Reduced tree growth across the semiarid United States due to asymmetric responses to intensifying precipitation extremes

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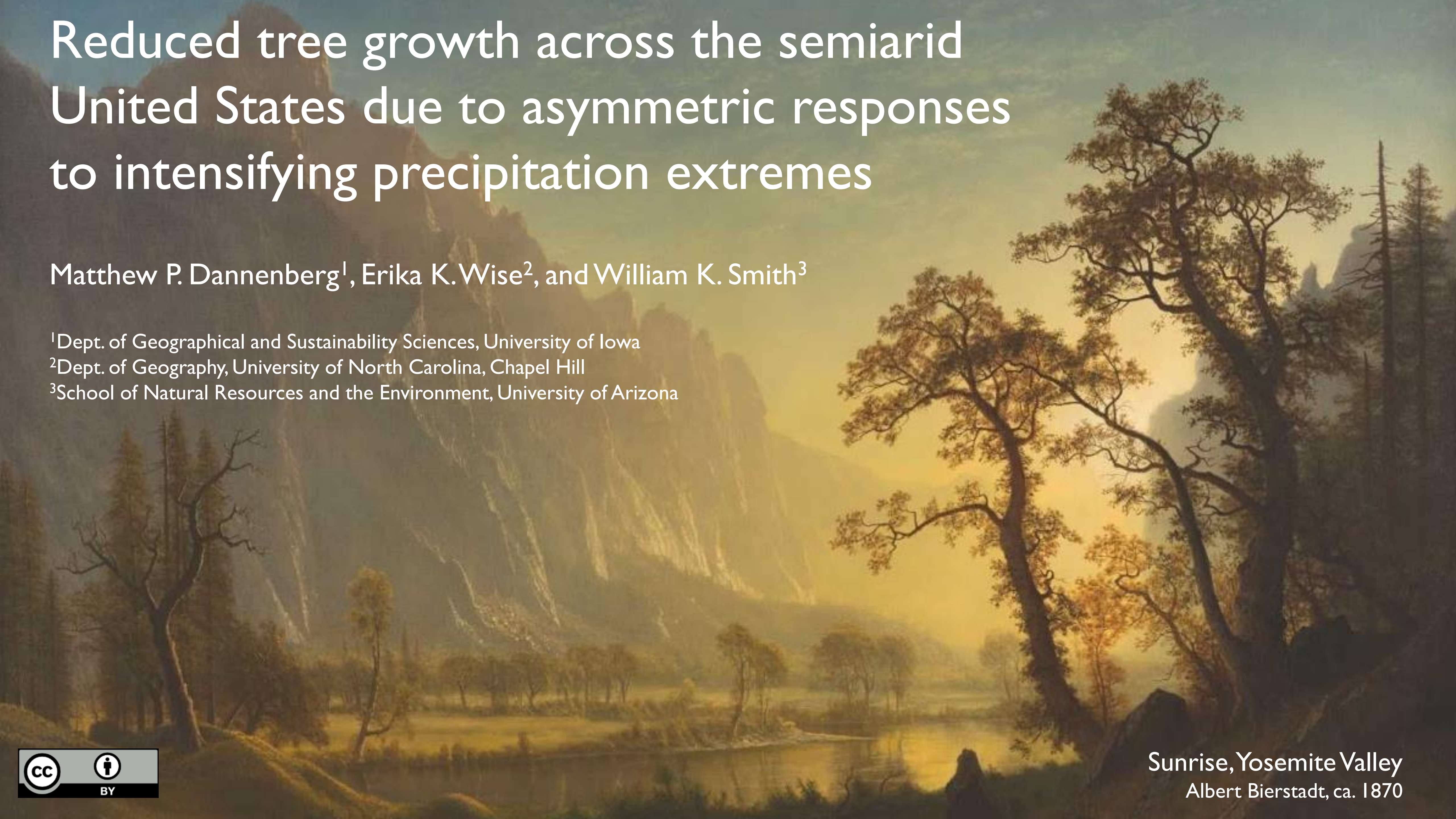
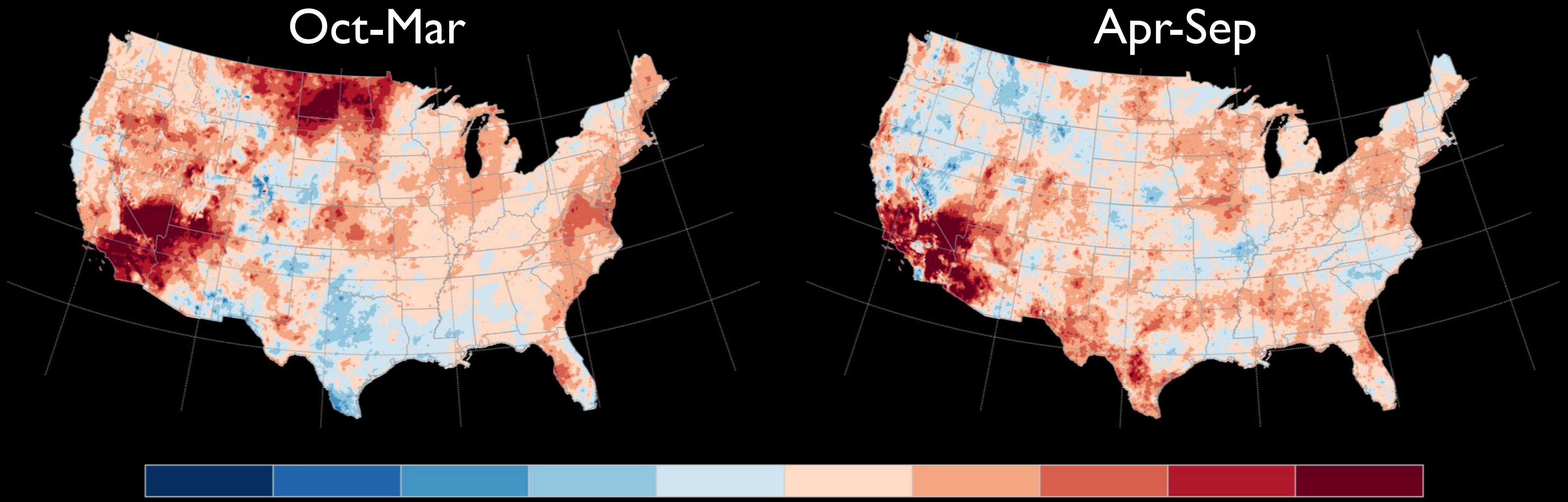


Sunrise, Yosemite Valley
Albert Bierstadt, ca. 1870

Precipitation variability has increased across most of the United States, especially the Southwest, over the past century



Change in precipitation variability (CV)

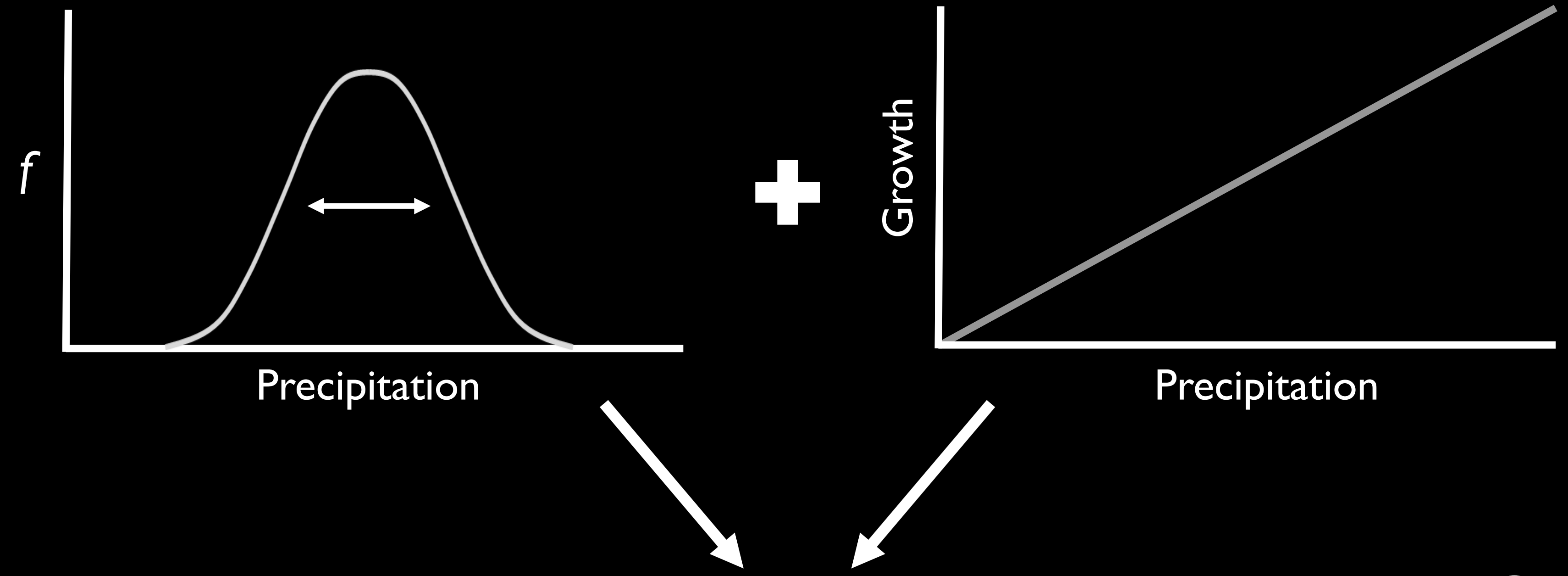
Dannenberg, Wise & Smith (2019), *Science Advances*

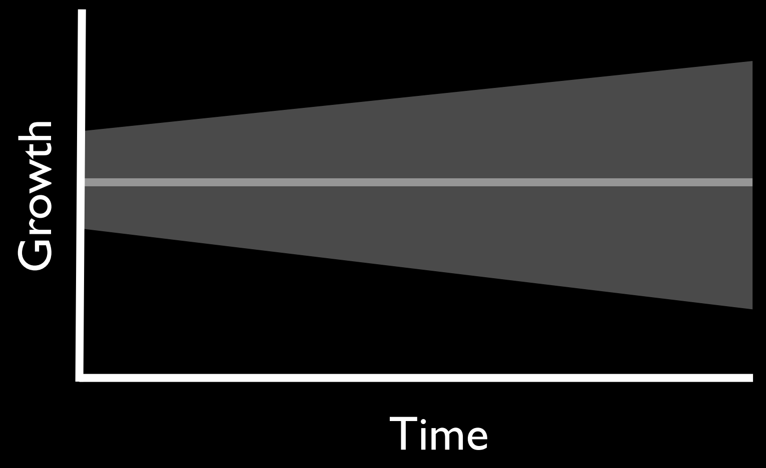
question

How does forest growth respond to increasing

precipitation variability?

Conceptual models

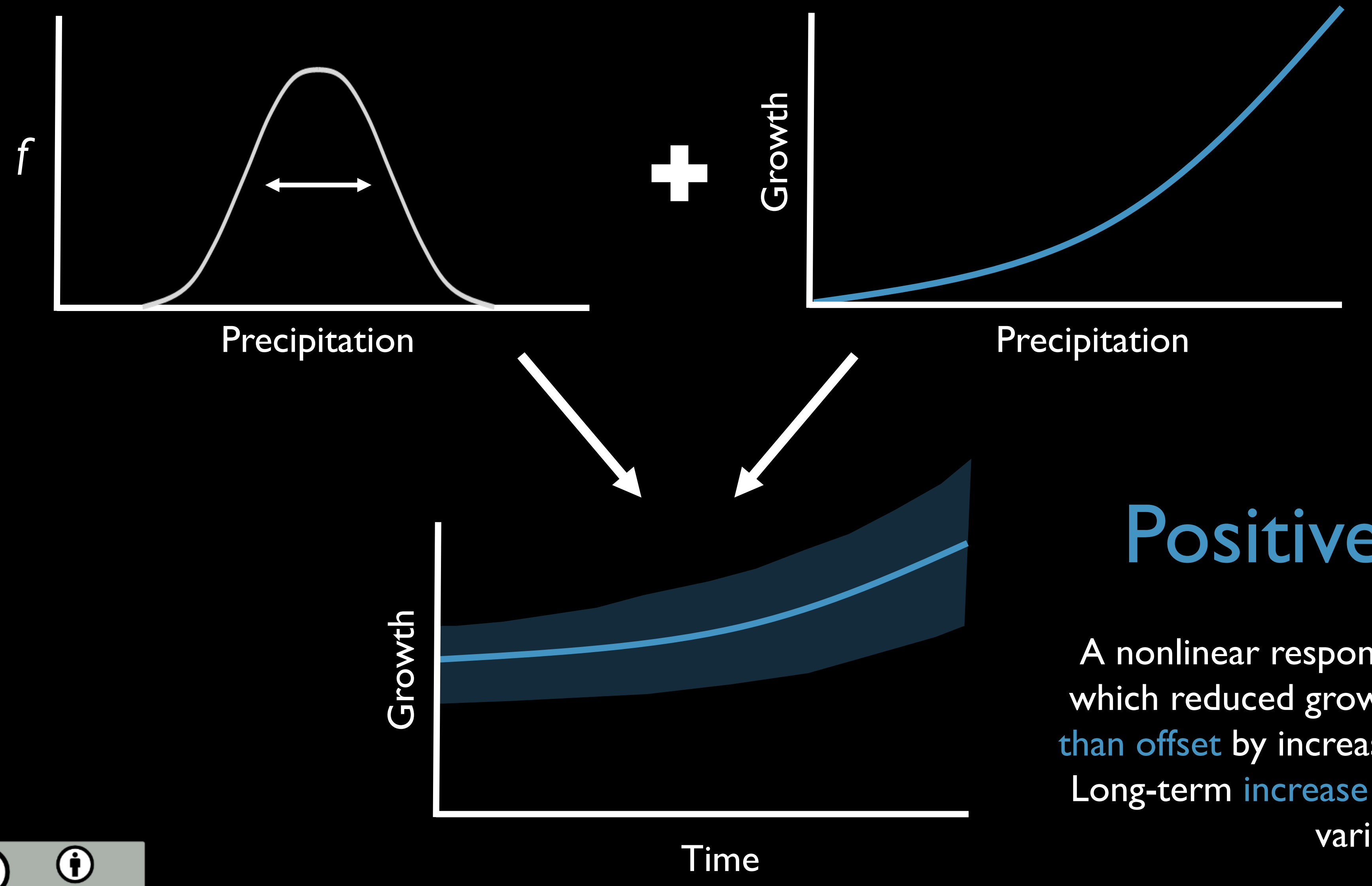




Symmetric

A linear response of growth to precipitation in which reduced growth during dry extremes is compensated by increased growth during wet extremes. No long-term change in mean growth as precipitation variability increases.

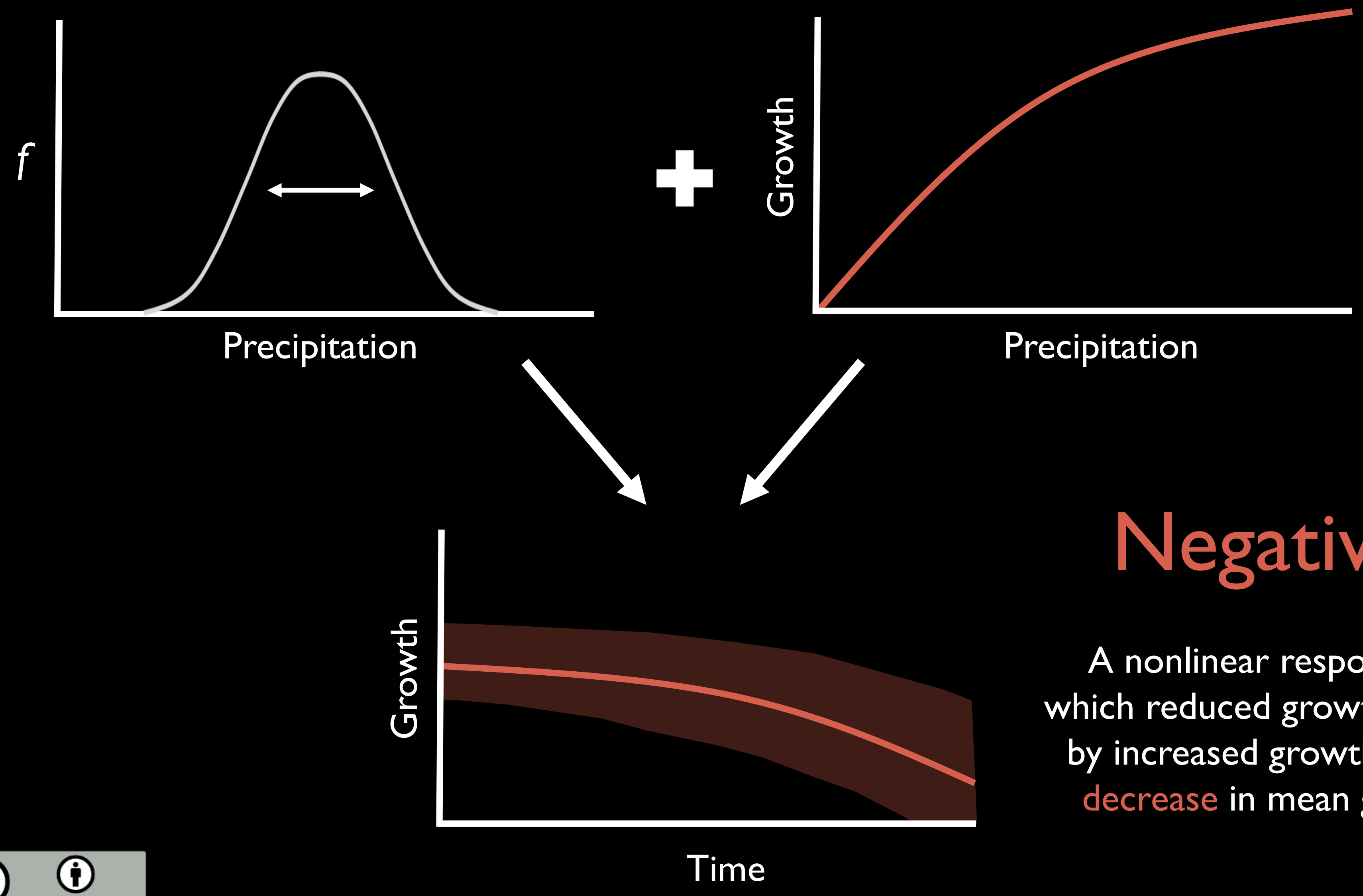
Conceptual models



Positive Asymmetric

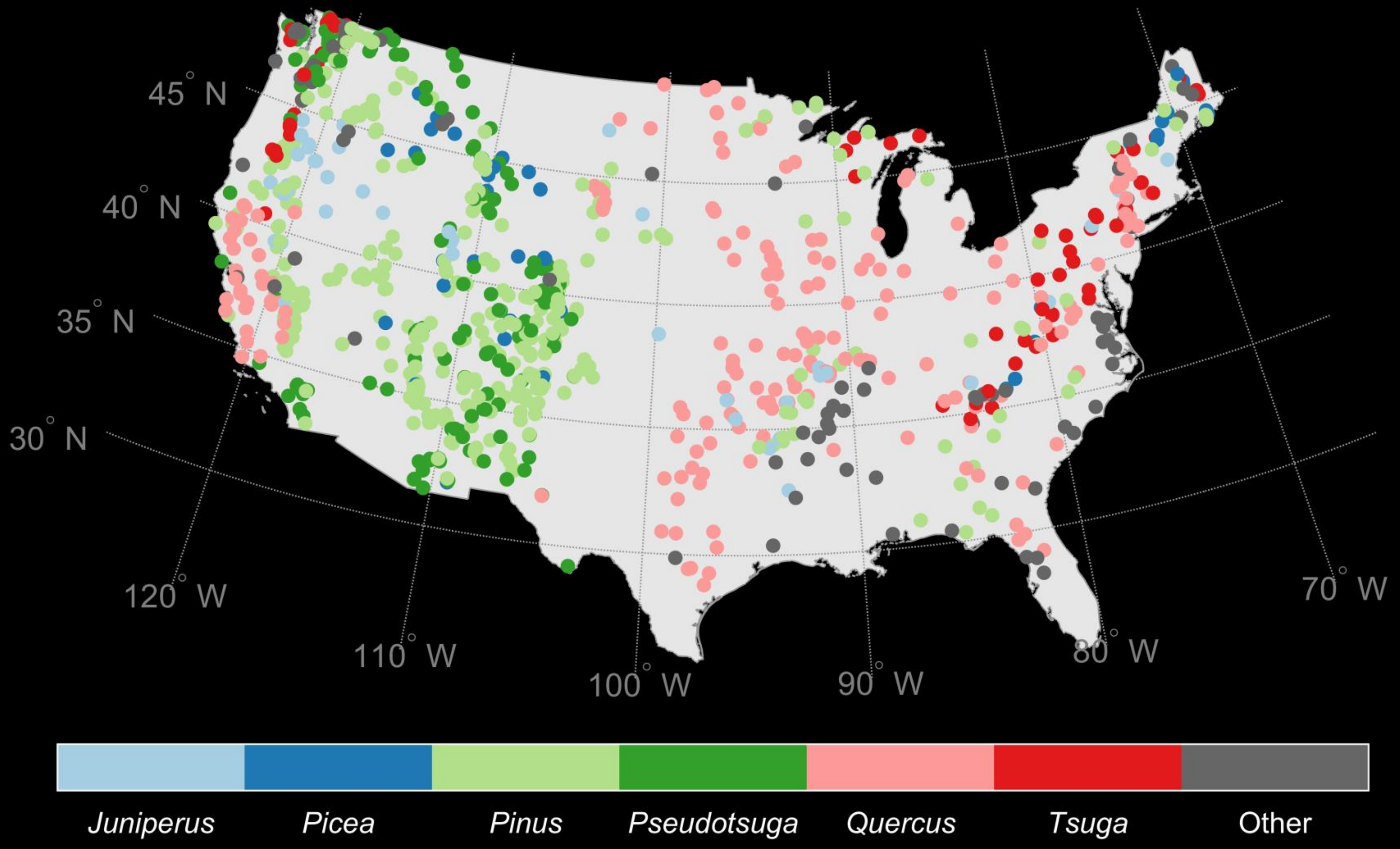
A nonlinear response of growth to precipitation in which reduced growth during dry extremes is more than offset by increased growth during wet extremes. Long-term increase in mean growth as precipitation variability increases.

Conceptual models



Negative Asymmetric

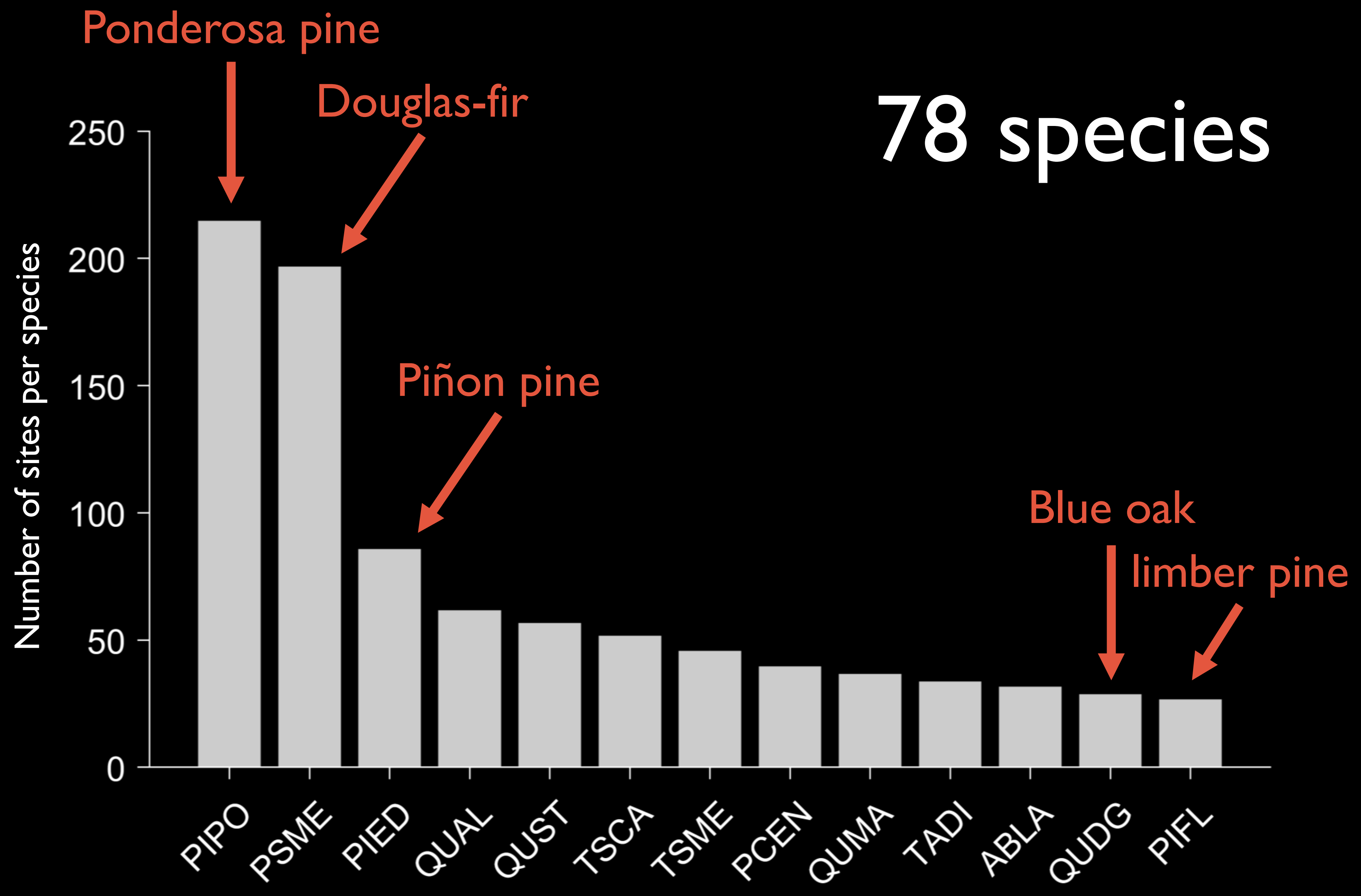
A nonlinear response of growth to precipitation in which reduced growth during dry extremes is not offset by increased growth during wet extremes. Long-term decrease in mean growth as precipitation variability increases.



Conceptual models were tested across the U.S. using growth records from 1,314 tree-ring sites and PRISM precipitation estimates.

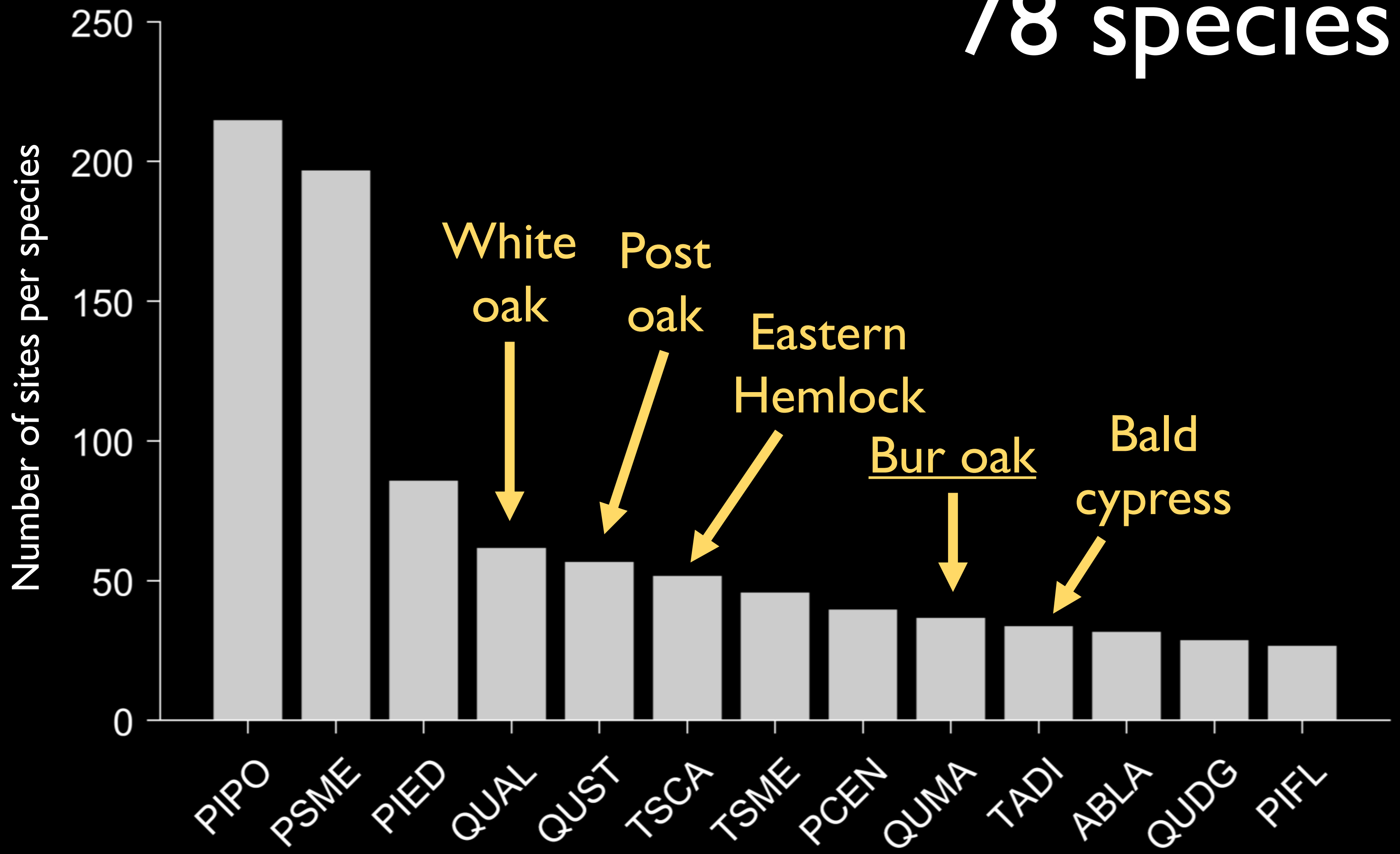
Dannenberg, Wise & Smith (2019), *Science Advances*

78 species



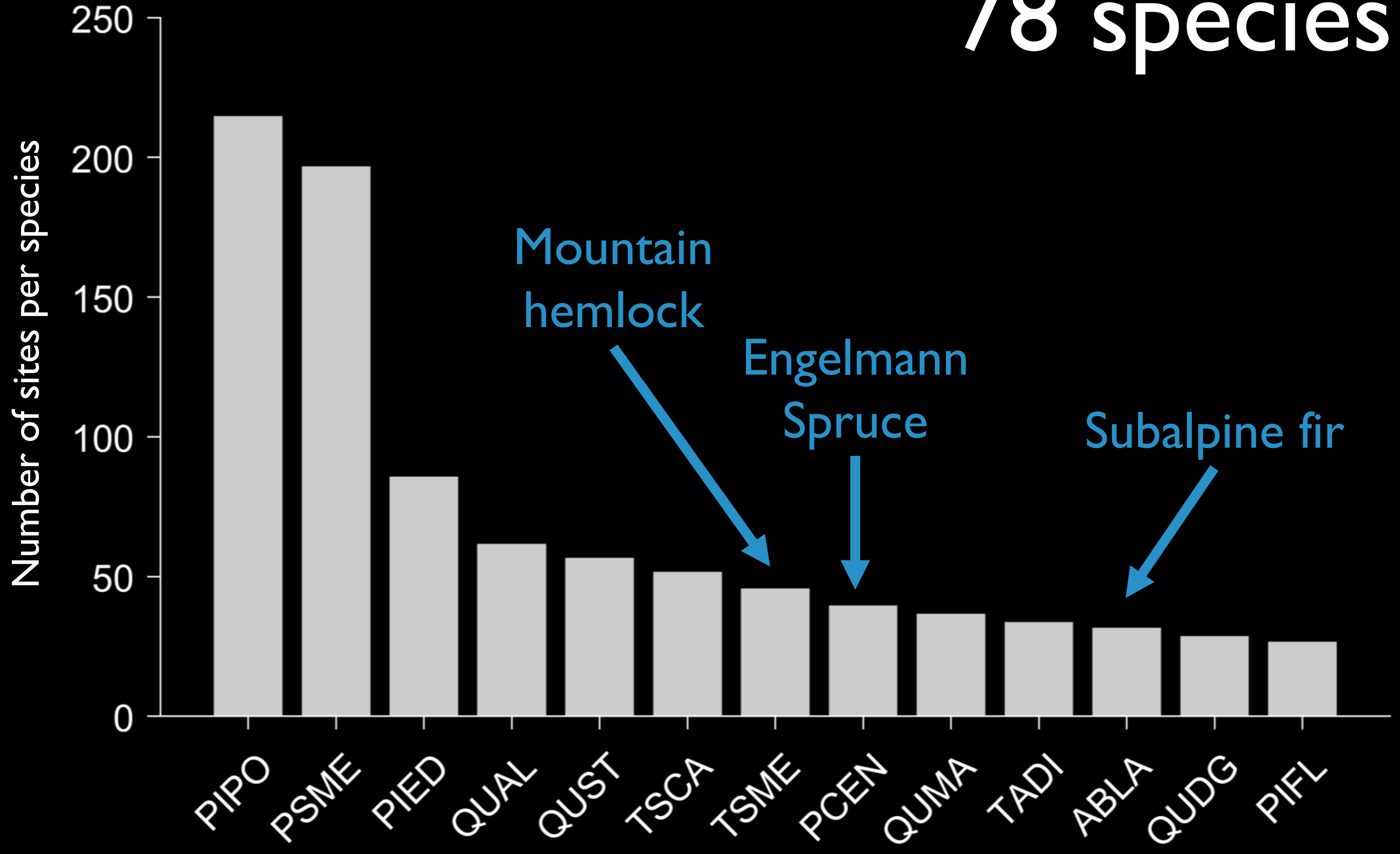
Dannenberg, Wise & Smith (2019), *Science Advances*

78 species



Dannenberg, Wise & Smith (2019), *Science Advances*

78 species



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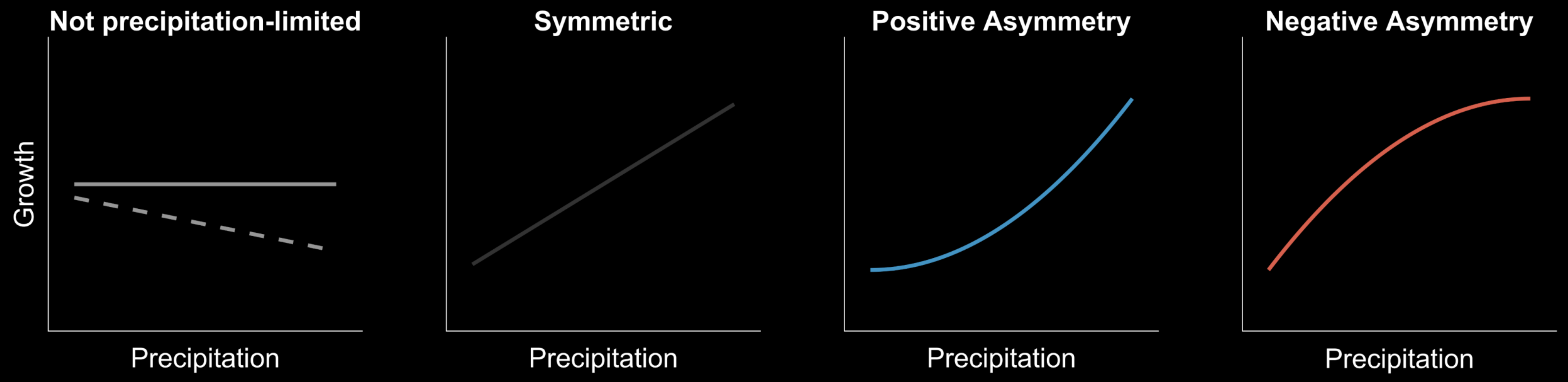
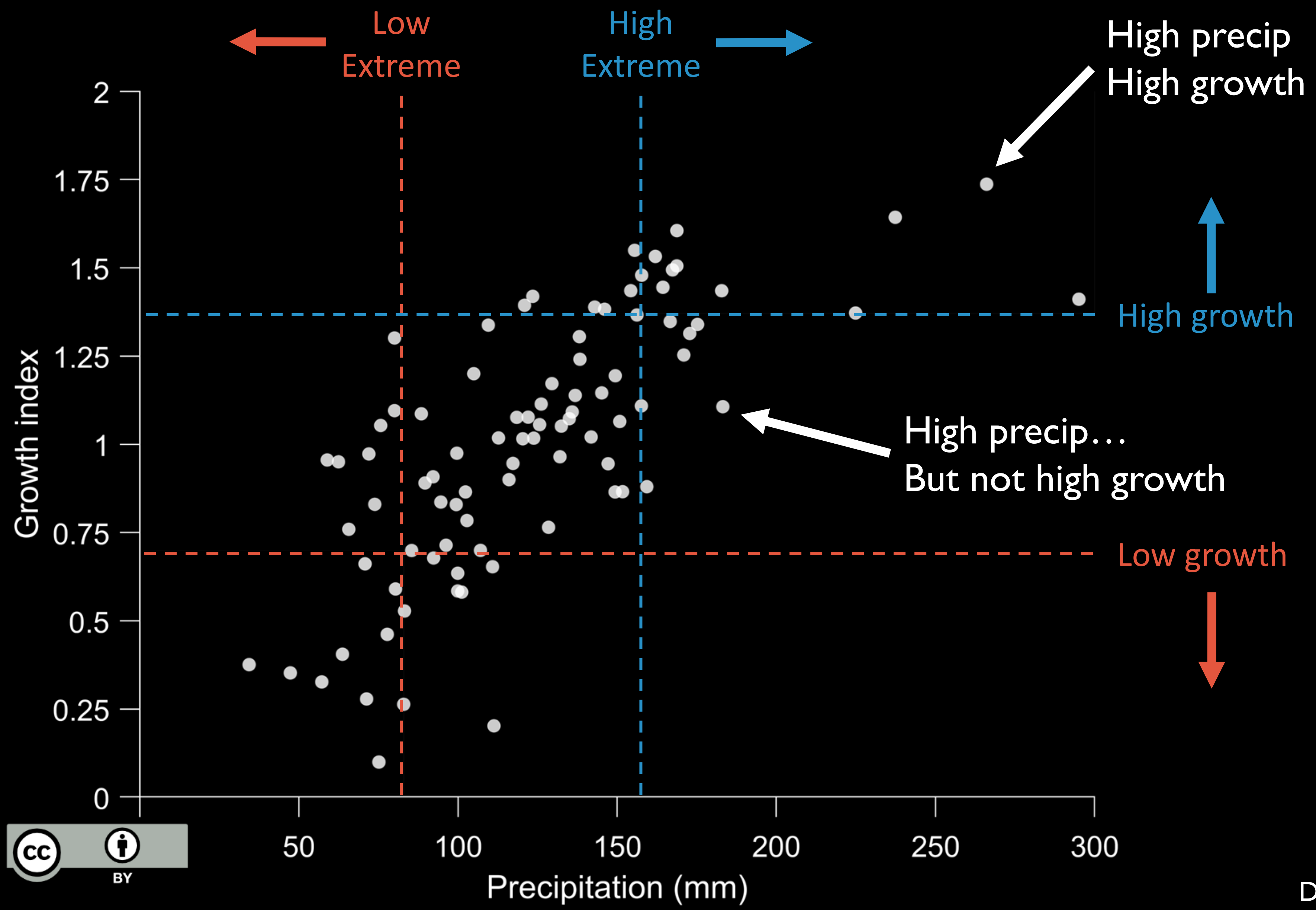
Methods



Growth responses from each tree-ring site were classified into one of four conceptual models based on the best fit from ordinary least squares regression

Dannenberg, Wise & Smith (2019), *Science Advances*

Methods



Responses to extreme events were detected using an extreme value capture method corrected for chance agreement using Cohen's kappa (κ)

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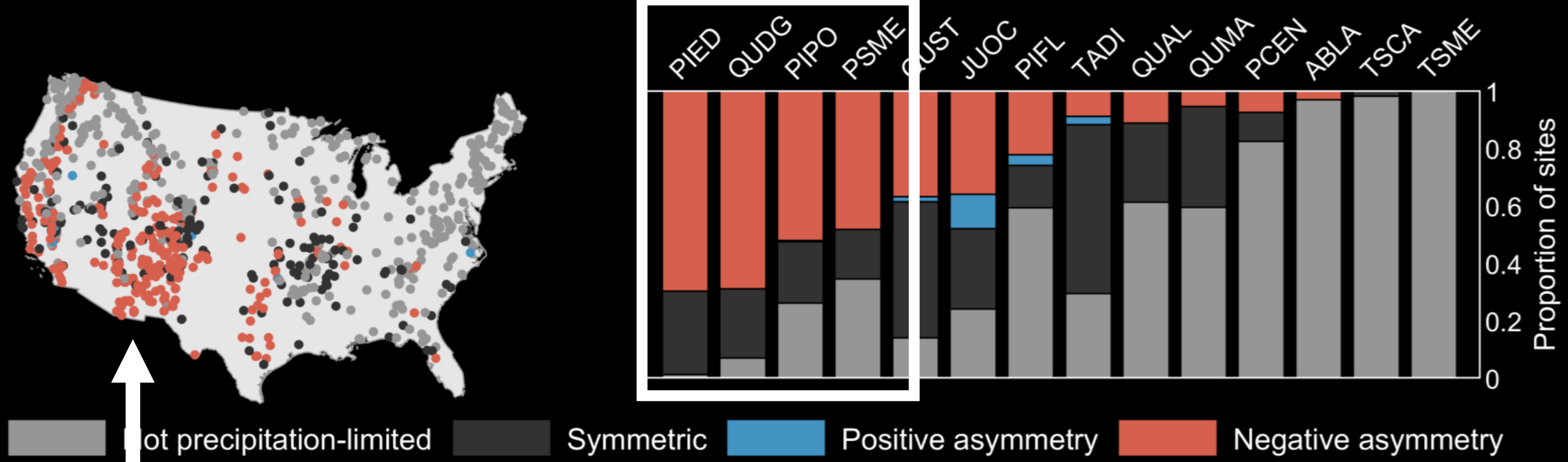
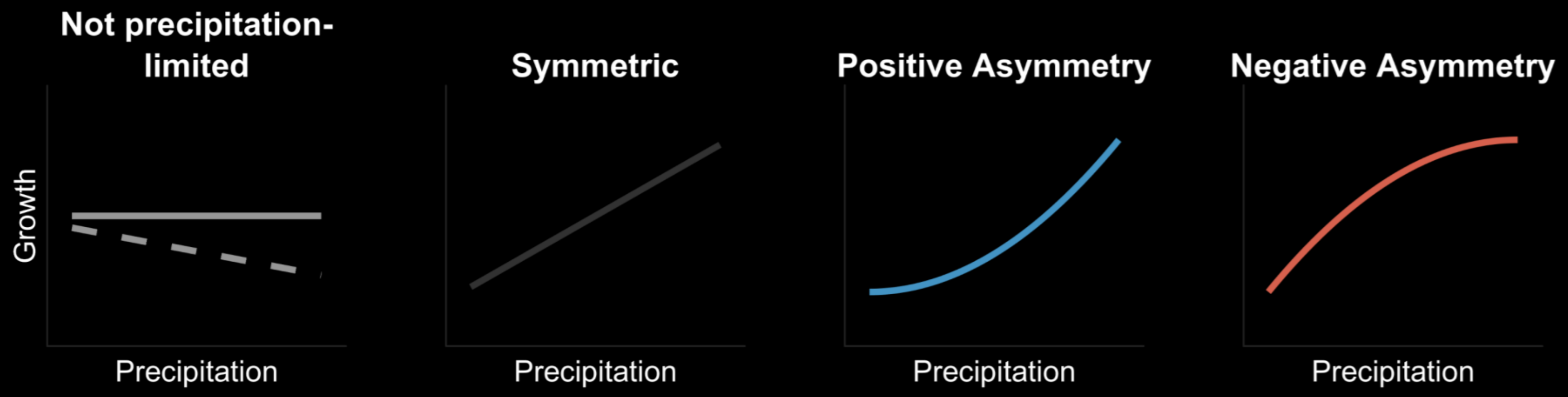
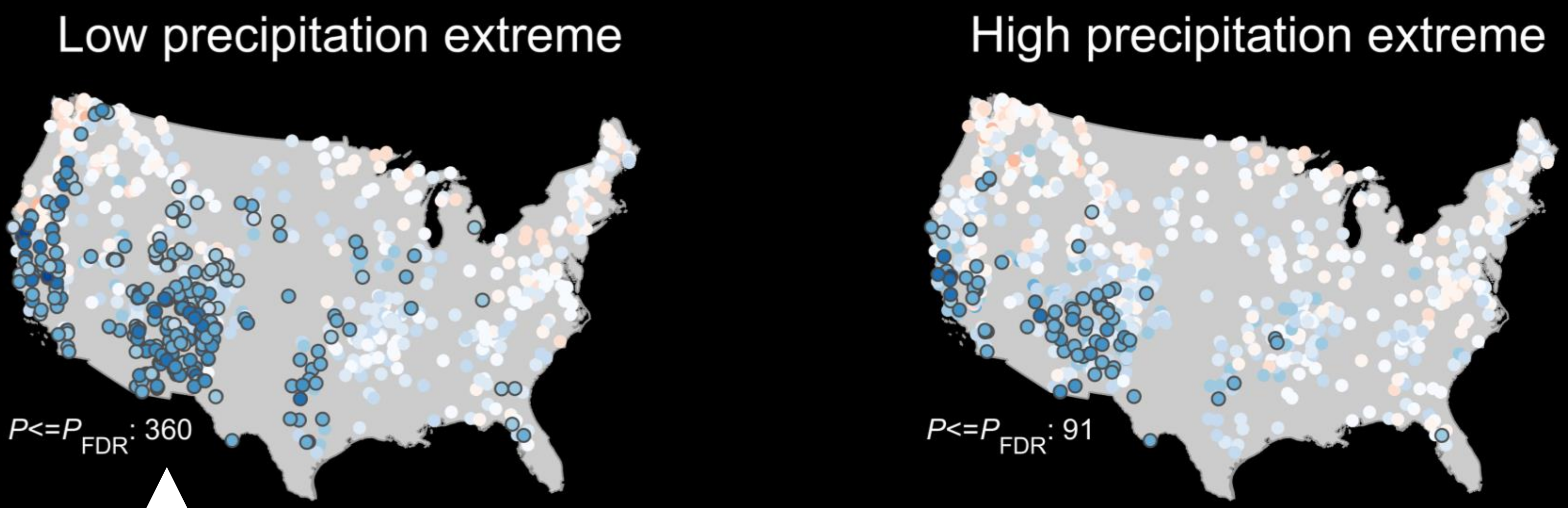
Cool season
(Oct-Mar)



Widespread negative asymmetries in western U.S.

(increasing precipitation yields diminishing returns for growth)





Dry years are very likely to have very low growth

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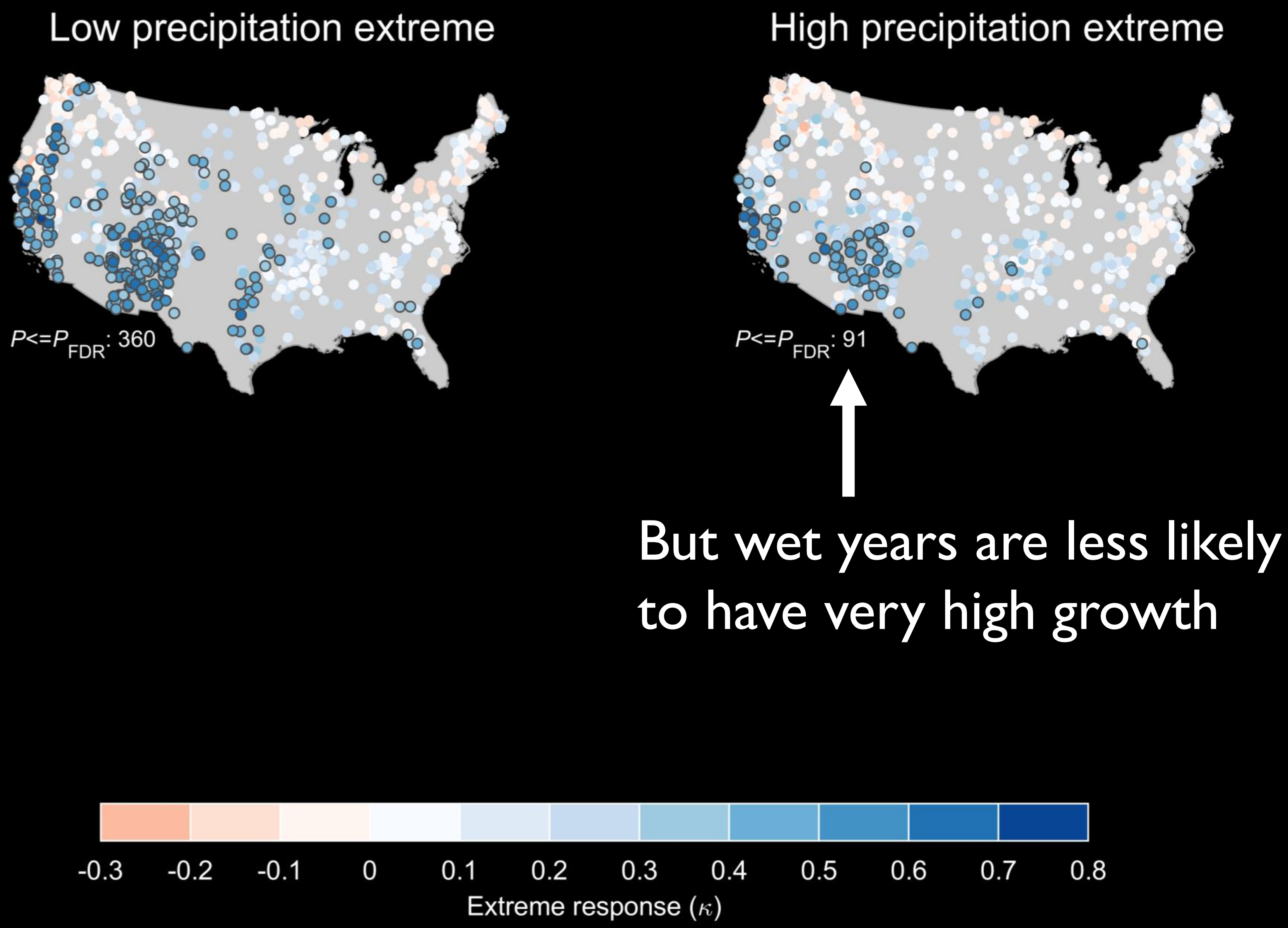


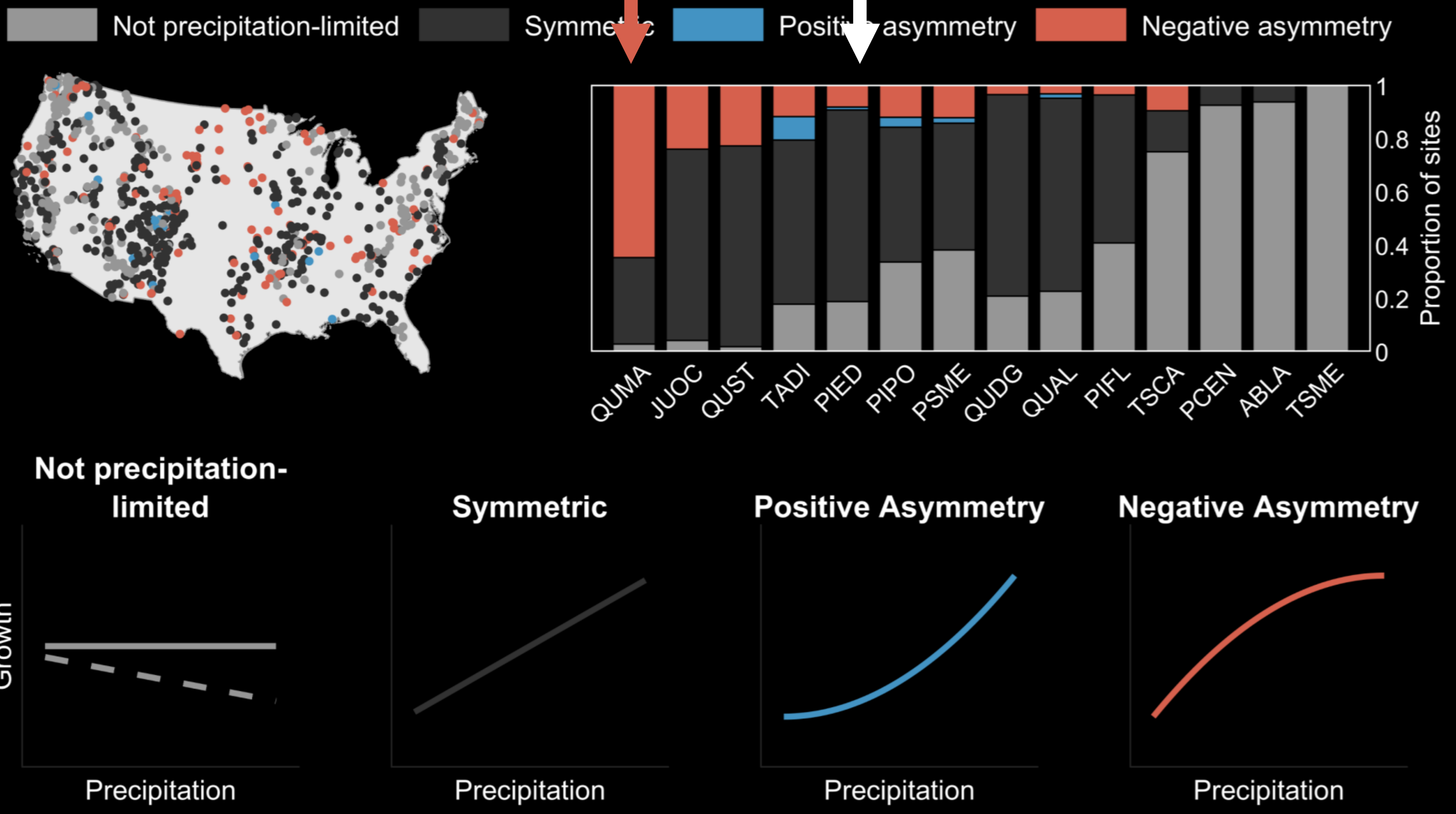
But wet years are less likely to have very high growth

Dannenberg, Wise & Smith (2019), *Science Advances*

Mostly symmetric throughout U.S.

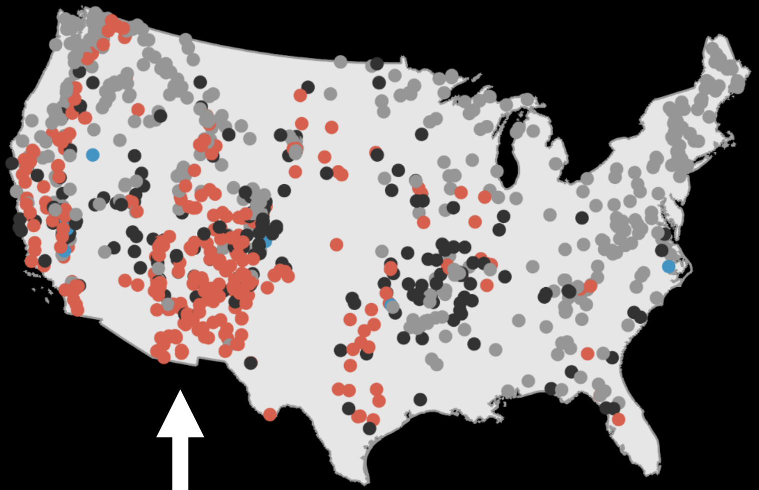
Except for bur oak

Warm season
(Apr-Sep)

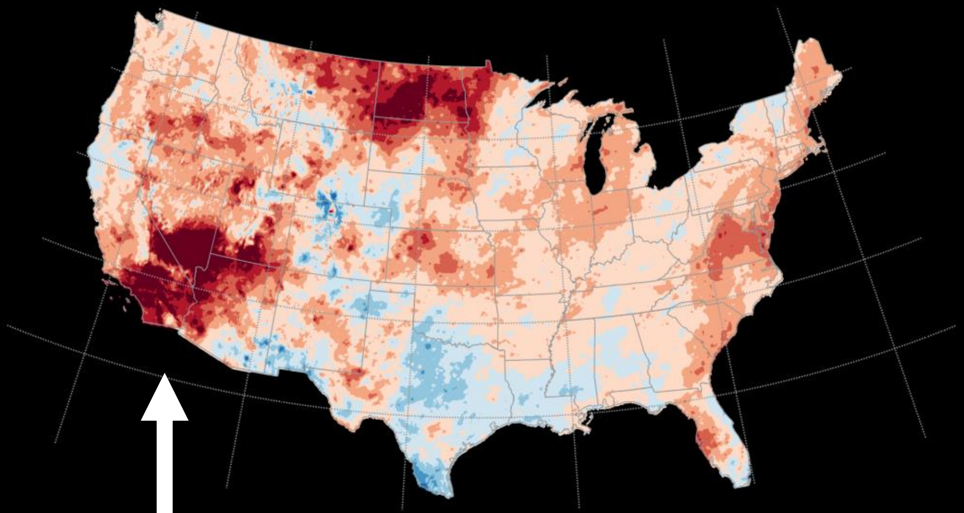


what long-term effect does increasing precipitation variability have on tree growth?

Growth Response

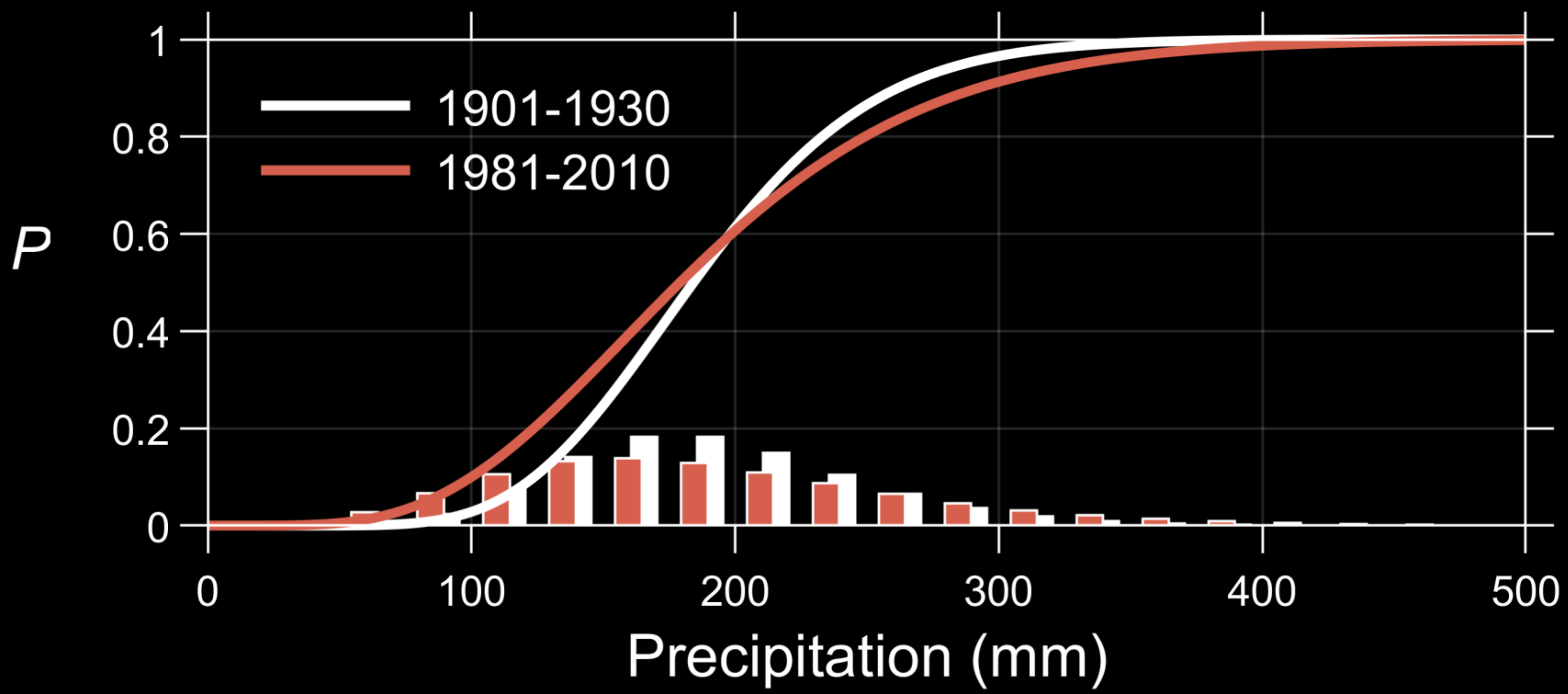


Change in precipitation variability



Widespread negative asymmetries between growth and precipitation

Large increase in precipitation variability



Simulations with two precipitation scenarios

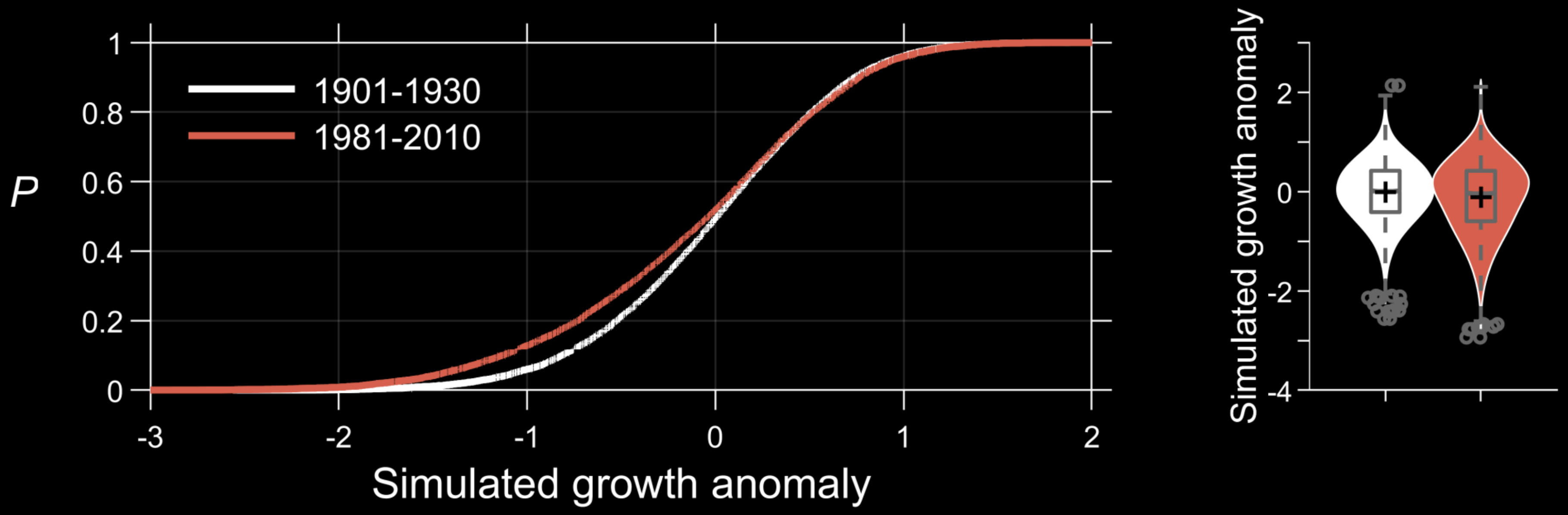
(same mean, different variance)

Dannenberg, Wise & Smith (2019), *Science Advances*

High-variability scenario:

Double the likelihood of low growth

No change in likelihood of high growth



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summary

1. Growth responds **asymmetrically** to precipitation variability (especially western conifers and bur oak)

2. Increased precipitation variability can drive **decreases** in forest growth

ENVIRONMENTAL STUDIES

Reduced tree growth in the semiarid United States due to asymmetric responses to intensifying precipitation extremes

Matthew P. Dannenberg[1,2]*, Erika K. Wise[3], William K. Smith[2]

Earth's hydroclimatic variability is increasing, with changes in the frequency of extreme events that may negatively affect forest ecosystems. We examined possible consequences of changing precipitation variability using tree rings in the conterminous United States. While many growth records showed either little evidence of precipitation limitation or linear relationships to precipitation, growth of some species (particularly those in semiarid regions) responded asymmetrically to precipitation such that tree growth reductions during dry years were greater than, and not compensated by, increases during wet years. The U.S. Southwest, in particular, showed a large increase in precipitation variability, coupled with asymmetric responses of growth to precipitation. Simulations suggested roughly a twofold increase in the probability of large negative growth anomalies across the Southwest resulting solely from 20th century increases in variability of cool-season precipitation. Models project continued increases in precipitation variability, portending future growth reductions across semiarid forests of the western United States.

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