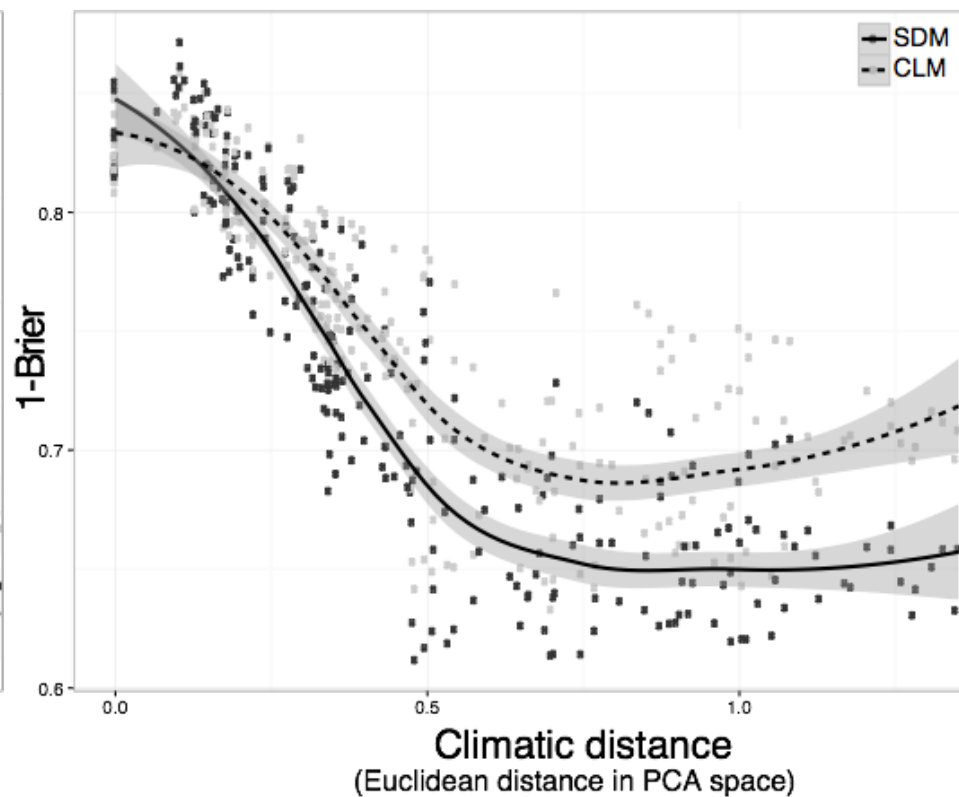


Model performance & future novelty

DISCRIMINATION

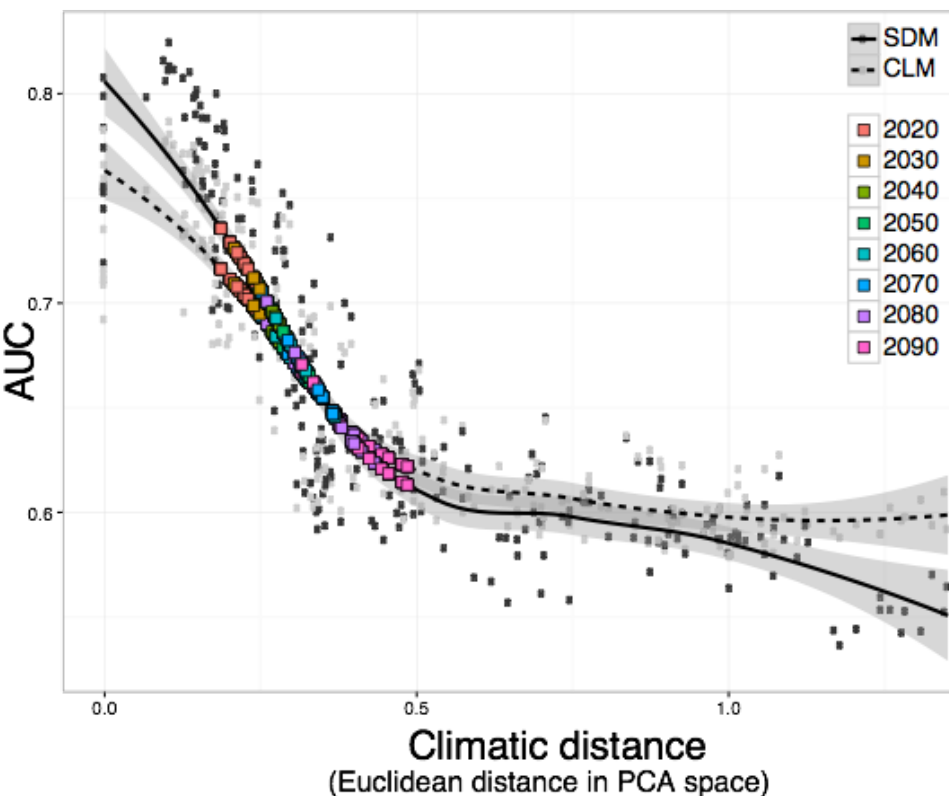


CALIBRATION

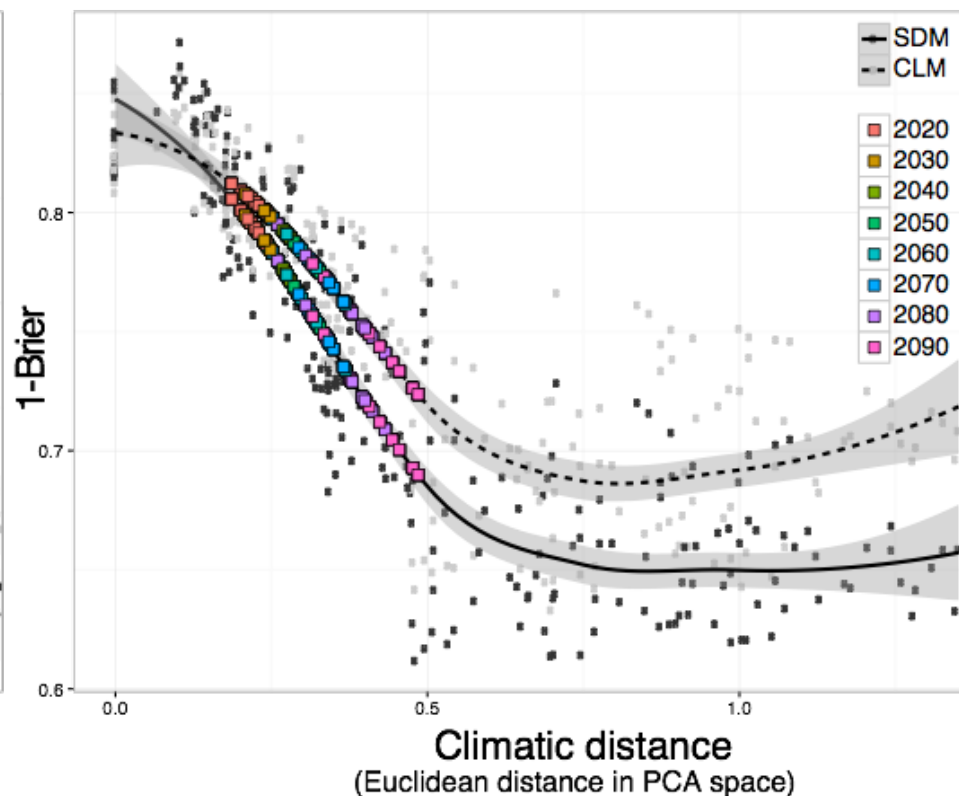


Model performance & future novelty

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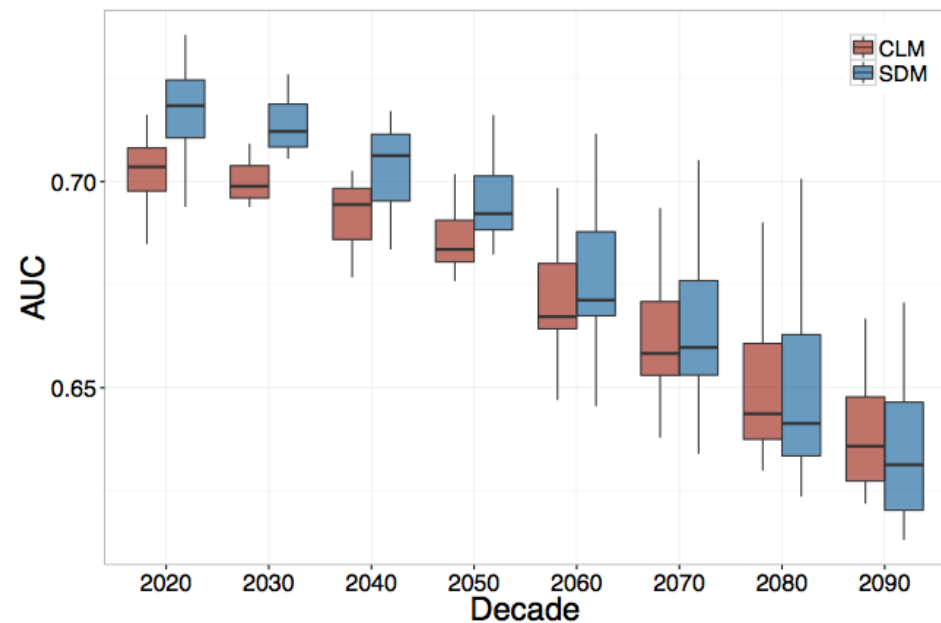


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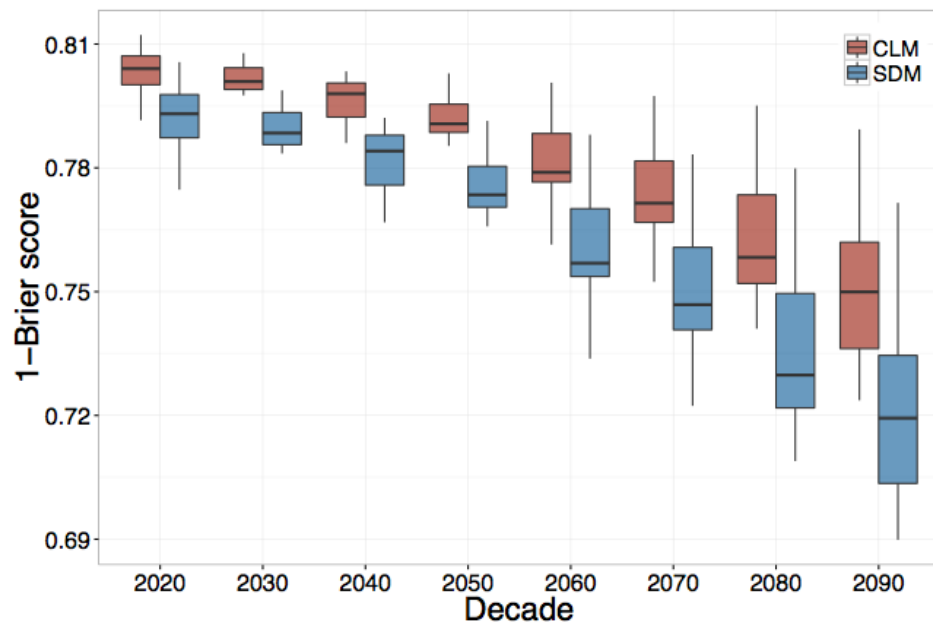


Model performance & future novelty

DISCRIMINATION



CALIBRATION



How might future climate novelty impact model performance?

- ▮ How does future climate novelty compare to past climate novelty?
 - ▮ Future climates will be at least as novel as climates from 8,000 – 14,000 years ago, and for some regions, will far exceed the magnitude of novelty observed over the last 21,000 years.
- ▮ What is the expected robustness of different modeling approaches?
 - ▮ Our results suggest that based on climate distance alone, model performance will not be much better than random by late 21st century.
 - ▮ Small, but measurable benefit to CLMs over SDMs.

Thanks! Questions?

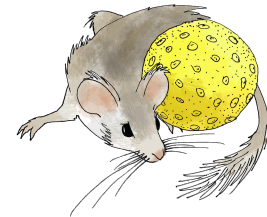
Blois lab

J. Eric Williams
Danaan DeNeve
Robert Boria
Nate Fox

Community paleomodeling

Matt Fitzpatrick
Jack Williams
Kaitlin Maguire
Diego Nieto-Lugilde
Simon Ferrier

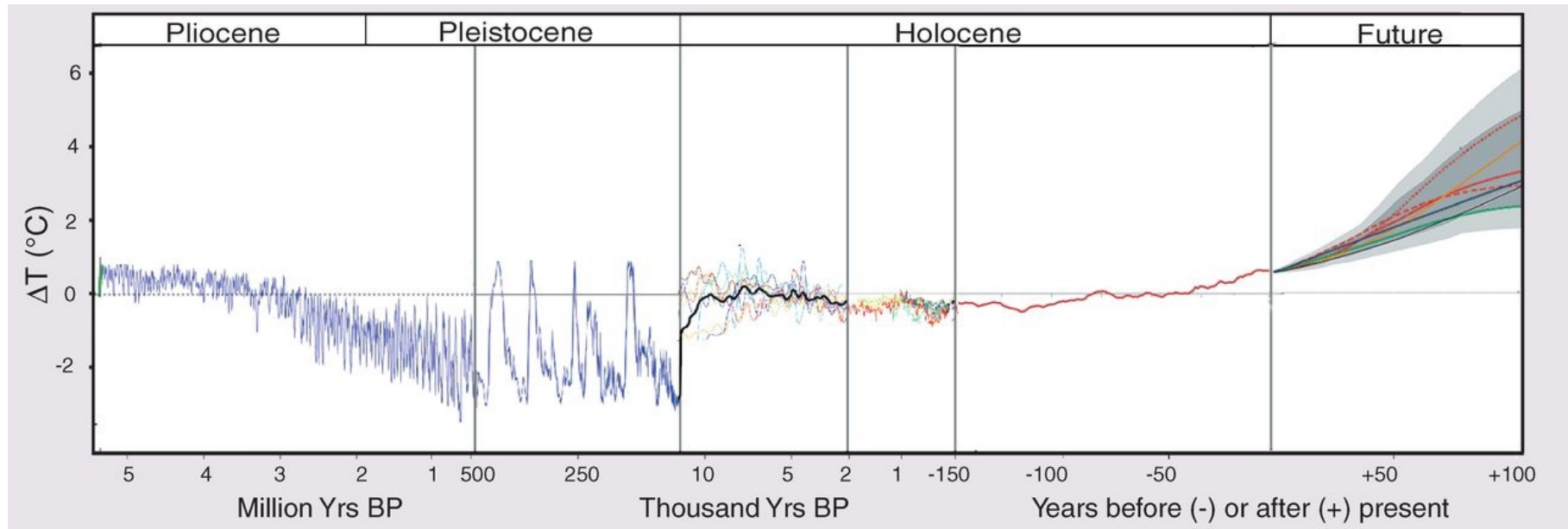
Neotoma database contributors



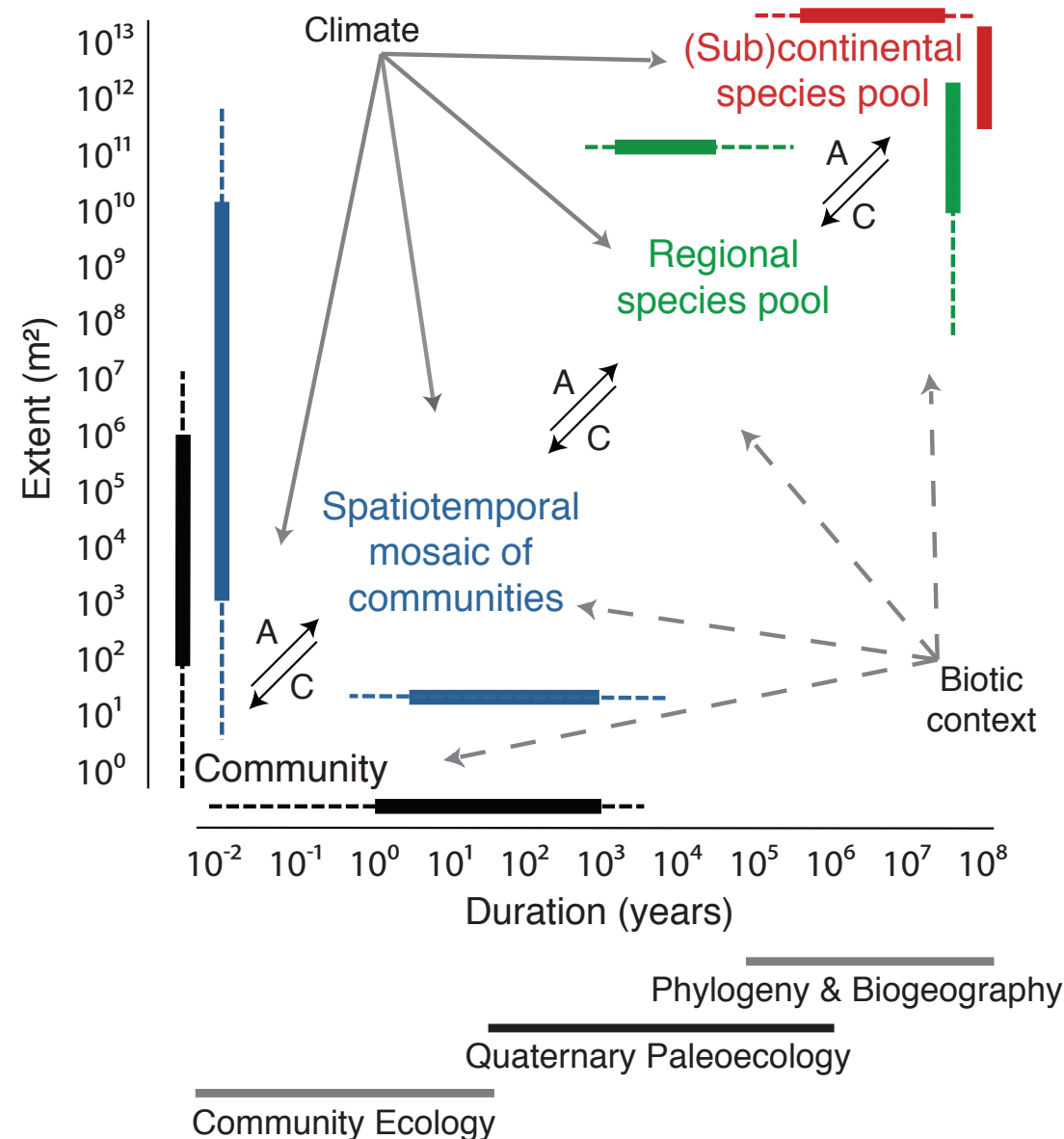
Funding: NSF DEB 1257033
NSF EAR 1623852



Past, present, and future climate change



What factors structure populations and communities across space and time?



▮ Goal: describe biodiversity patterns across the landscape today, and understand the processes that have led to those patterns

▮ Question: If the patterns continually shift, how does that influence inference of the underlying processes?