

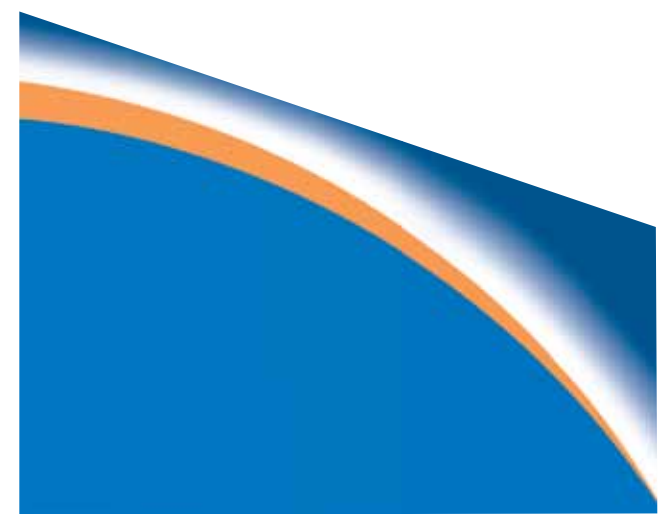
Paleoclimate constraints on the spatio-temporal scales of past and future drought in climate models

Sloan Coats

 @drynamics  scoatsclim.github.io

Collaborators: Arindam Banerjee and Qiang Fu (Univ. Minnesota);
Bette Otto-Bliesner, John Fasullo and Sam Stevenson (NCAR)

www2.ucar.edu



NCAR

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

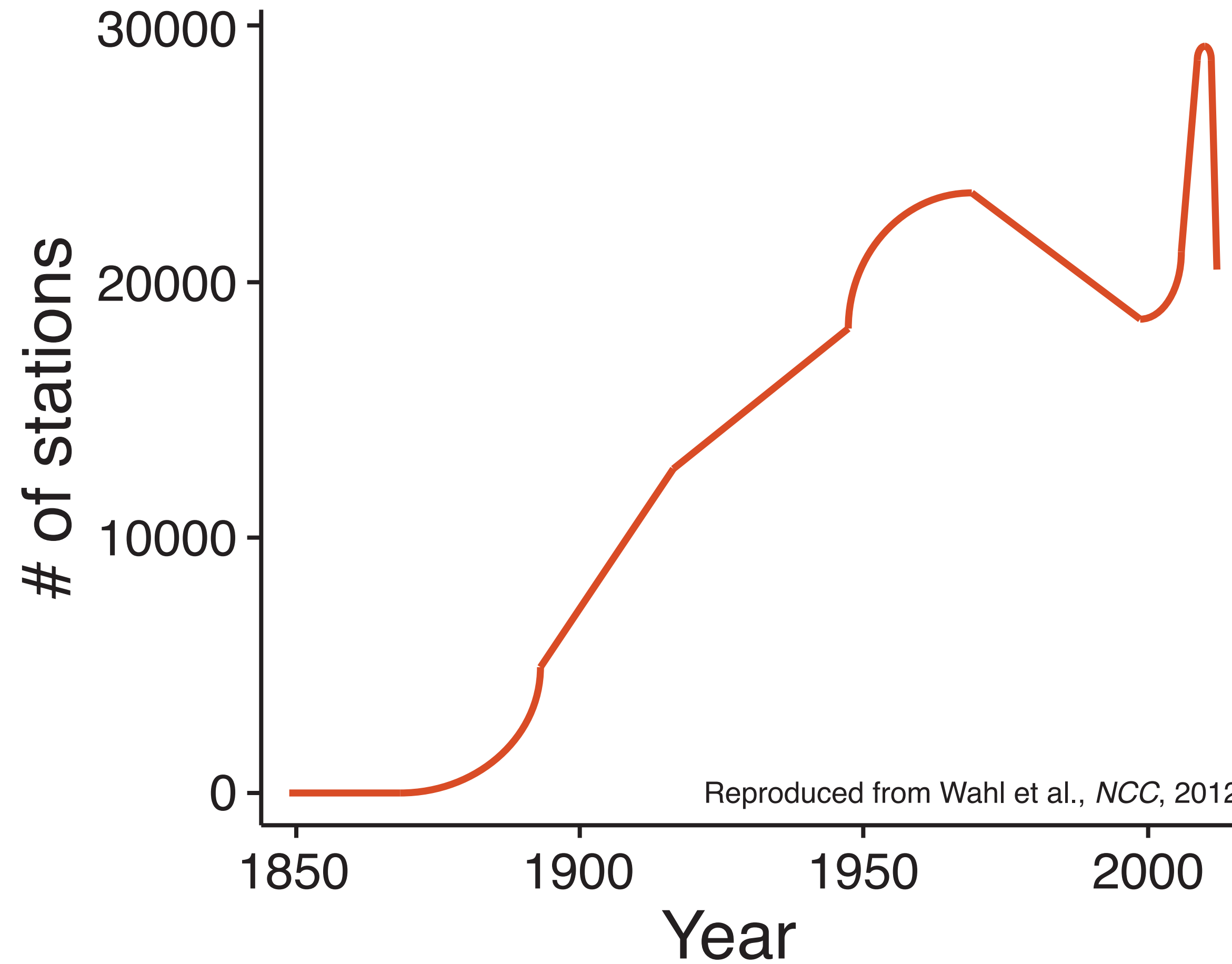


UCAR

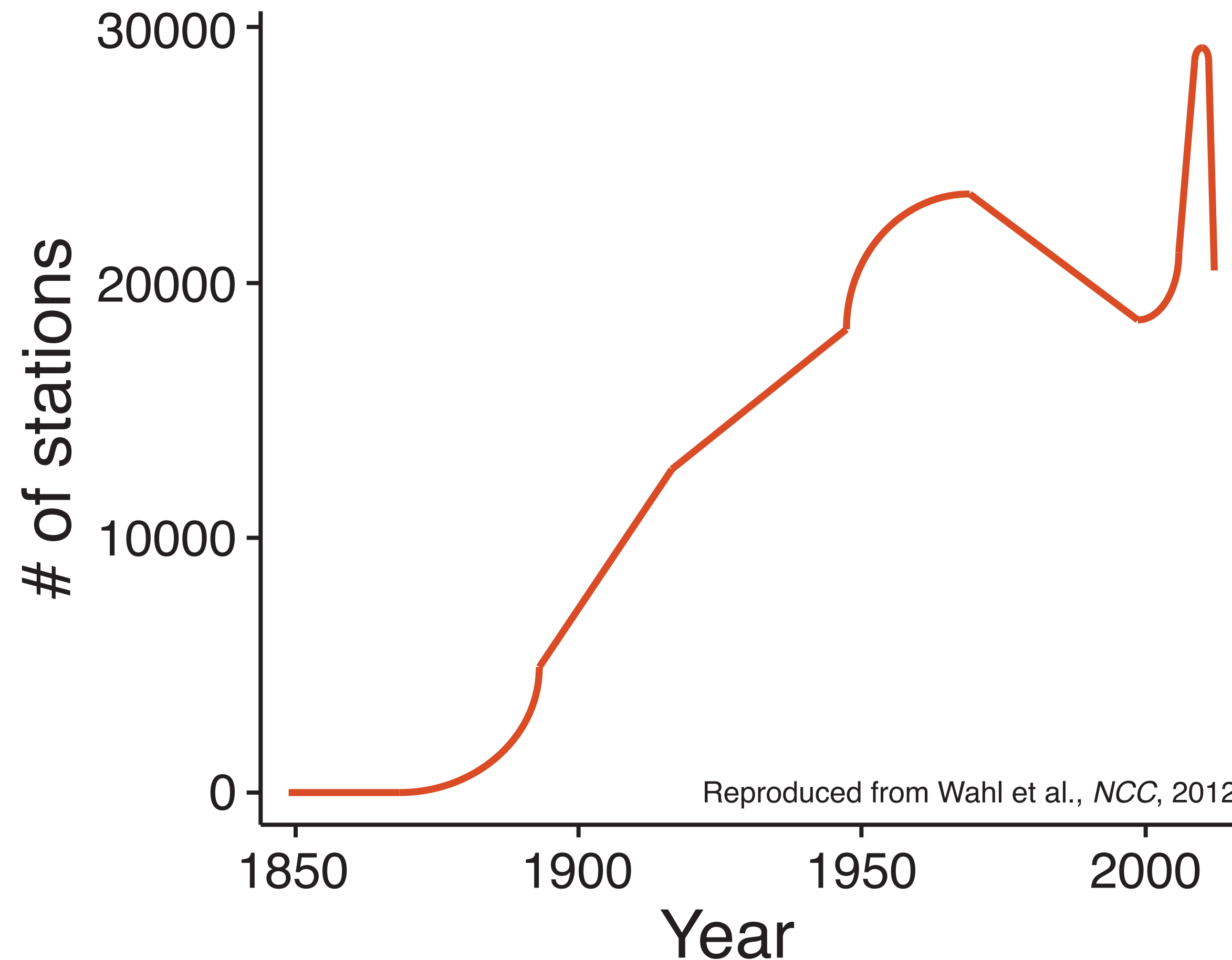
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH



Why use the paleoclimate record to constrain climate models?



Why use the paleoclimate record to constrain climate models?



Paleoclimate record of Common Era is best chance of extending instrumental record with similar spatial and temporal resolution

Why decadal-to-centennial timescales?

Projecting Future Hydroclimate!

- How will hydroclimate respond to increasing greenhouse gas concentrations over the next decade to century?
- How will these forced changes combine with internal climate variability to determine the actual impacts of hydroclimate change?
- Are models able to capture the full range of internal and forced components of past hydroclimate change on decadal-to-centennial timescales?

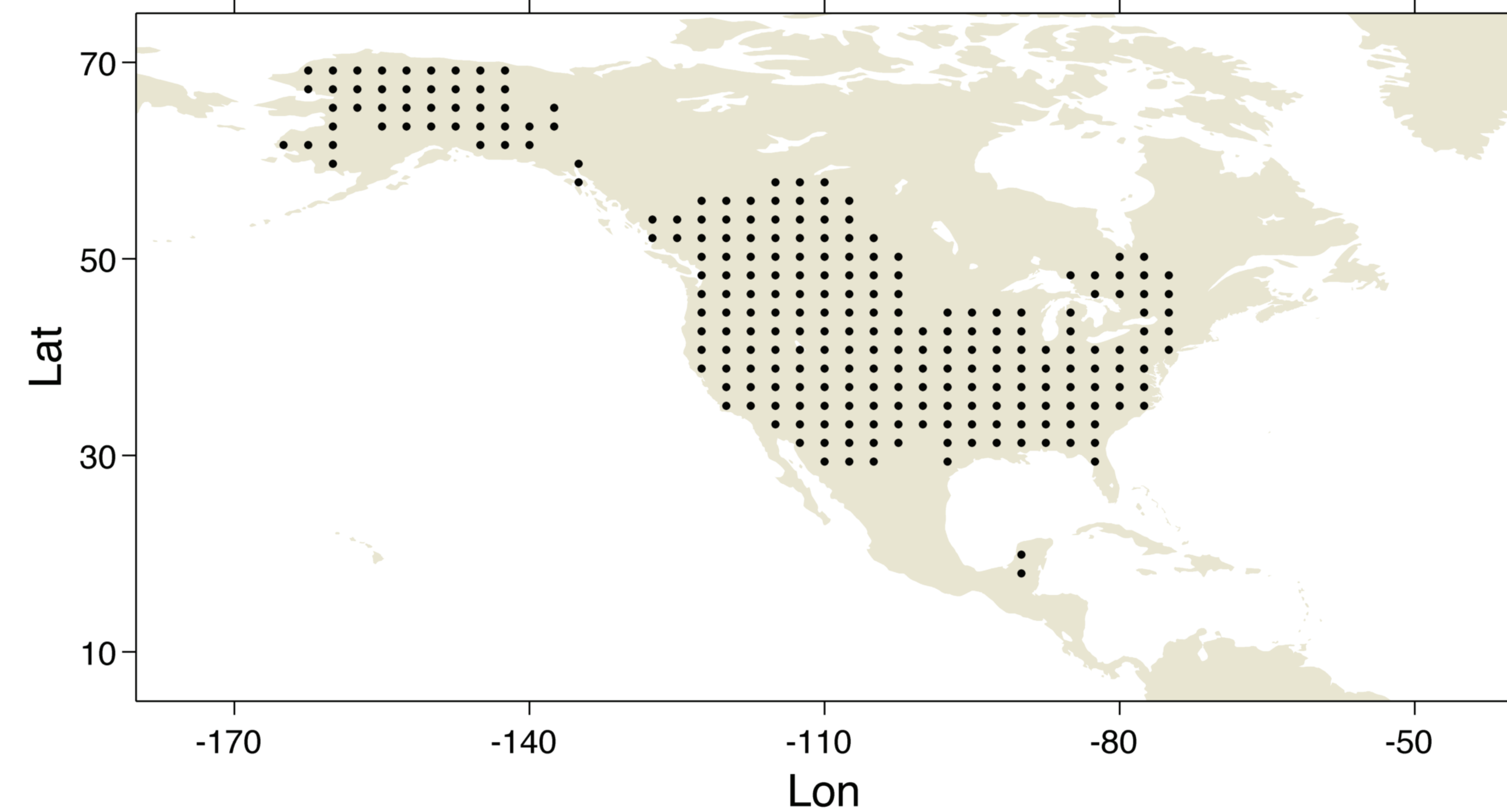
A case study of megadroughts

A case study of megadroughts

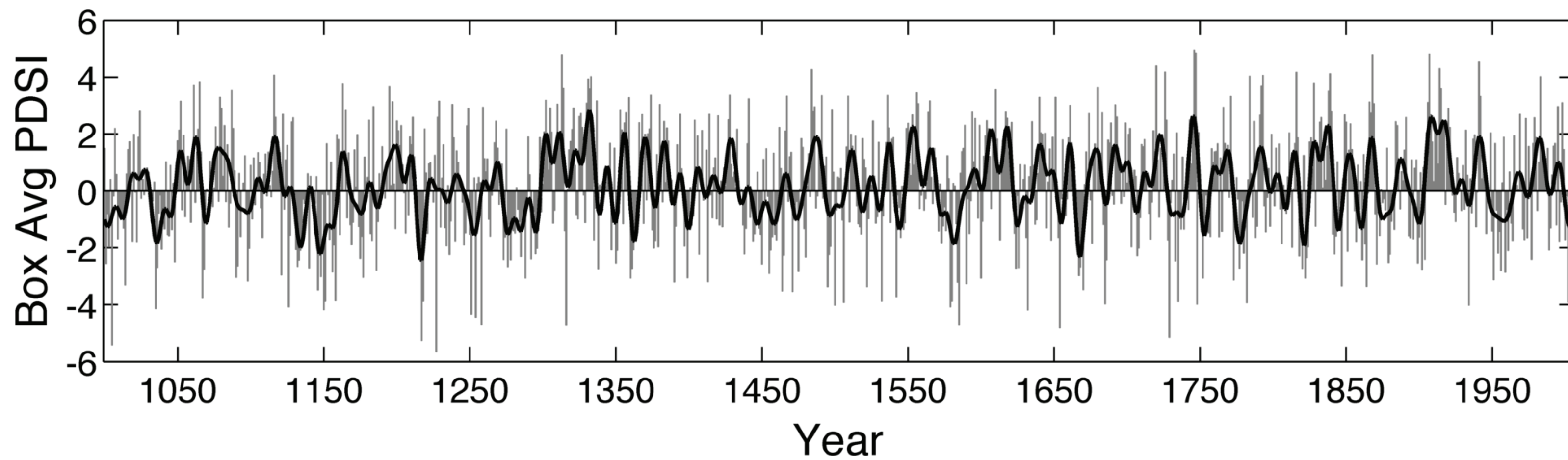
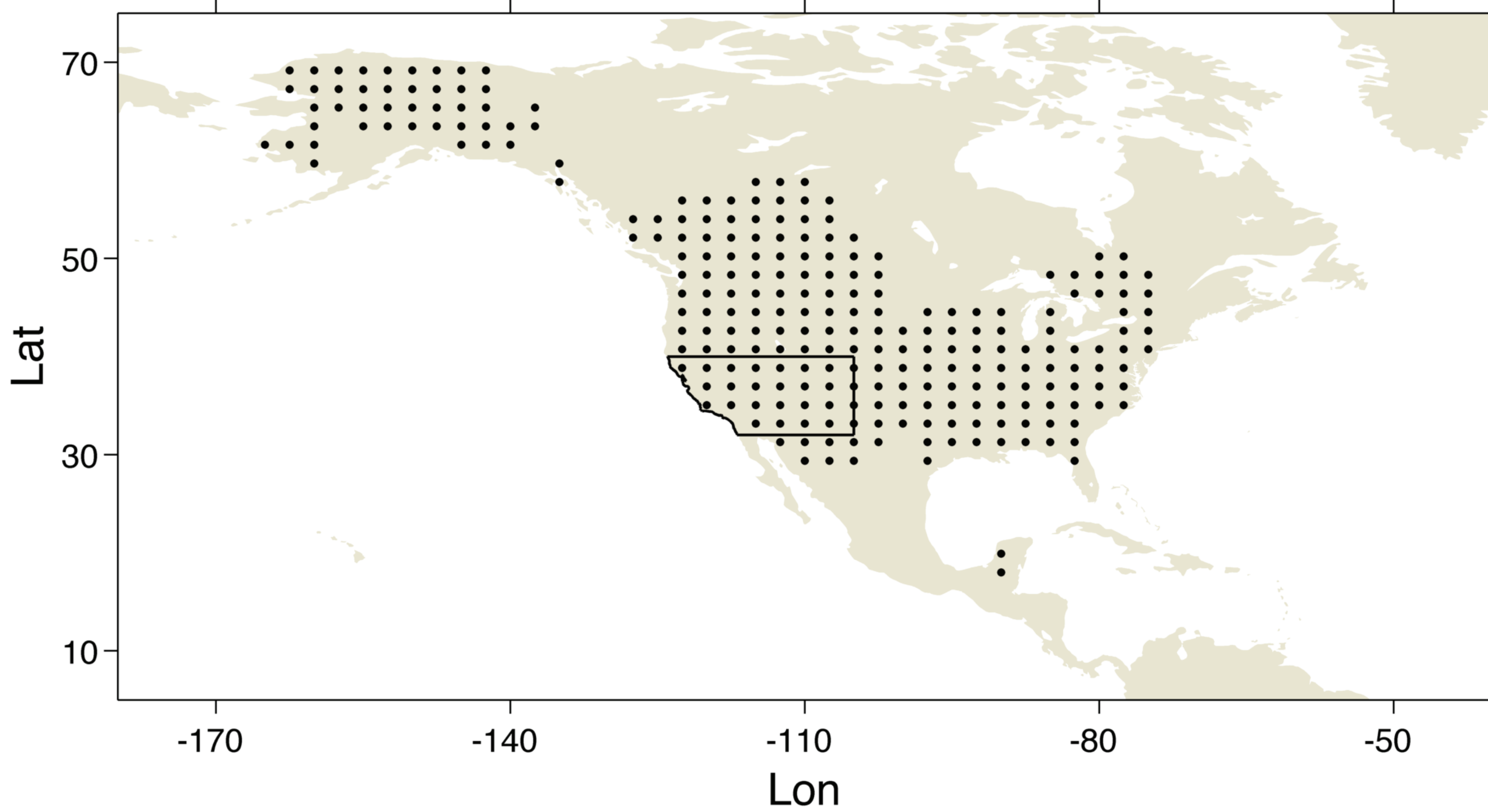
-North American Drought Atlas:
a tree-ring based reconstruction
(Cook et al. 2009)

-JJA PDSI

-On a grid for
1000-2000 C.E.



A case study of megadroughts



Stochastically Generated North American Megadroughts

SAMANTHA STEVENSON, AXEL TIMMERMANN, AND YOSHIMITSU CHIKAMOTO

International Pacific Research Center, University of Hawai'i at Mānoa, Honolulu, Hawaii

SALLY LANGFORD

Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, Colorado

PEDRO DIÑEZIO

International Pacific Research Center, University of Hawai'i at Mānoa, Honolulu, Hawaii

(Manuscript received 12 November 2013, in final form 29 October 2014)

A case study of megadroughts

-Do models simulate megadroughts?

Are Simulated Megadroughts in the North American Southwest Forced?*

SLOAN COATS

Lamont-Doherty Earth Observatory, Columbia University, Palisades, and Department of Earth and Environmental Science, Columbia University, New York, New York

JASON E. SMERDON

Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York

BENJAMIN I. COOK

NASA Goddard Institute for Space Studies, New York, and Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York

RICHARD SEAGER

Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York

Megadroughts in Southwestern North America in ECHO-G Millennial Simulations and Their Comparison to Proxy Drought Reconstructions*

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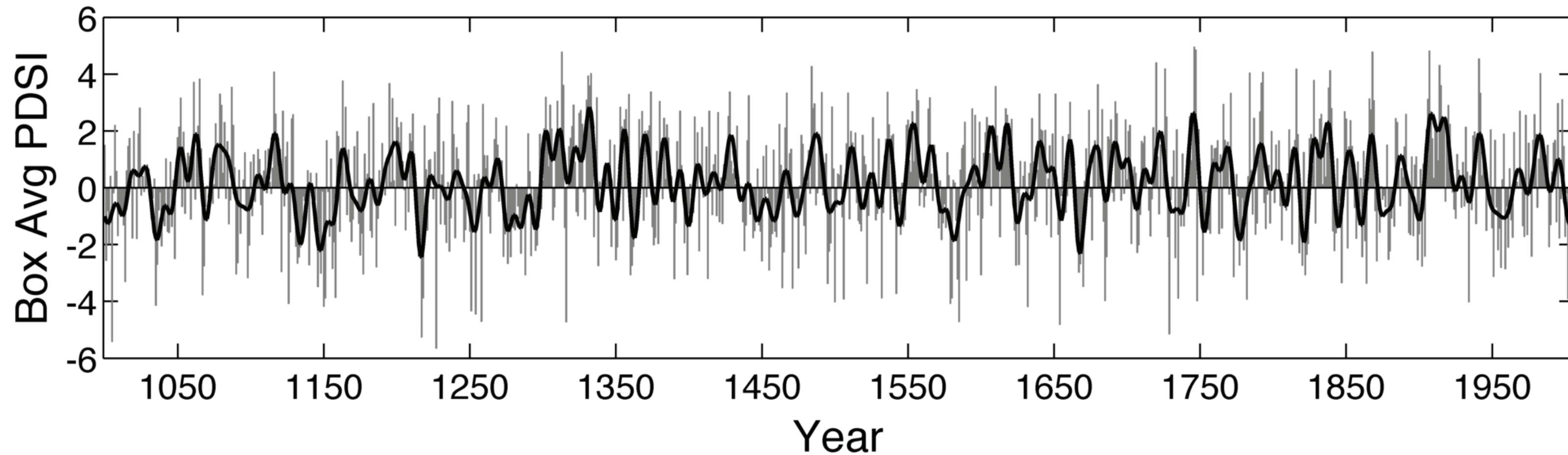
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J. F. GONZÁLEZ-ROUCO

Instituto de Geociencias (UCM-CSIC) Facultad de Ciencias Físicas, Universidad Complutense, Madrid, Spain

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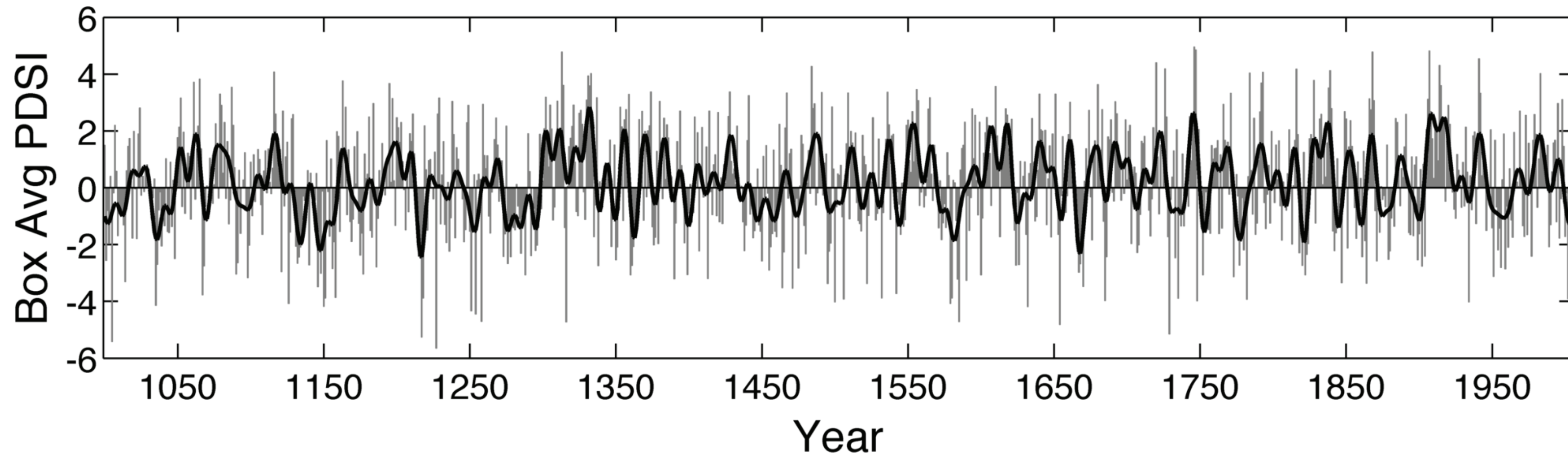
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A case study of megadroughts

RESEARCH ARTICLE

CLIMATOLOGY

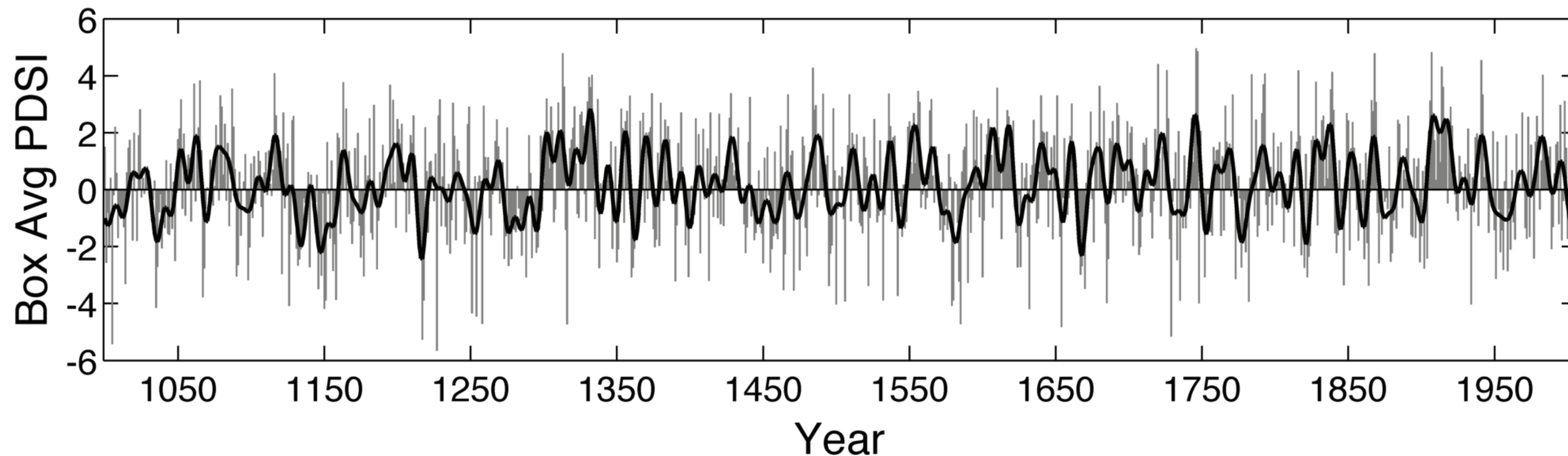
Unprecedented 21st century drought risk American Southwest and Central Plains

Benjamin I. Cook,^{1,2*} Toby R. Ault,³ Jason E. Smerdon²

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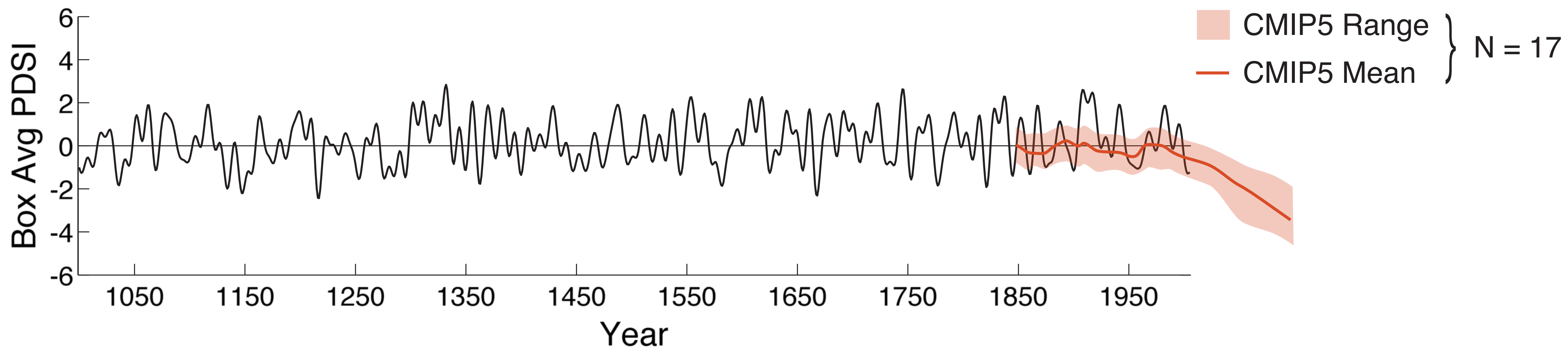
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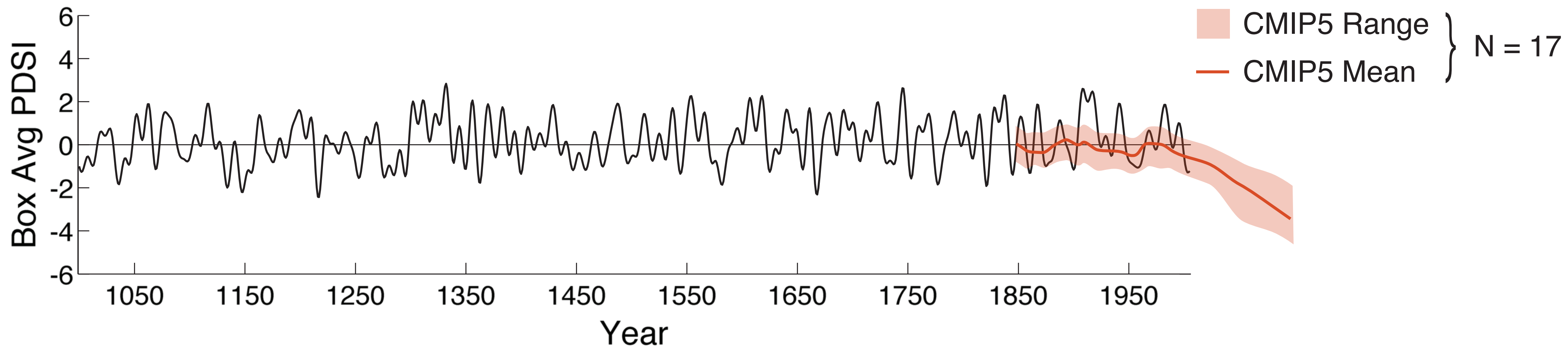
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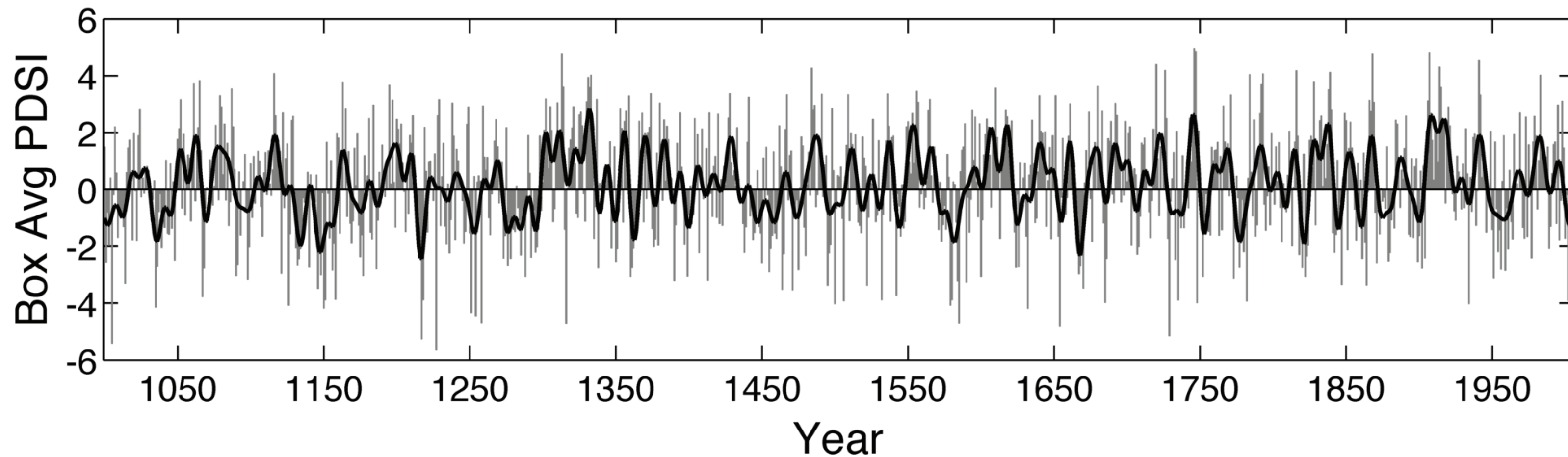
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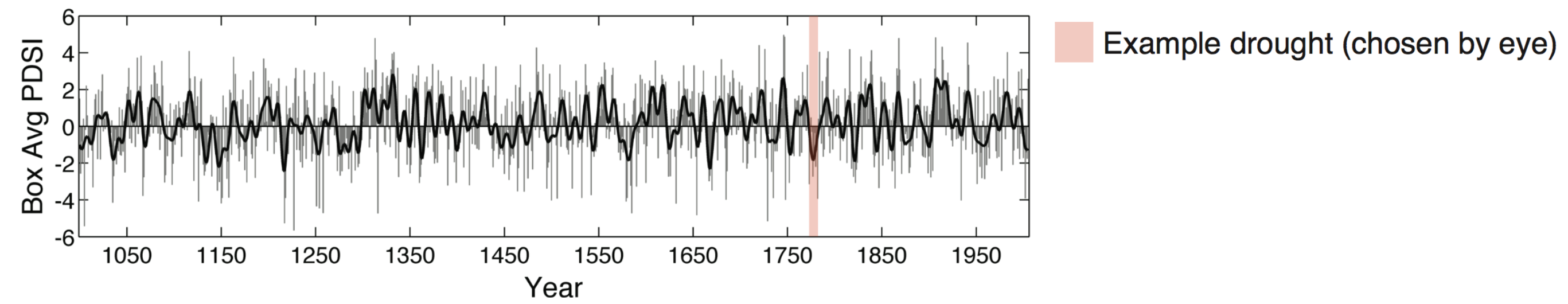
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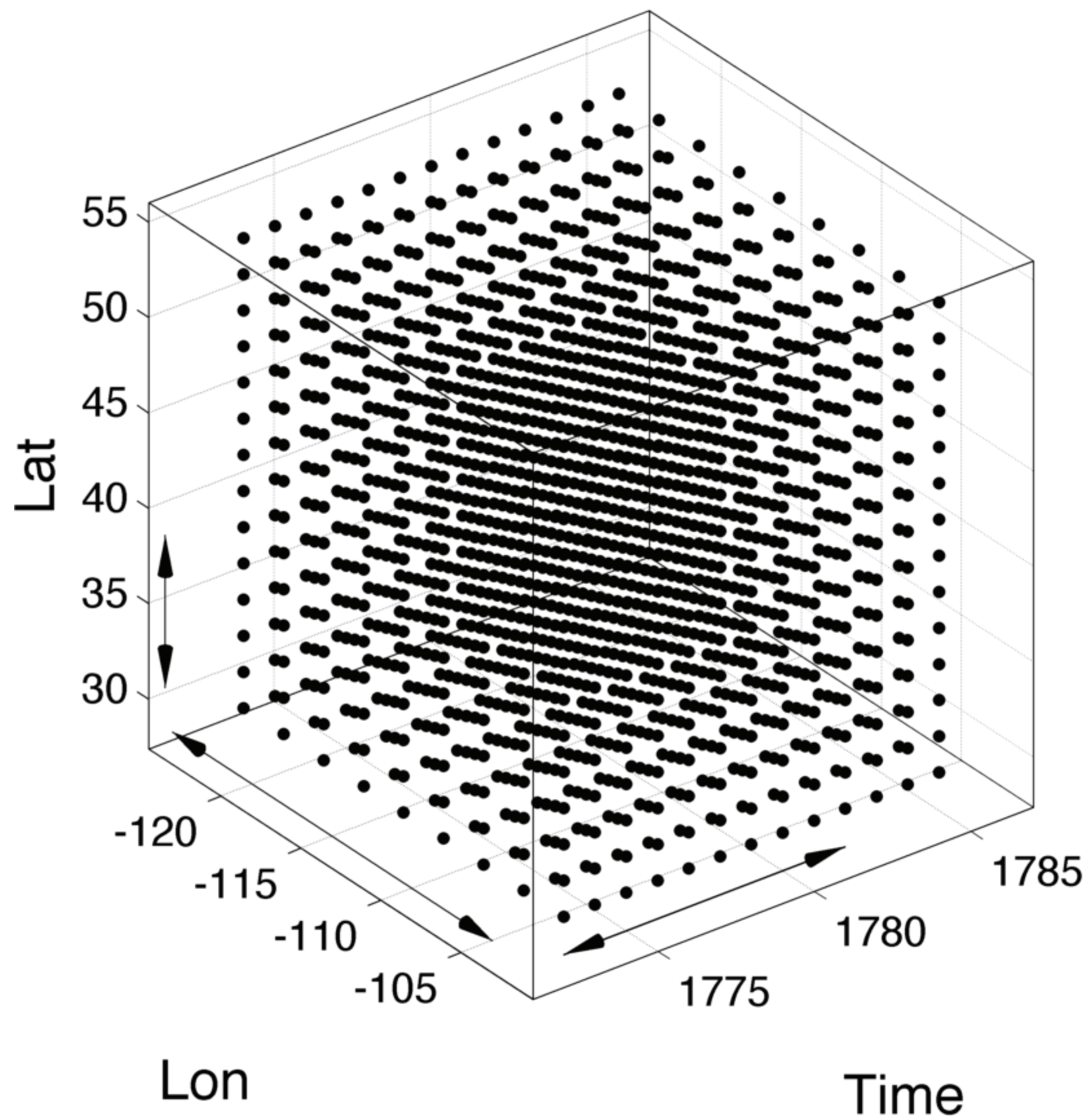


Identify (and characterize) droughts in 3D

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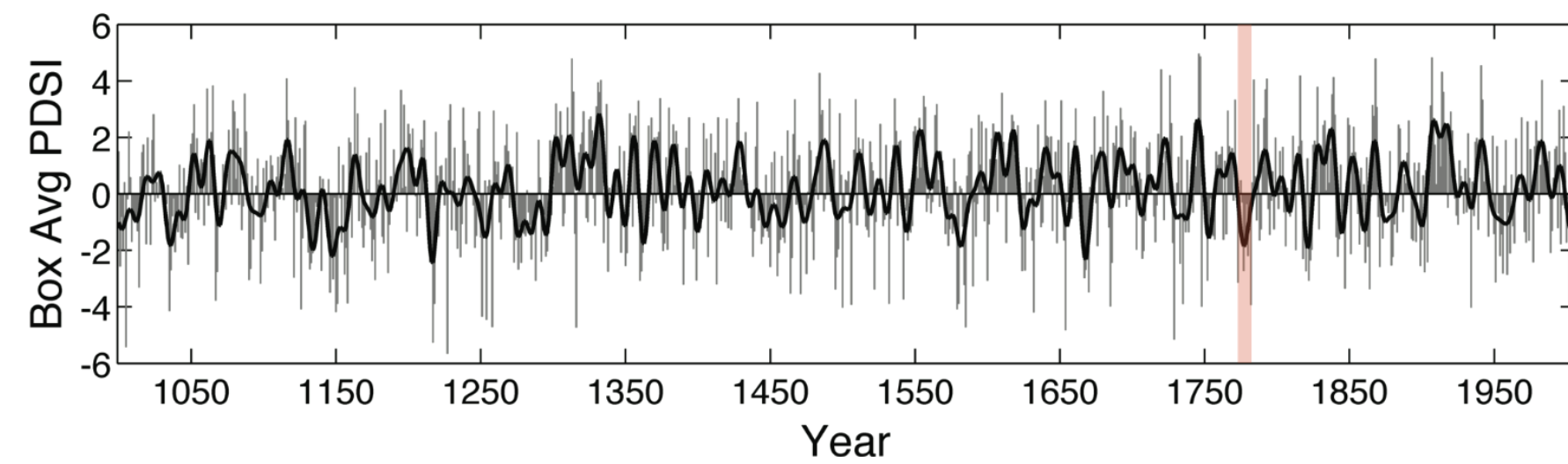


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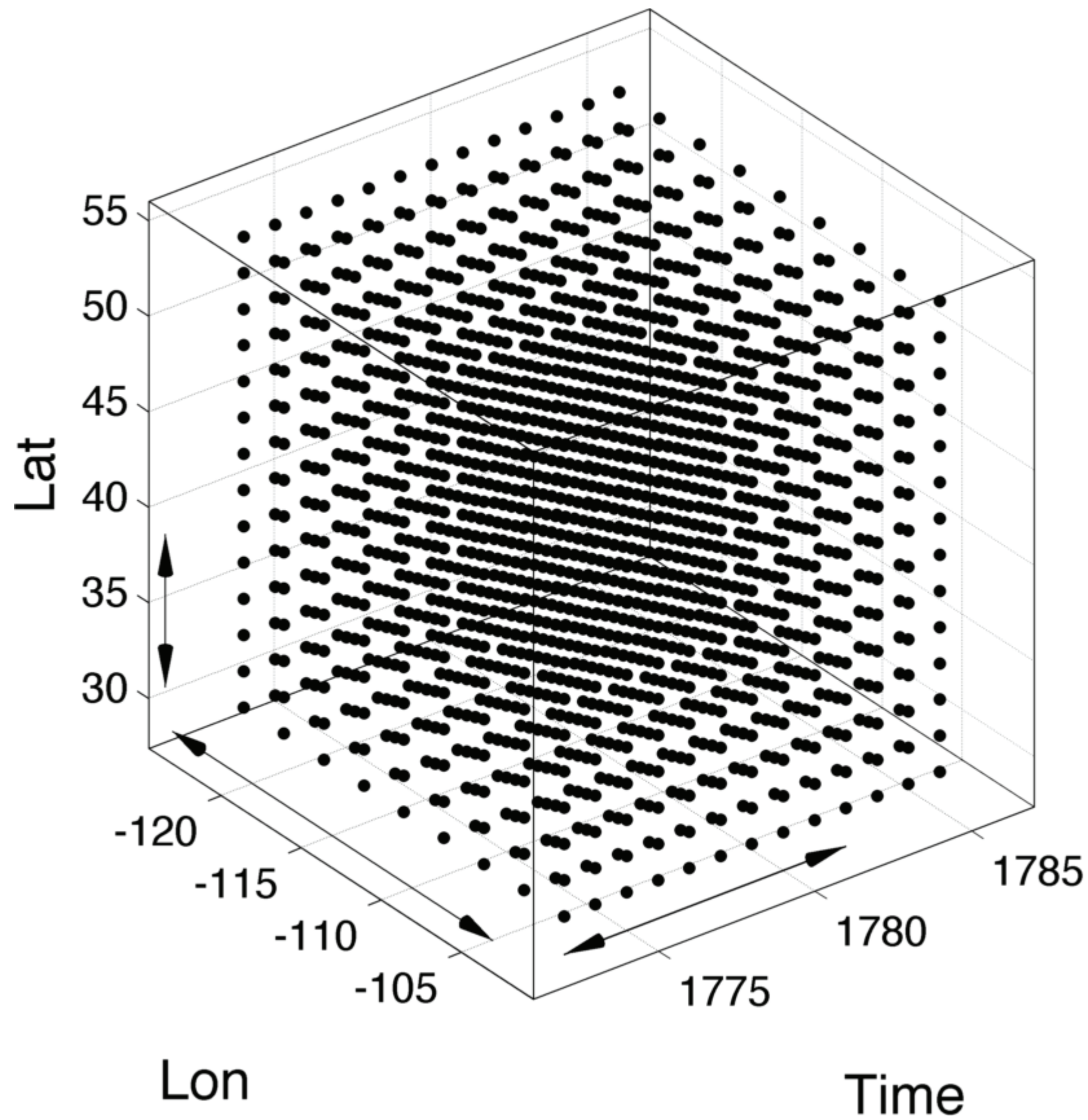
● space-time grid point

↕ spatial bounds of SW and temporal length of drought



Example drought (chosen by eye)

Identify (and characterize) droughts in 3D

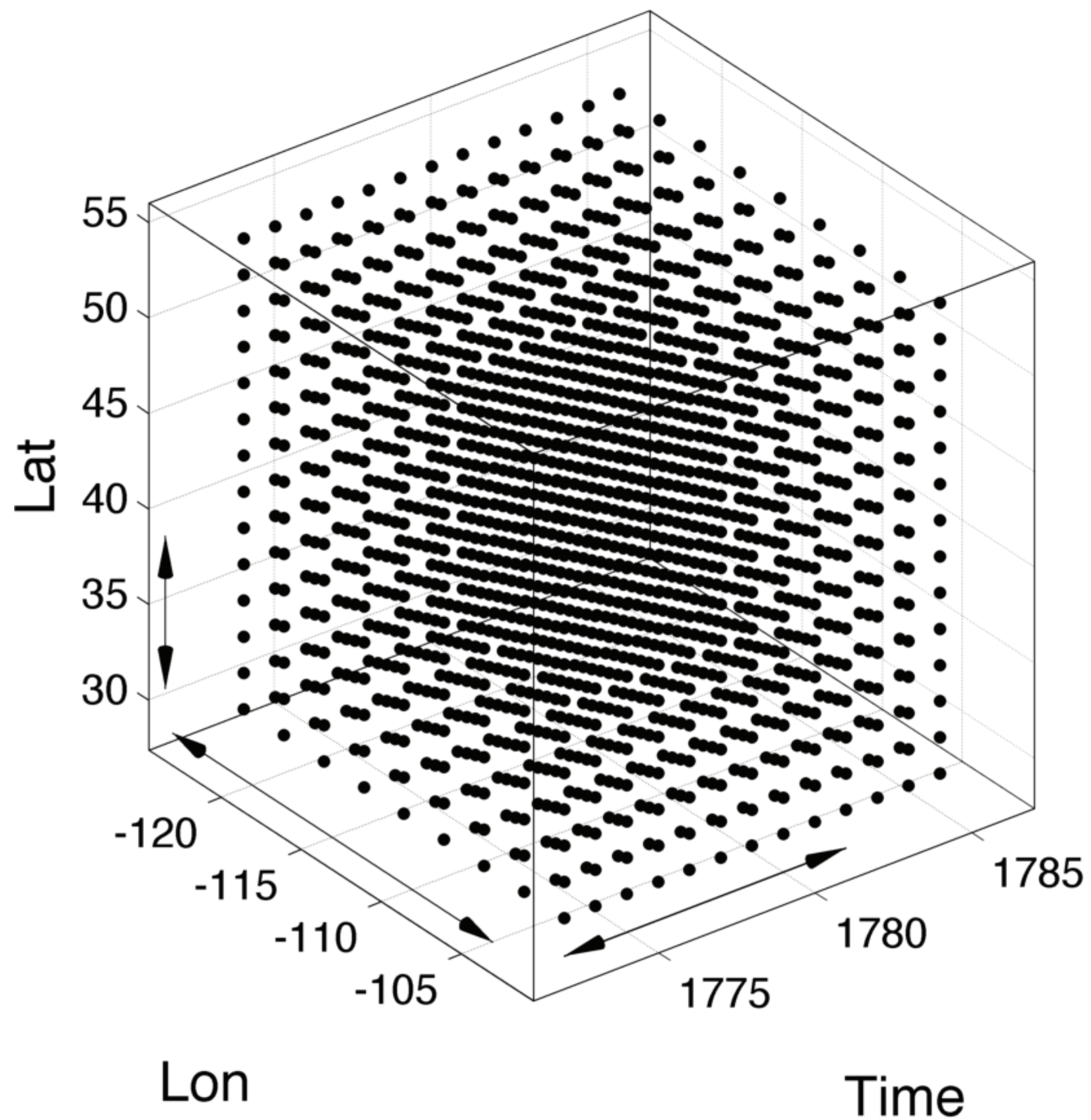


Assign to each space-time grid point a 1 (drought) or 0 (normal state)

● space-time grid point

▼ spatial bounds of SW and temporal length of drought

Identify (and characterize) droughts in 3D

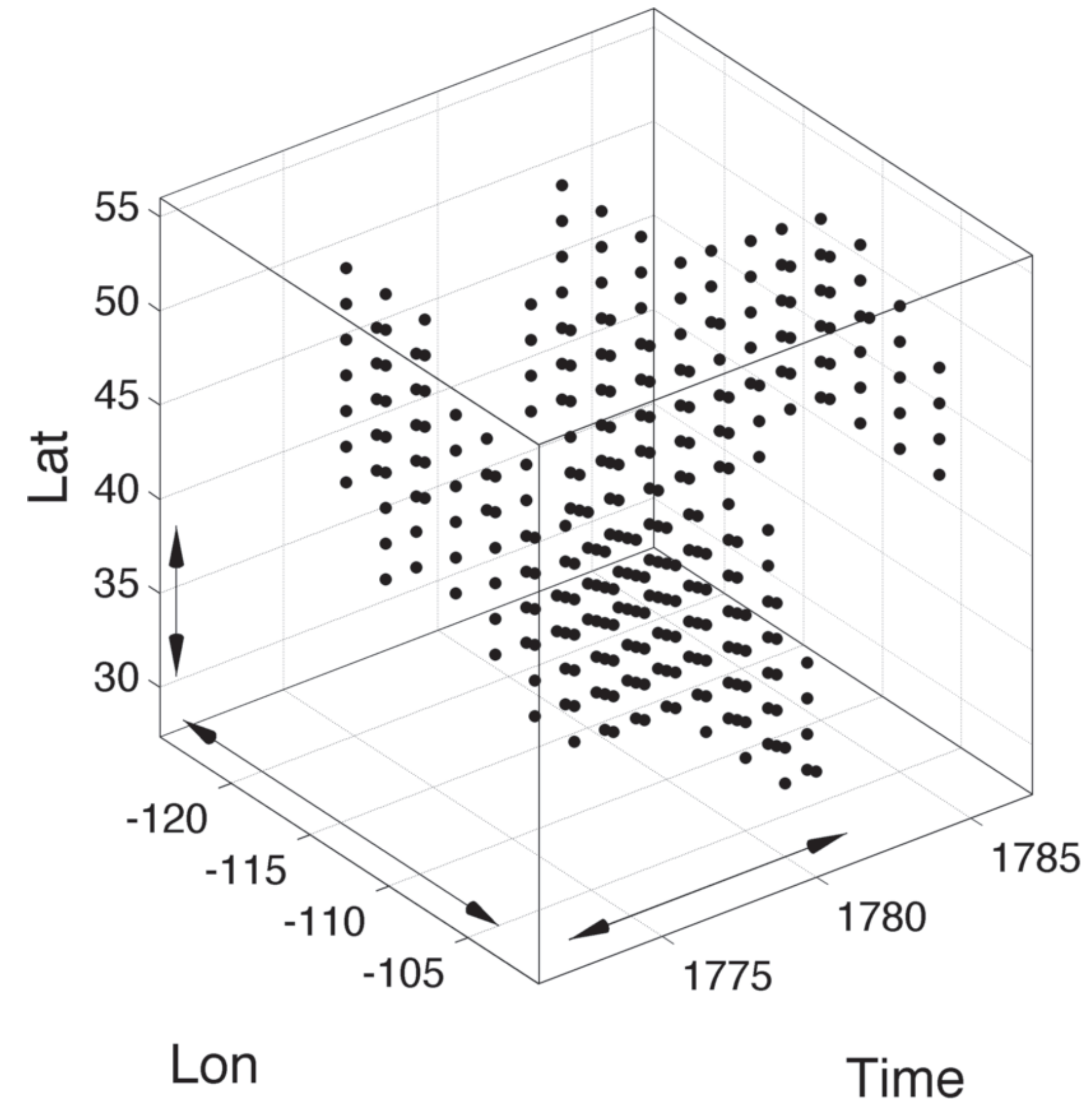


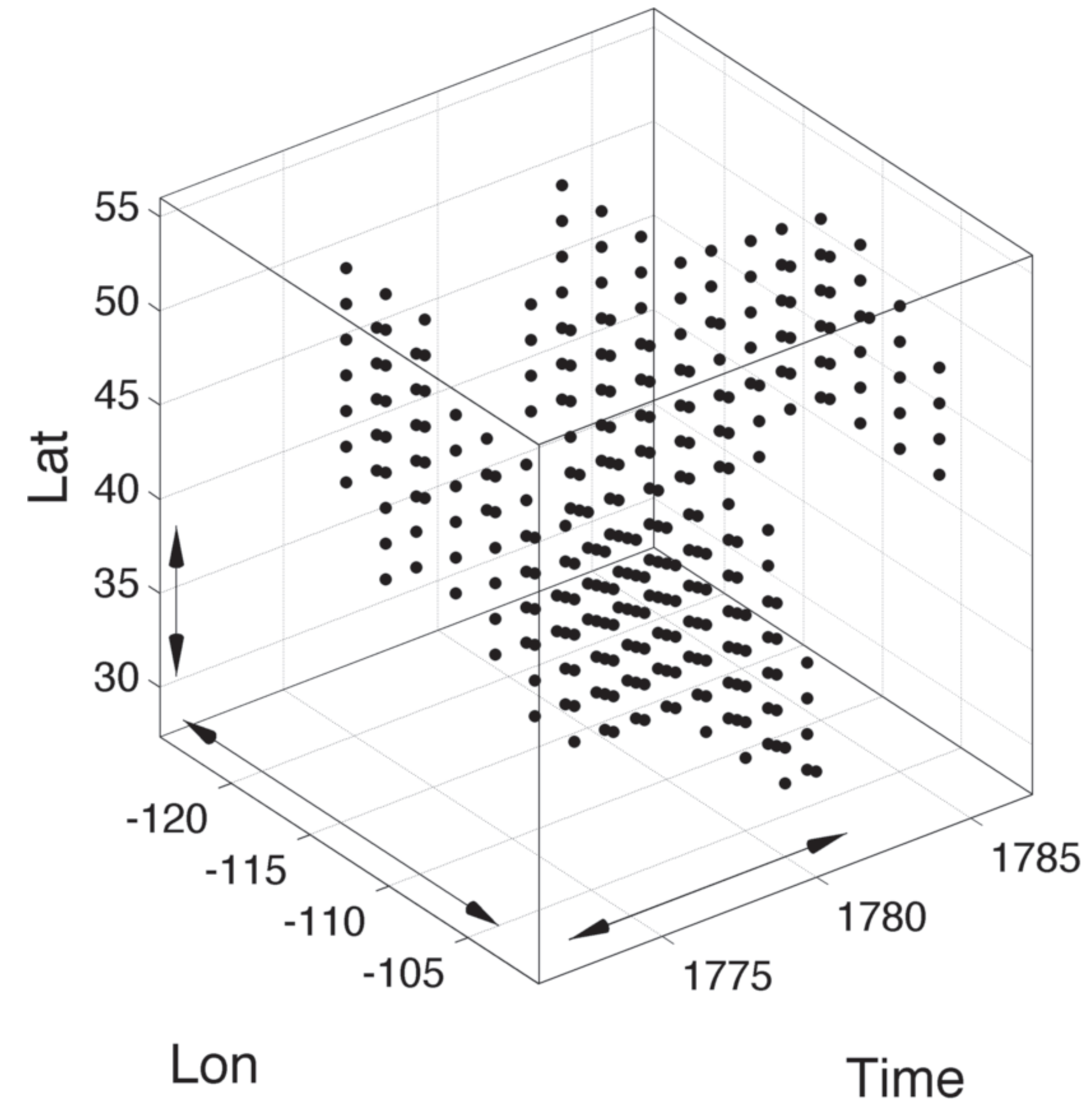
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Finding the most likely configuration of a binary Markov Random Field (MRF)

● space-time grid point

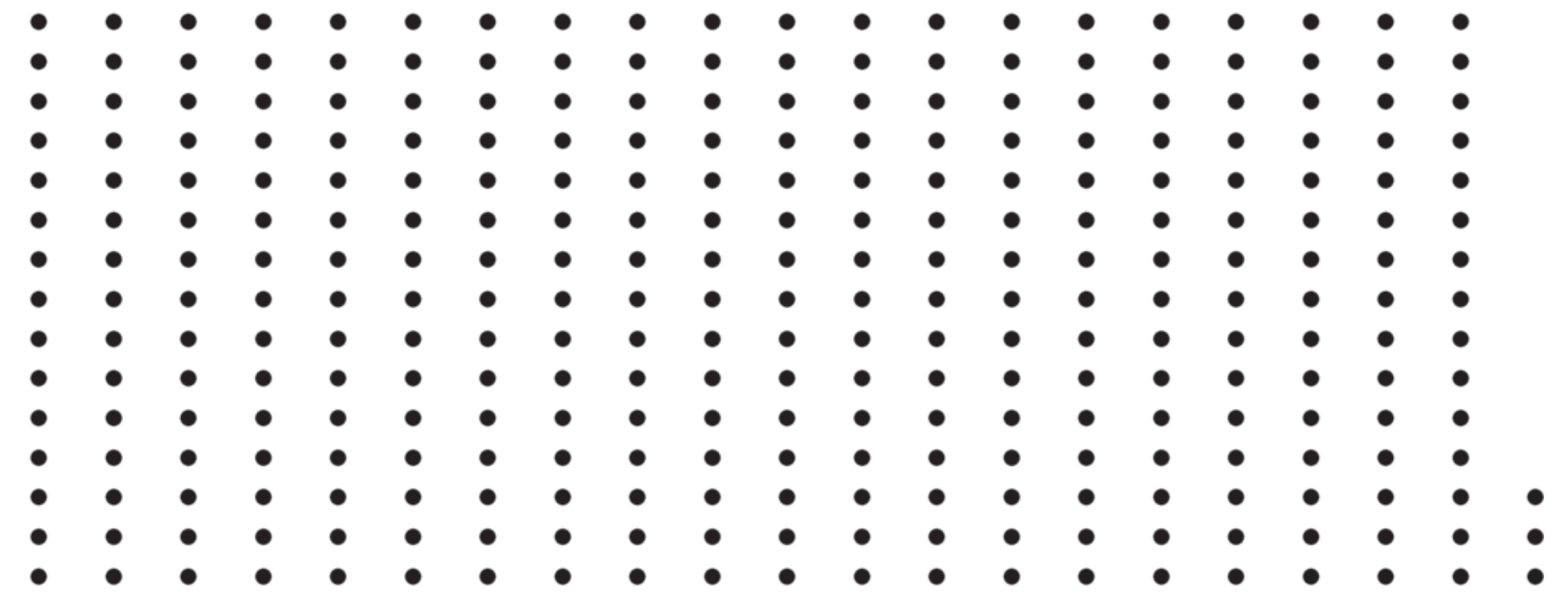
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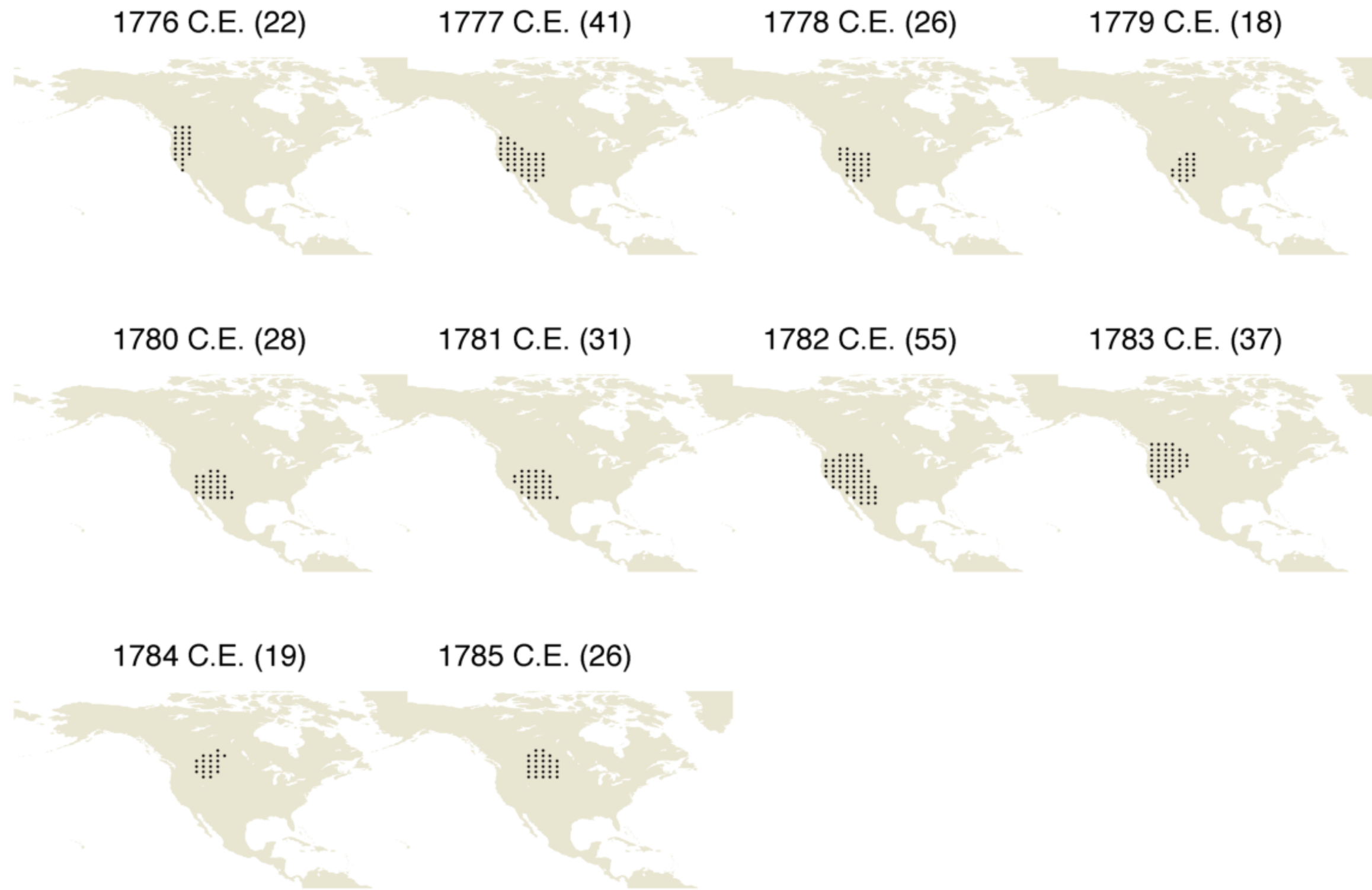
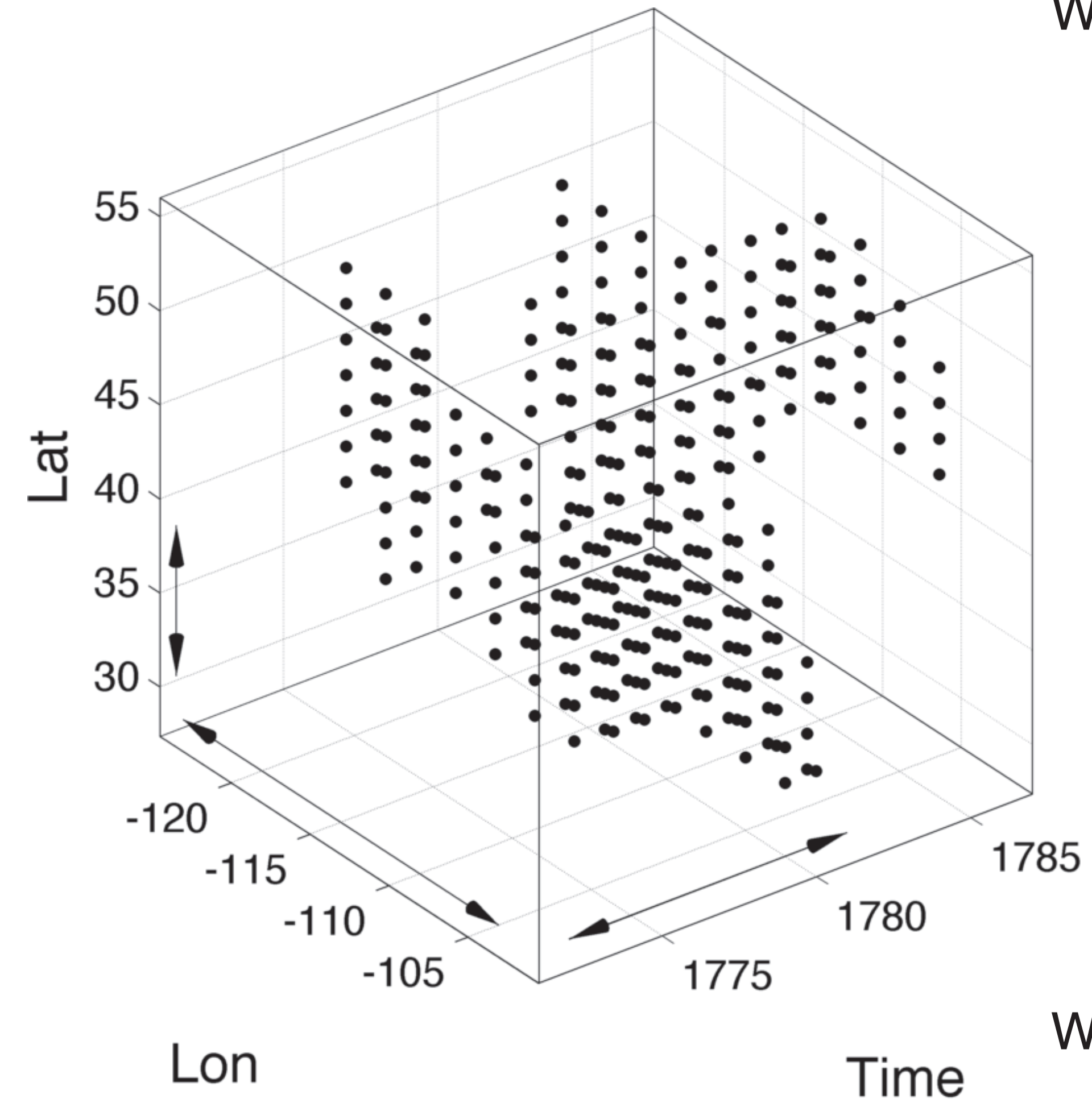


Unwrap

Size = total # grid points = 303

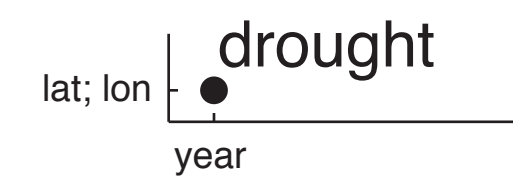
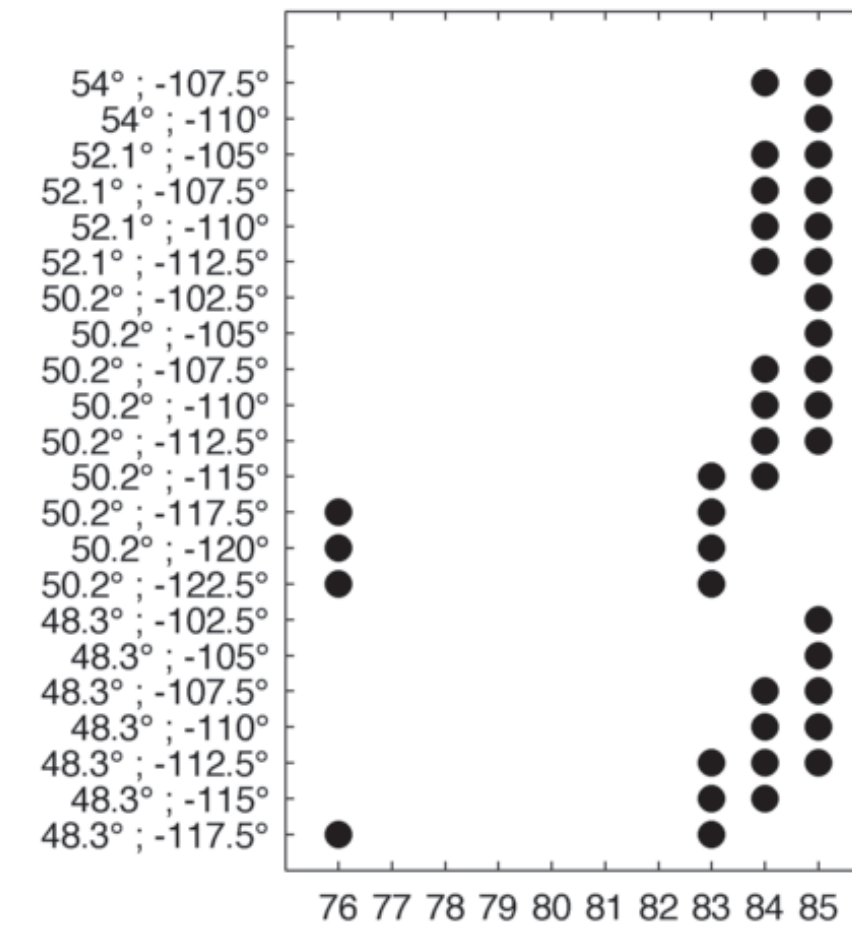
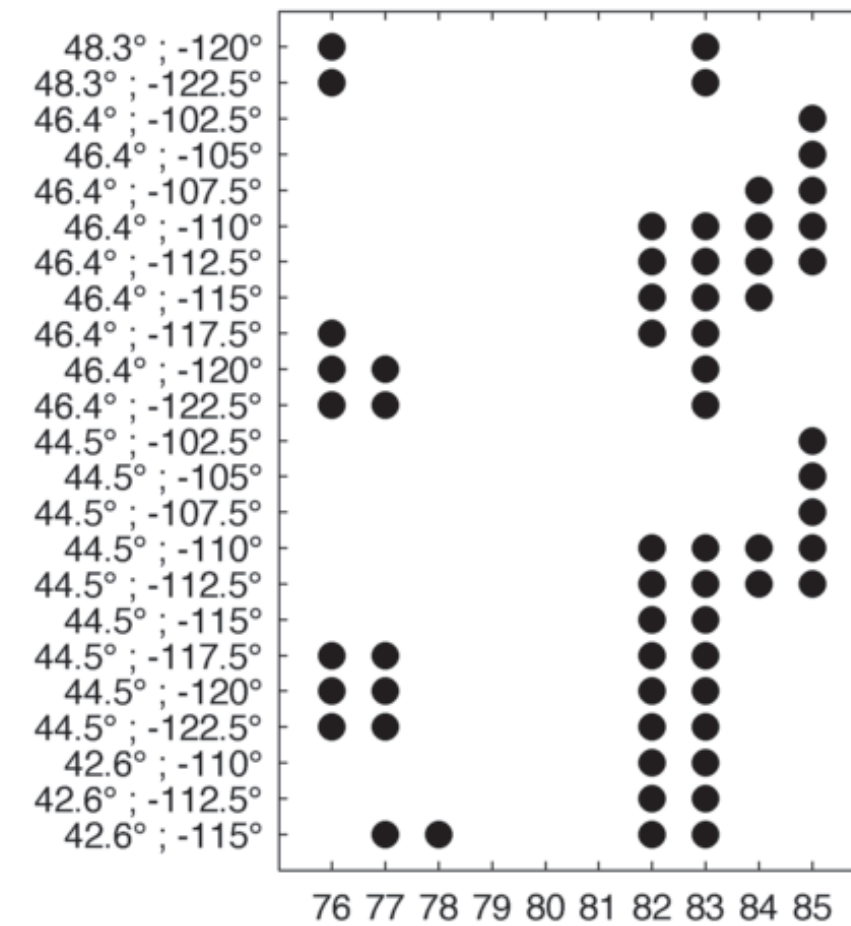
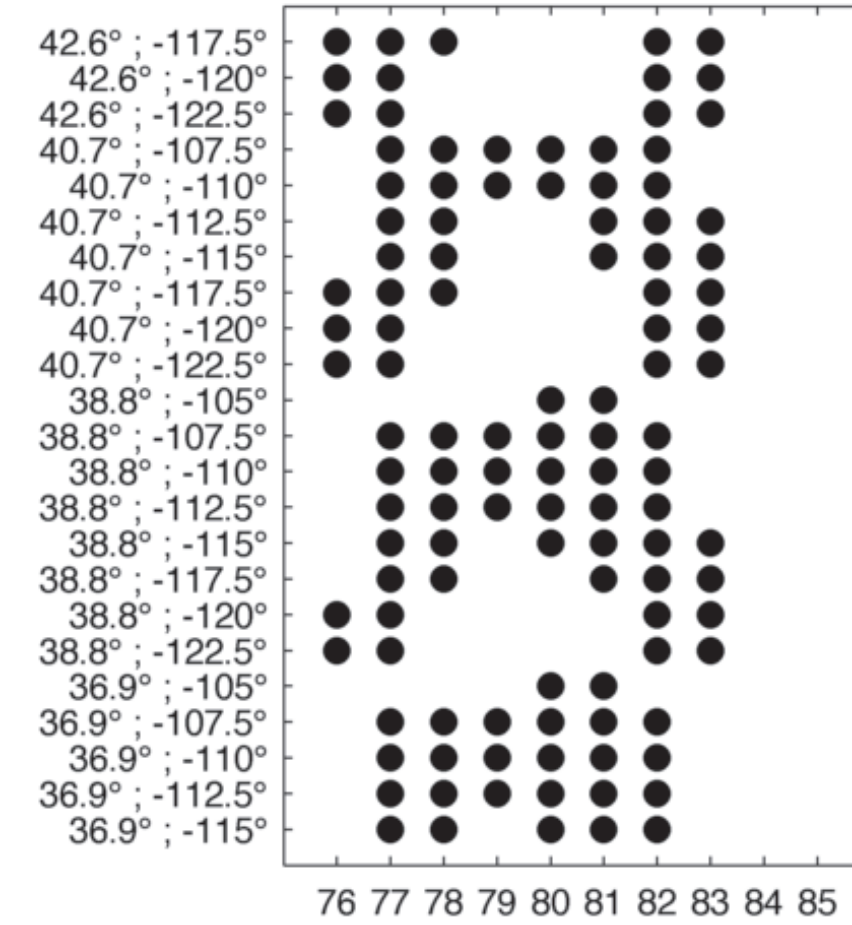
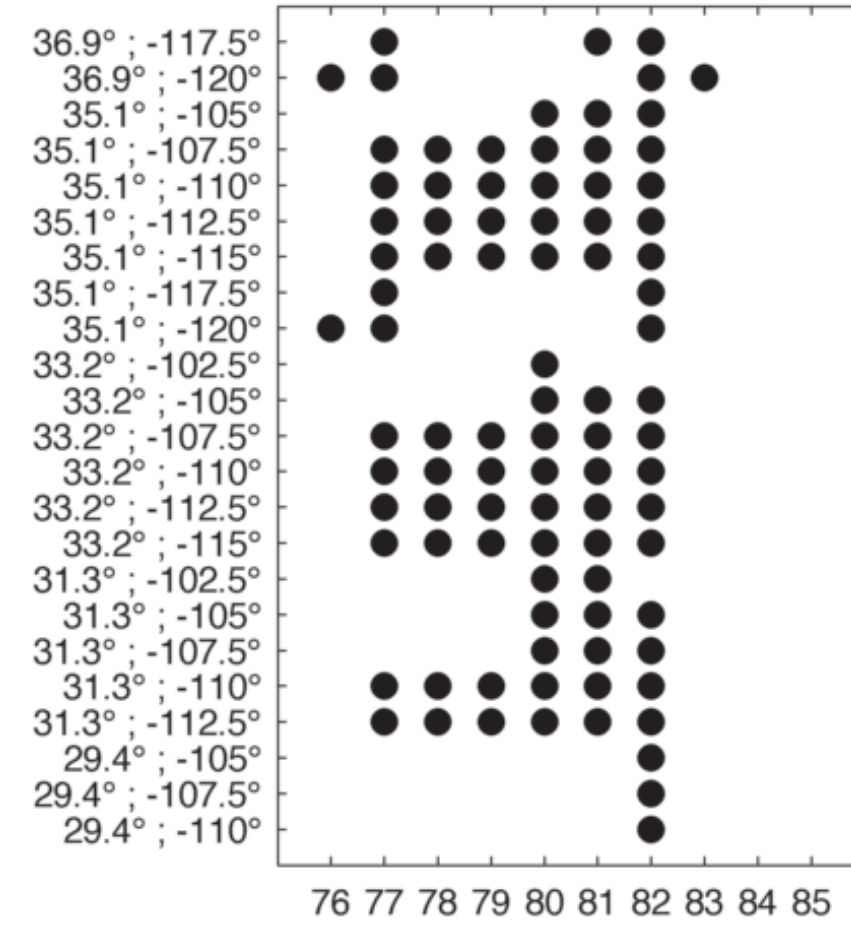
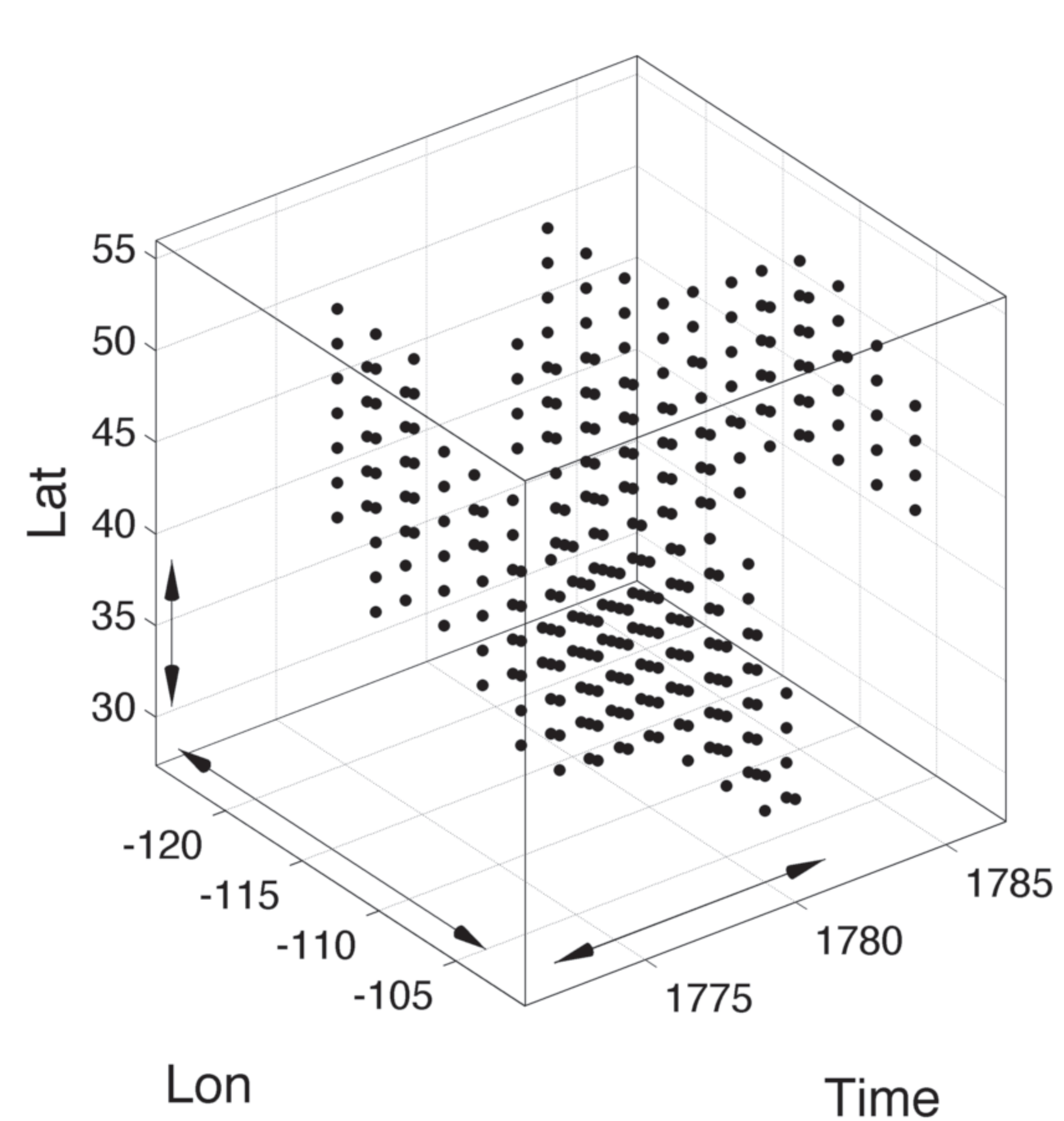


Width = max # of spatial grid points in any year of drought = 55

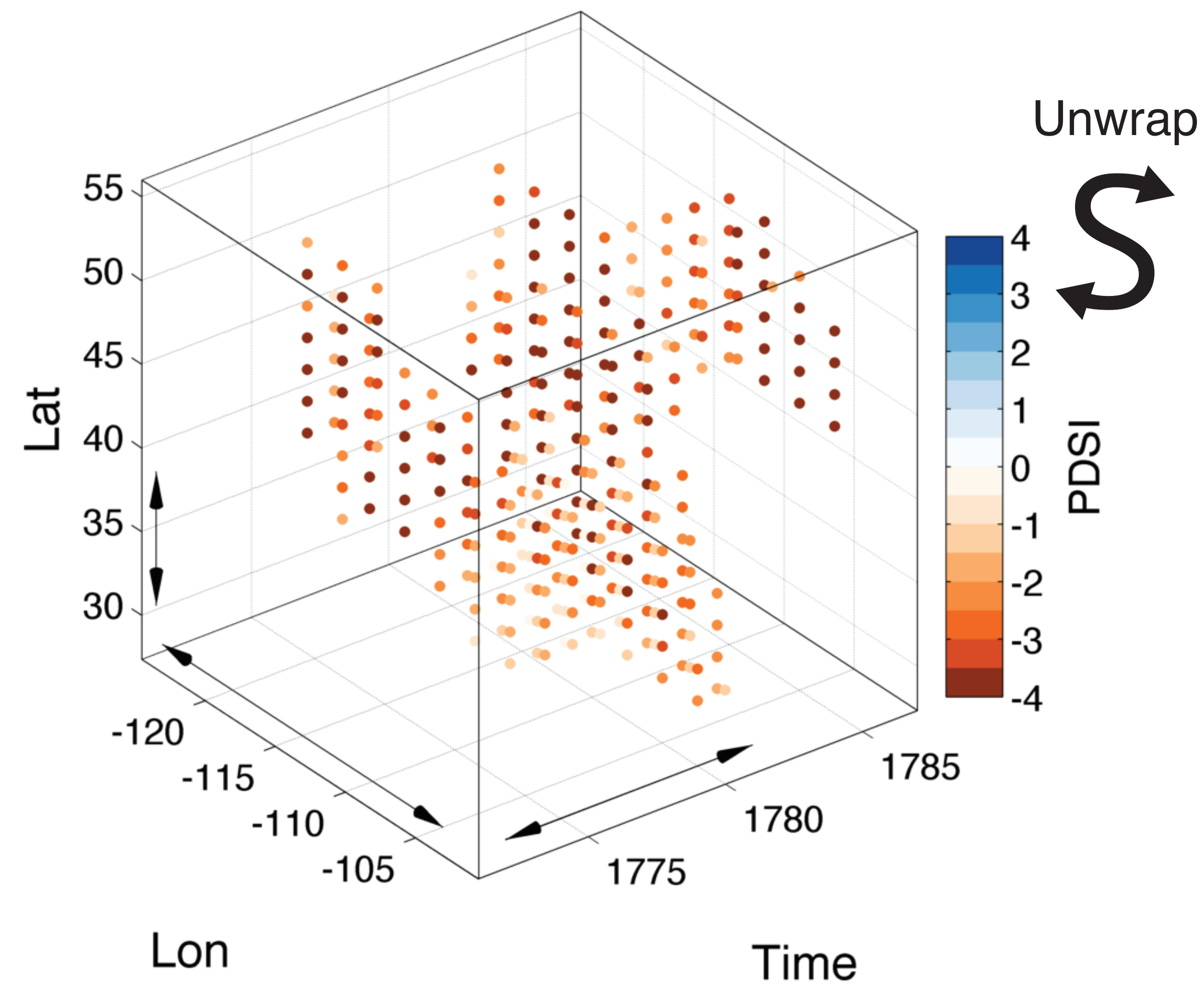


Width = max(22, 41, 26, 18, 28, 31, 55, 37, 19, 26) = 55

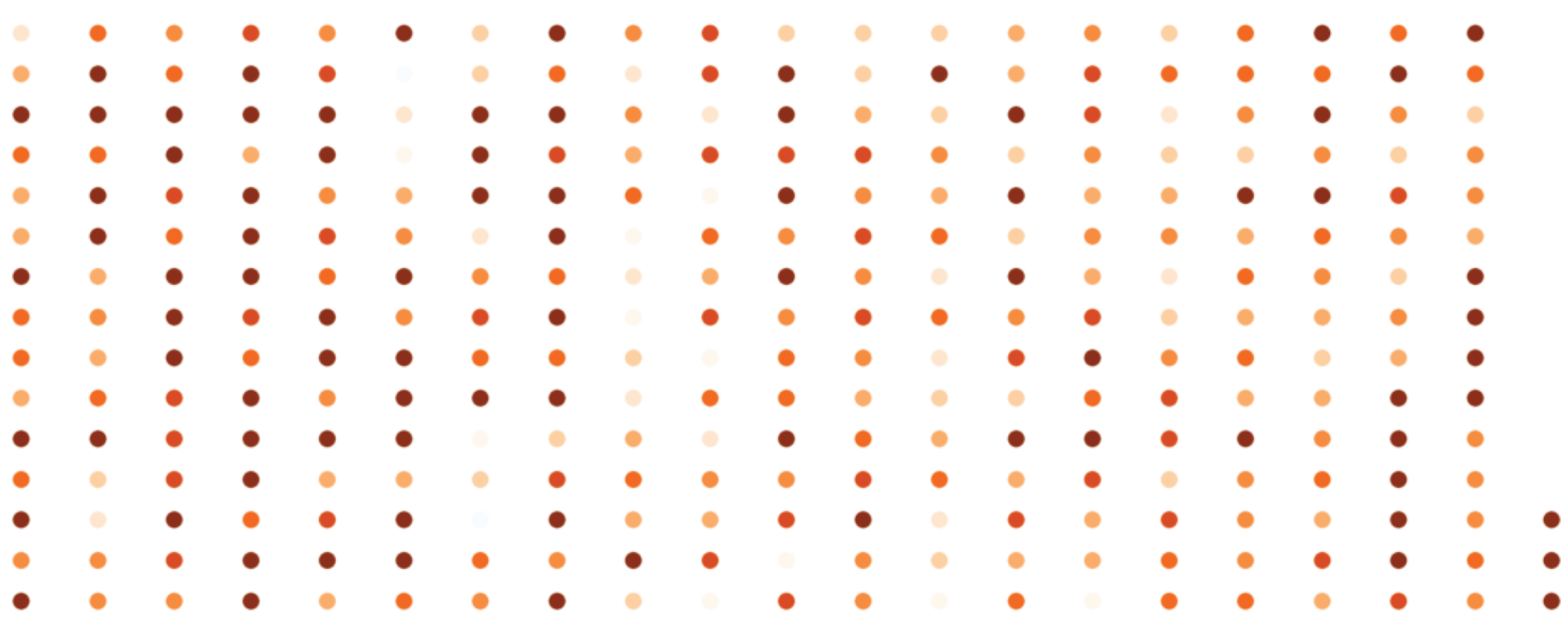
Length = max # of years that any spatial grid point is in drought = 6



Length = max(1, 1, 1, 6, 6, 3, 3, 2, 6, 6, 6, 6, 3, 1, 3, 2, 6, 6, 2, 3, 5, 6, 6, 6, 2, 4, 4, 5, 6, 6, 6, 6, 2, 4, 4, 5, 5, 5, 6, 6, 1, 4, 5, 4, 2, 2, 4, 4, 4, 2, 4, 4, 1, 1, 1, 3, 3, 3, 3, 4, 4, 2, 2, 1, 2, 2, 2, 2, 3, 2, 2, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 1, 1, 2, 2) = 6



Severity = sum(grid point PDSI) = -868.5



Up to now just shown one drought over NADA

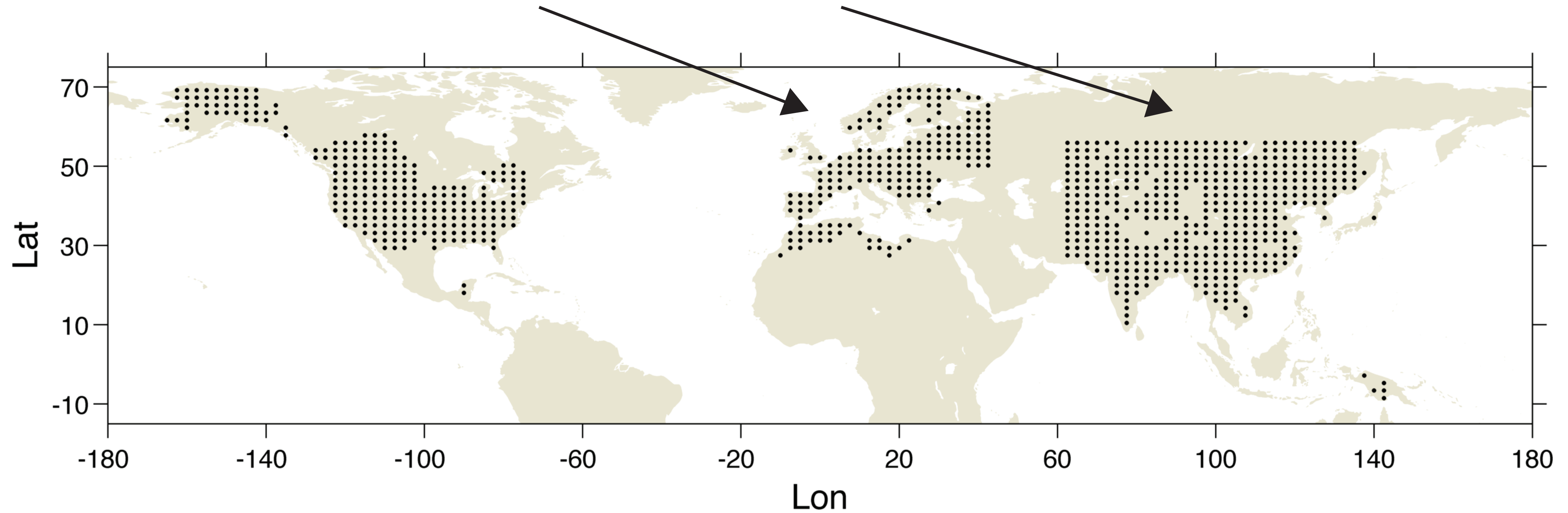
Up to now just shown one drought over NADA

-Calculate from 1000-2000 C.E.

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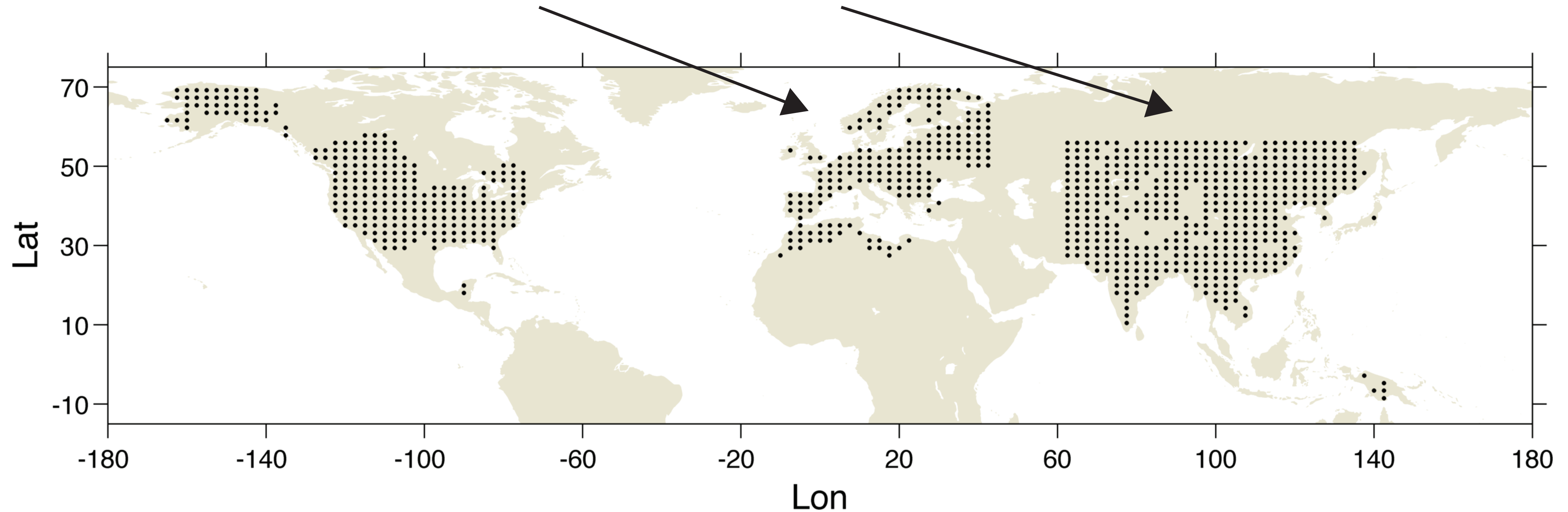
-Also calculate for the OWDA and MADA



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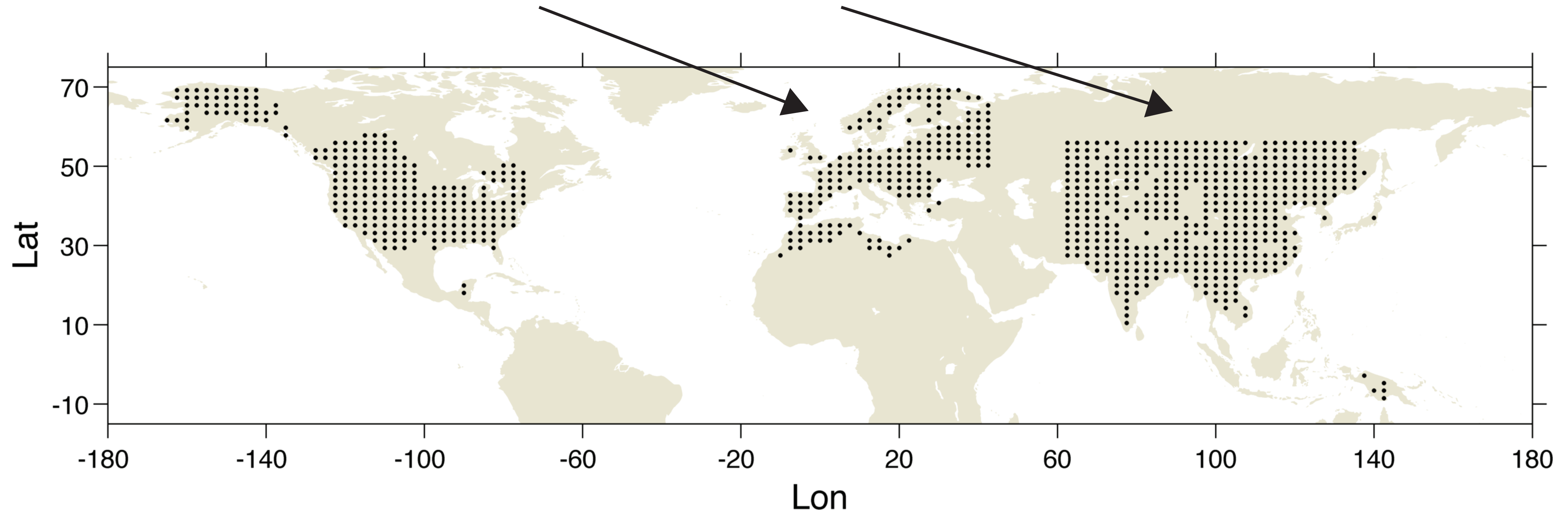


-Same grid and time period 4 CESM, 1 CCSM and 1 IPSL simulations

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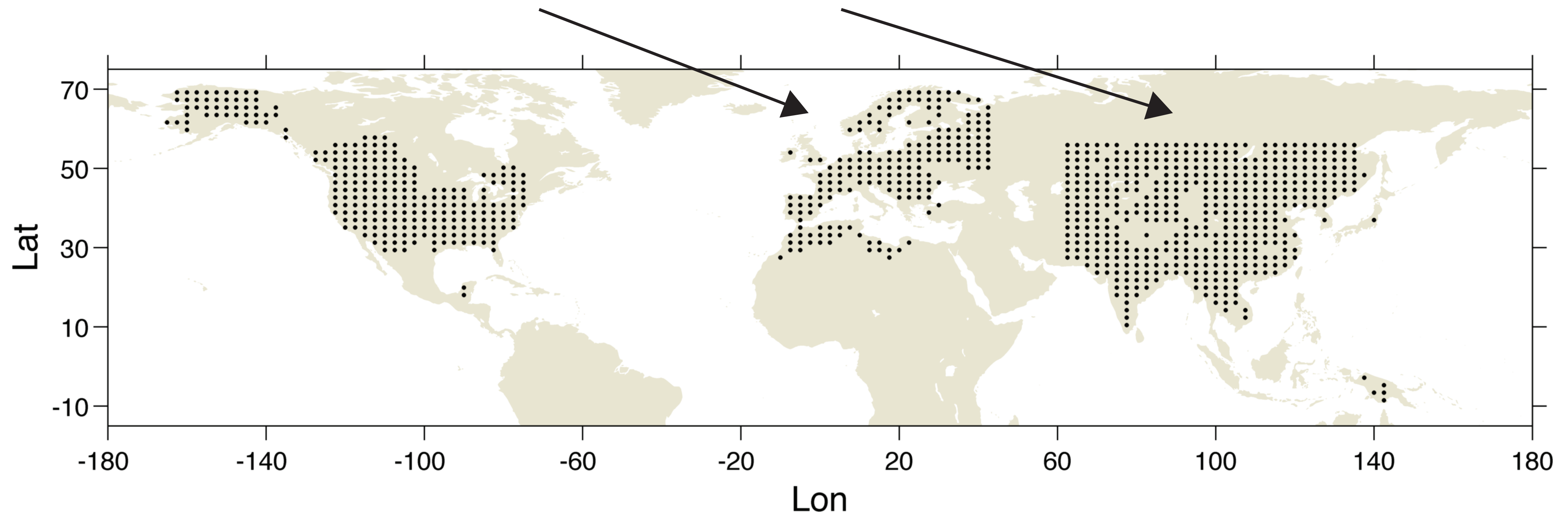
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-Same grid through 2100 C.E. use 32 CMIP5 simulations

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-Analyze megadrought characteristics in past:

paleoclimate record
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Top ten most severe = megadroughts

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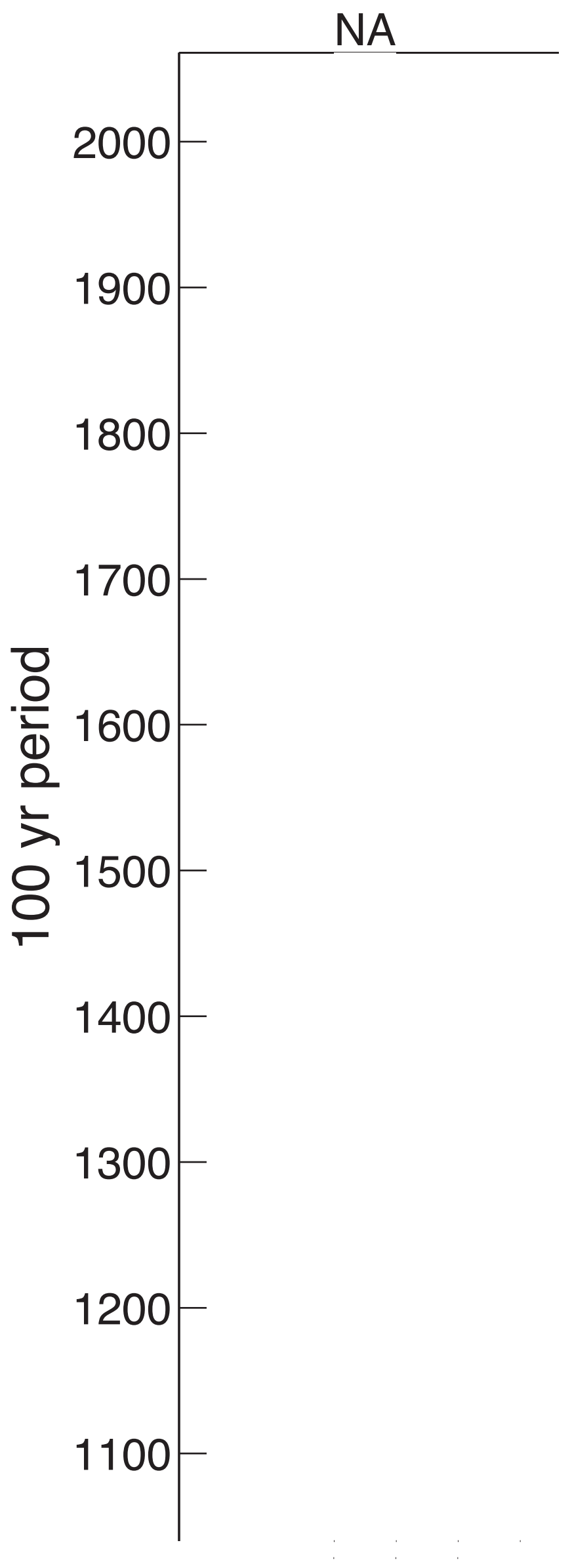
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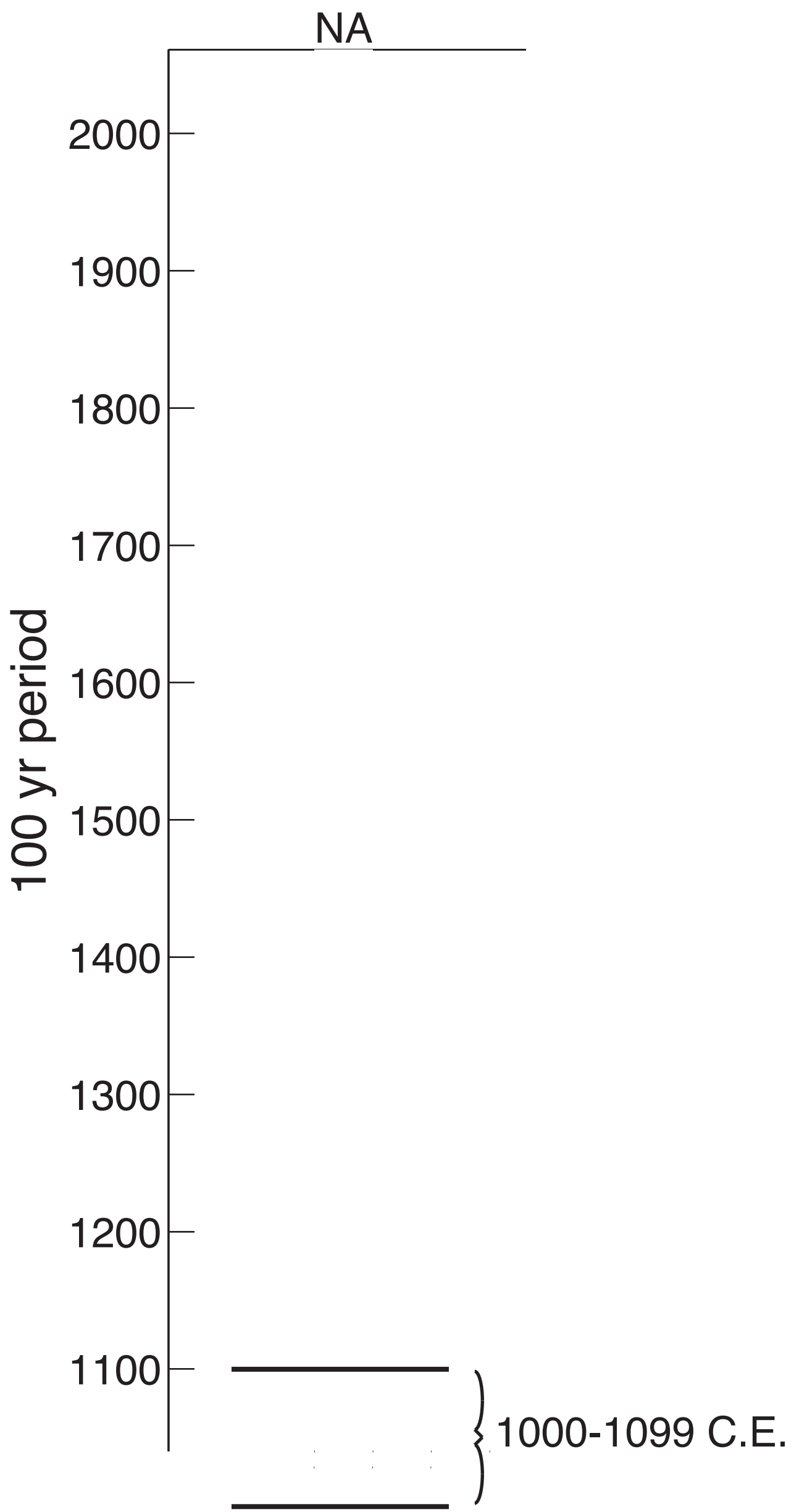
-How do megadrought characteristics change in the future?

Megadroughts for every 100-yr period

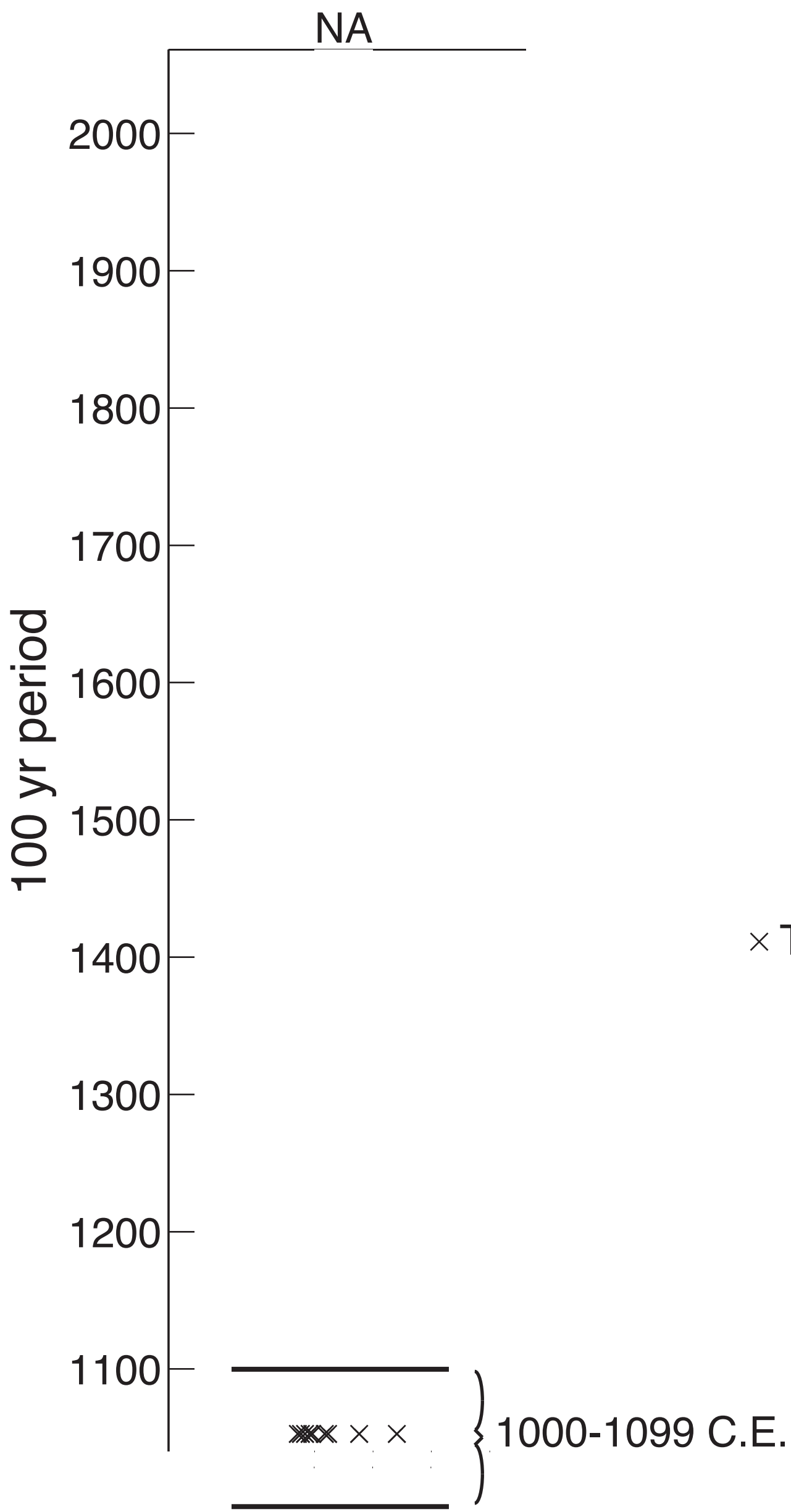
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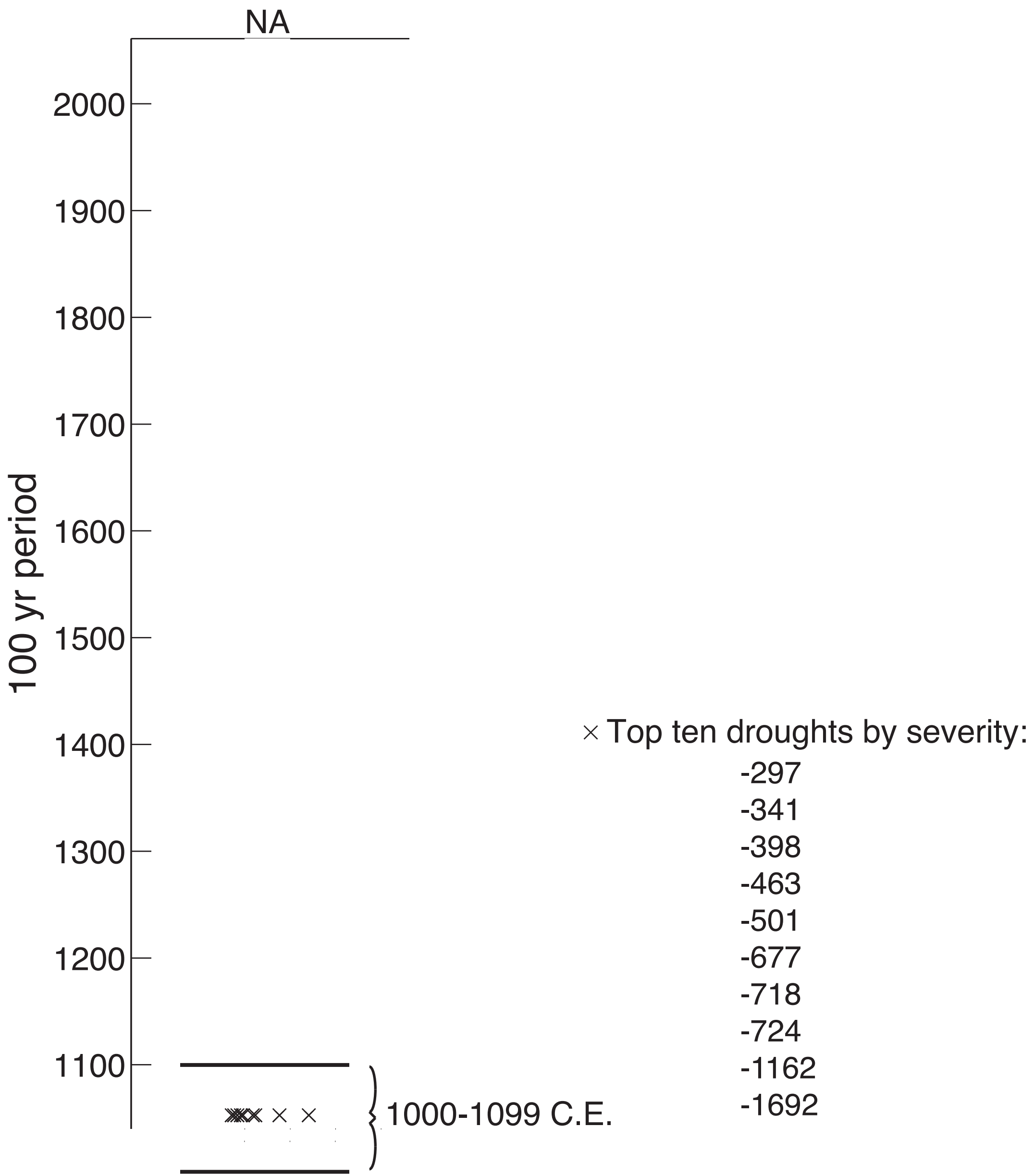
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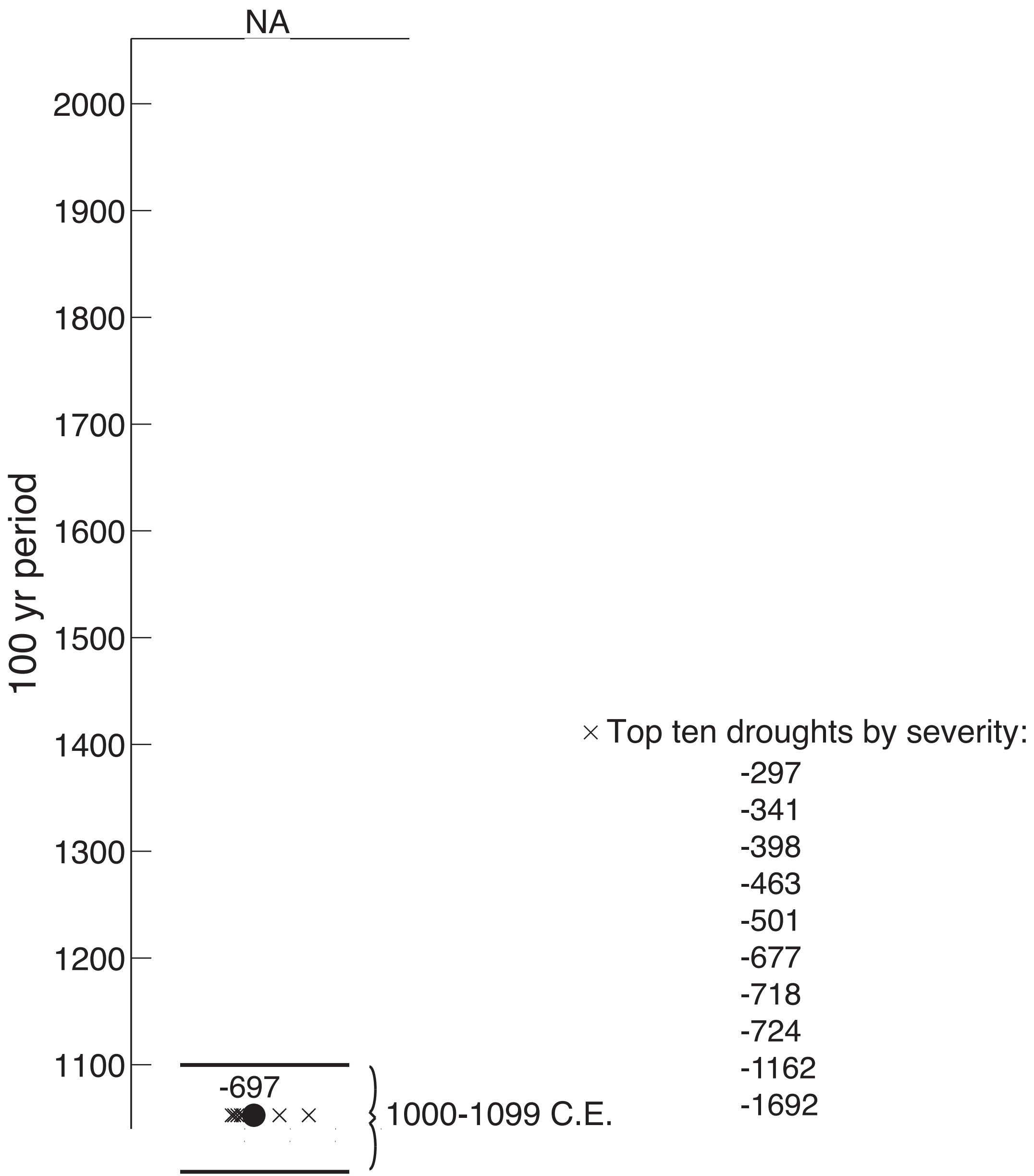
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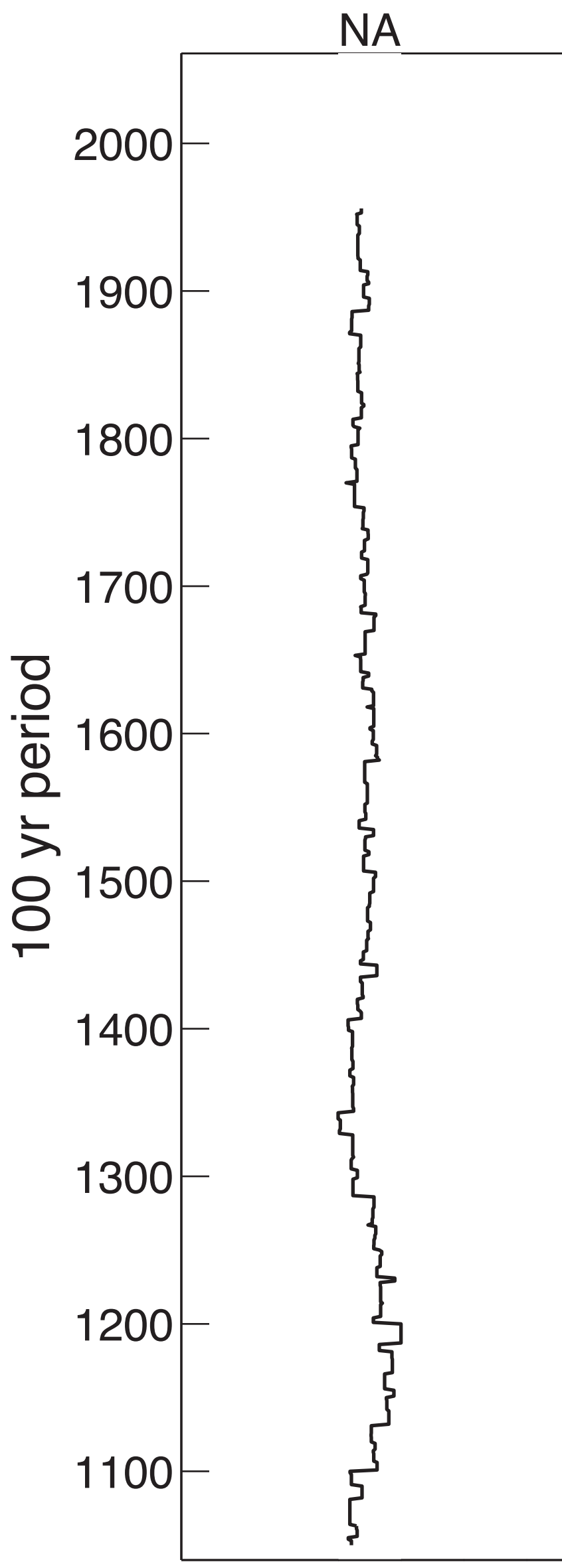
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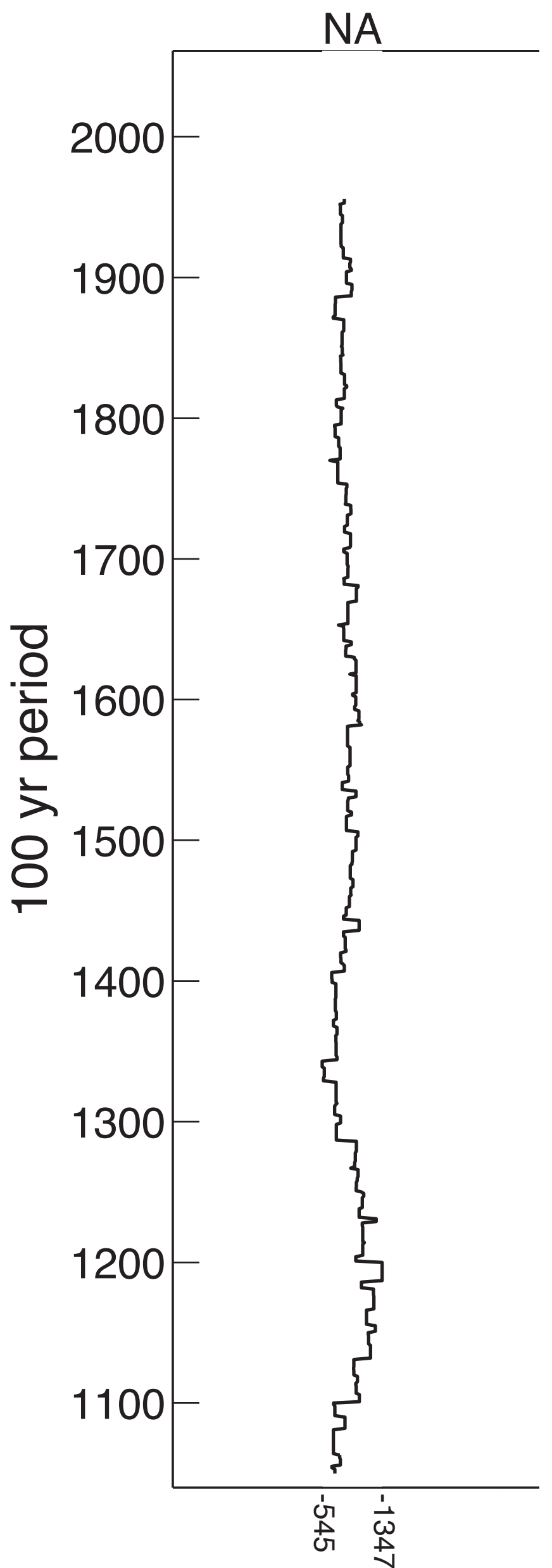


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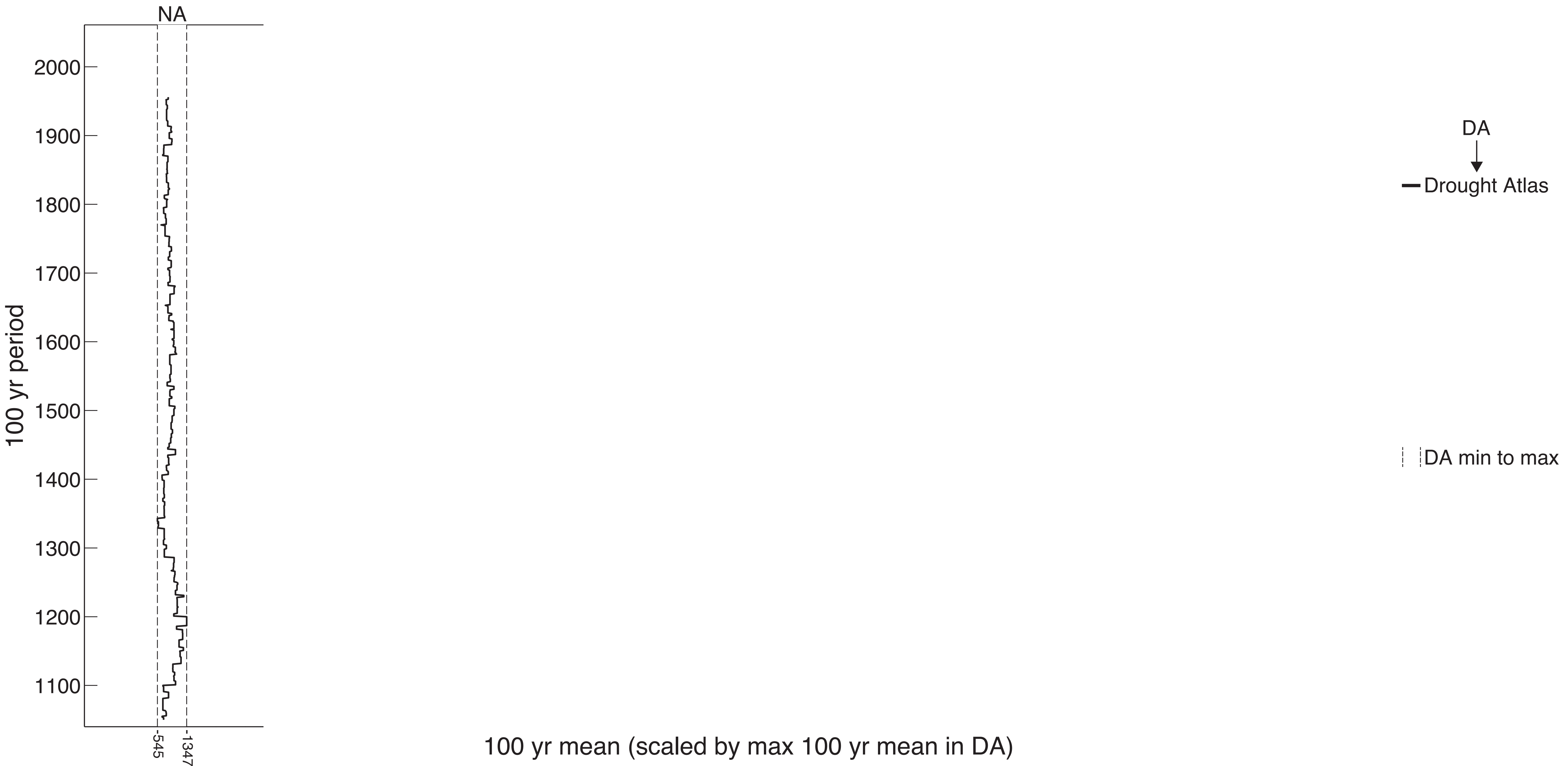
DA
↓
— Drought Atlas

Megadroughts for every 100-yr period

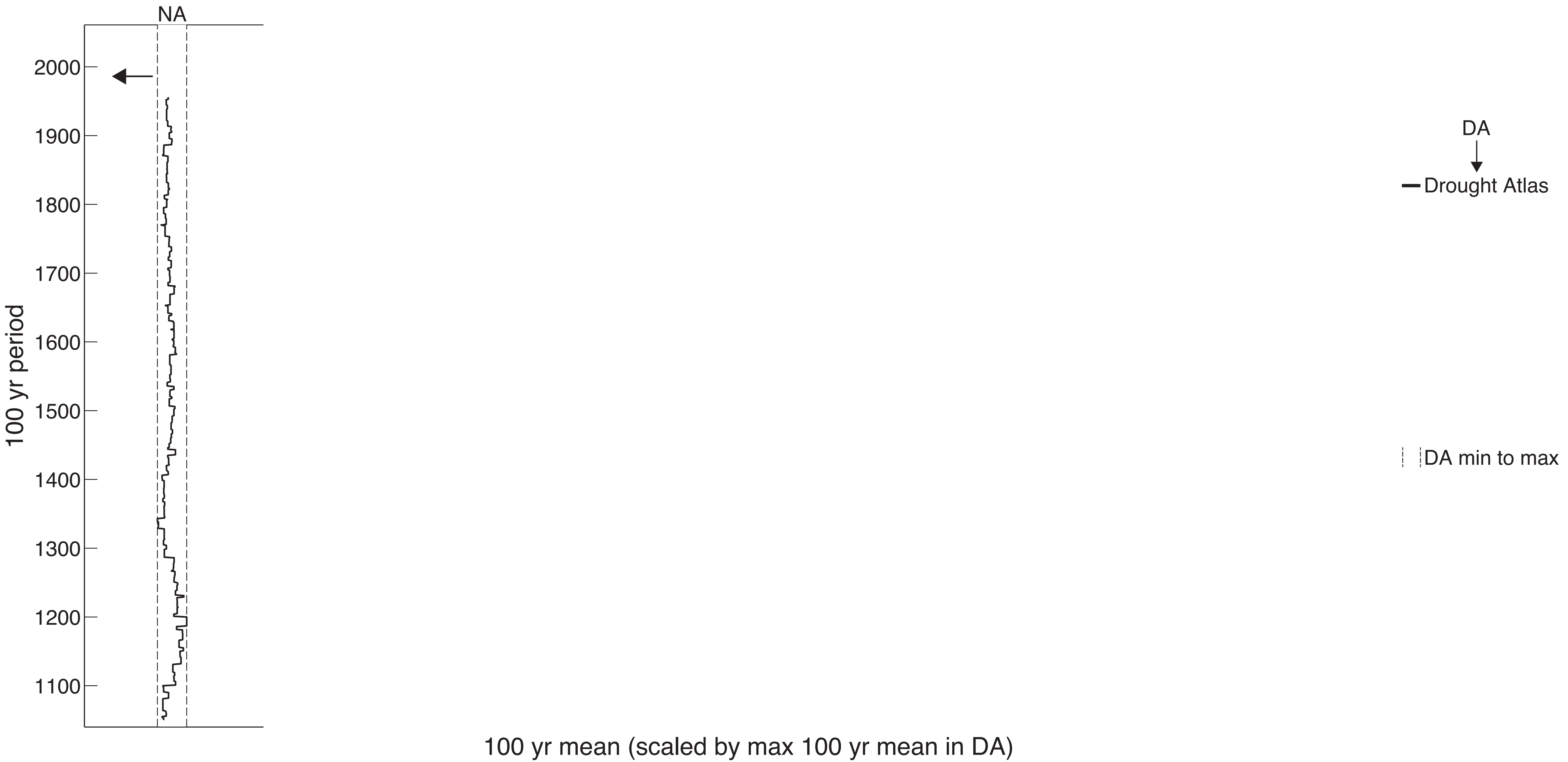


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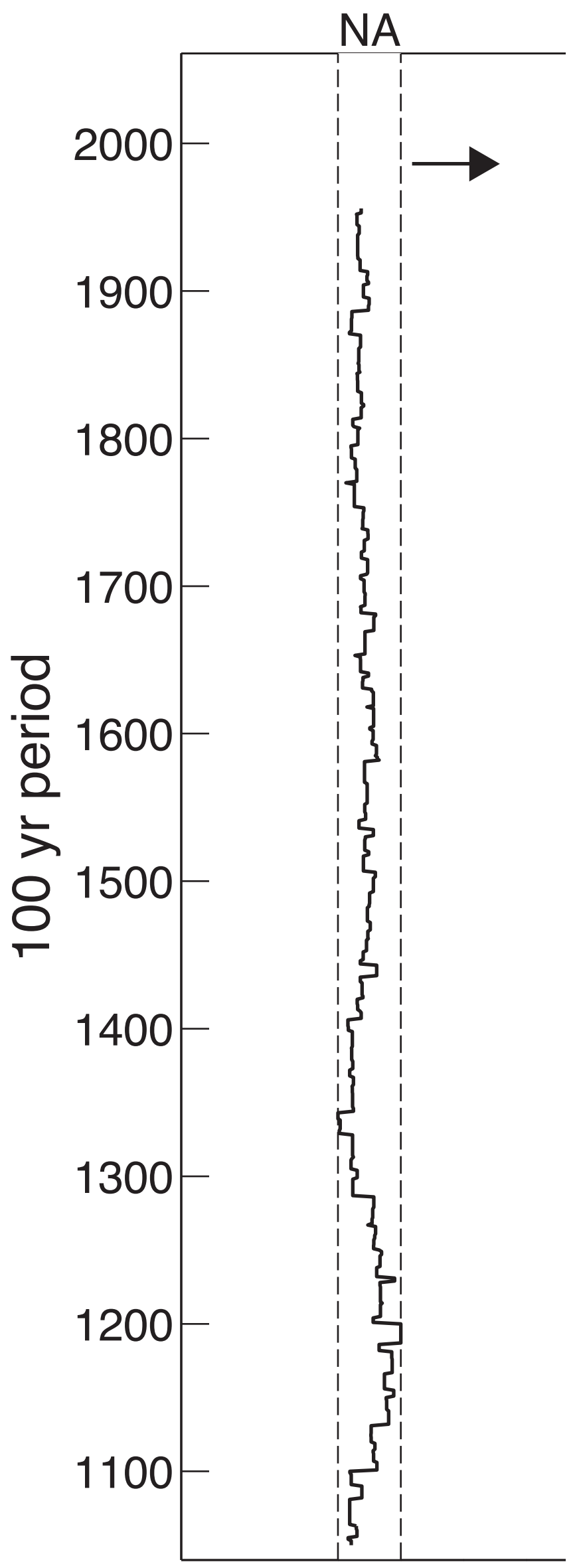
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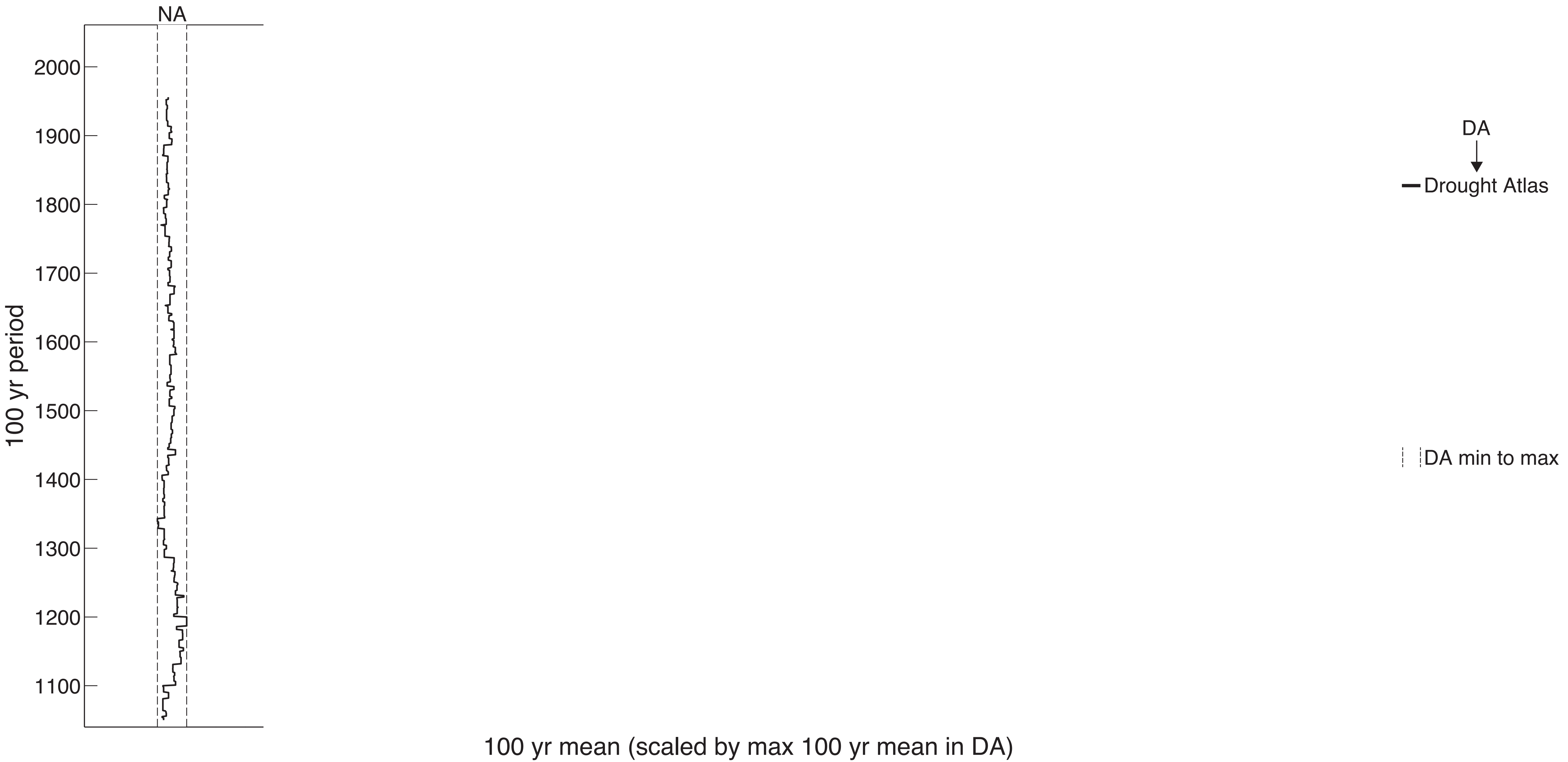
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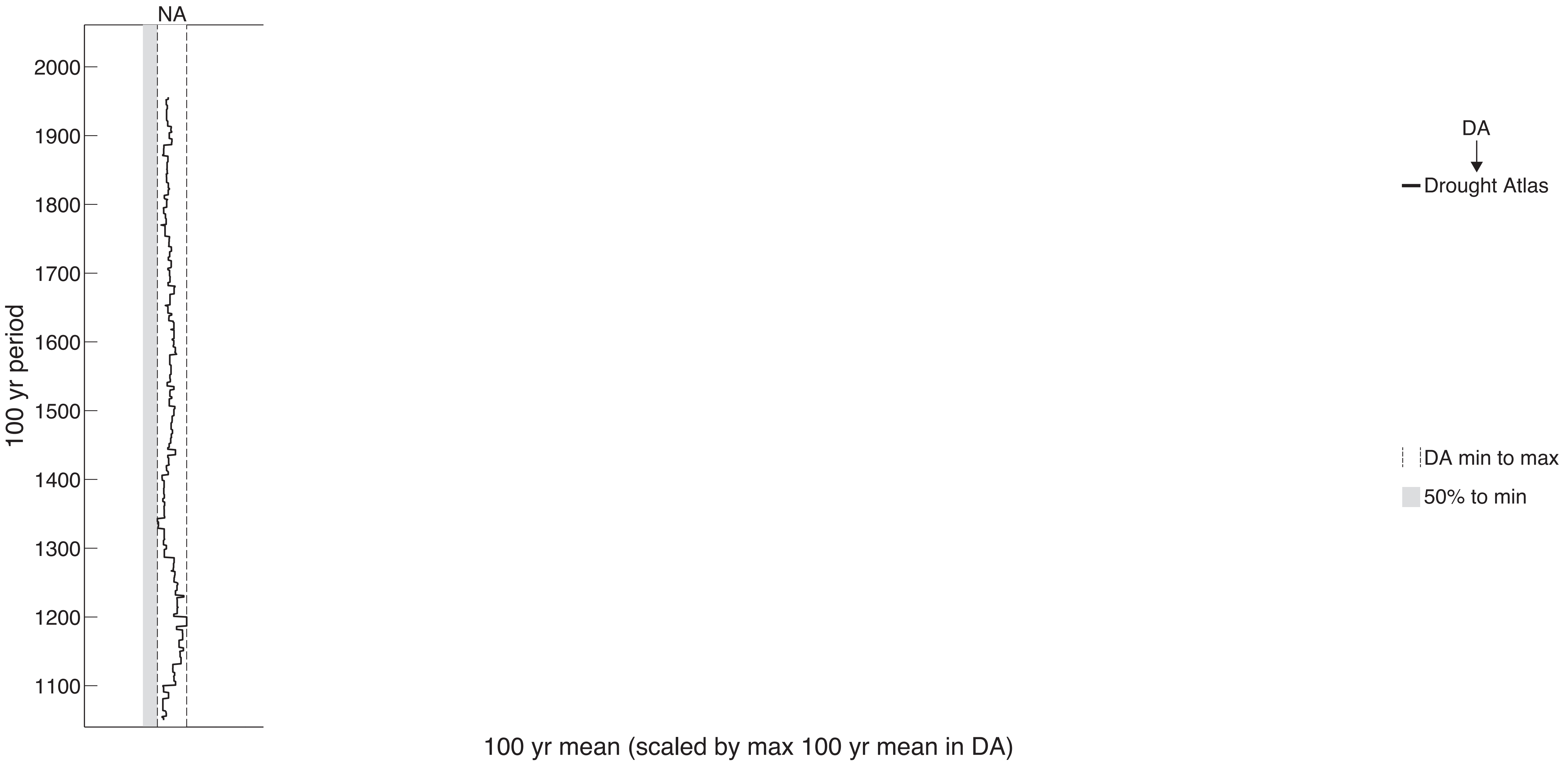
100 yr mean (scaled by max 100 yr mean in DA)



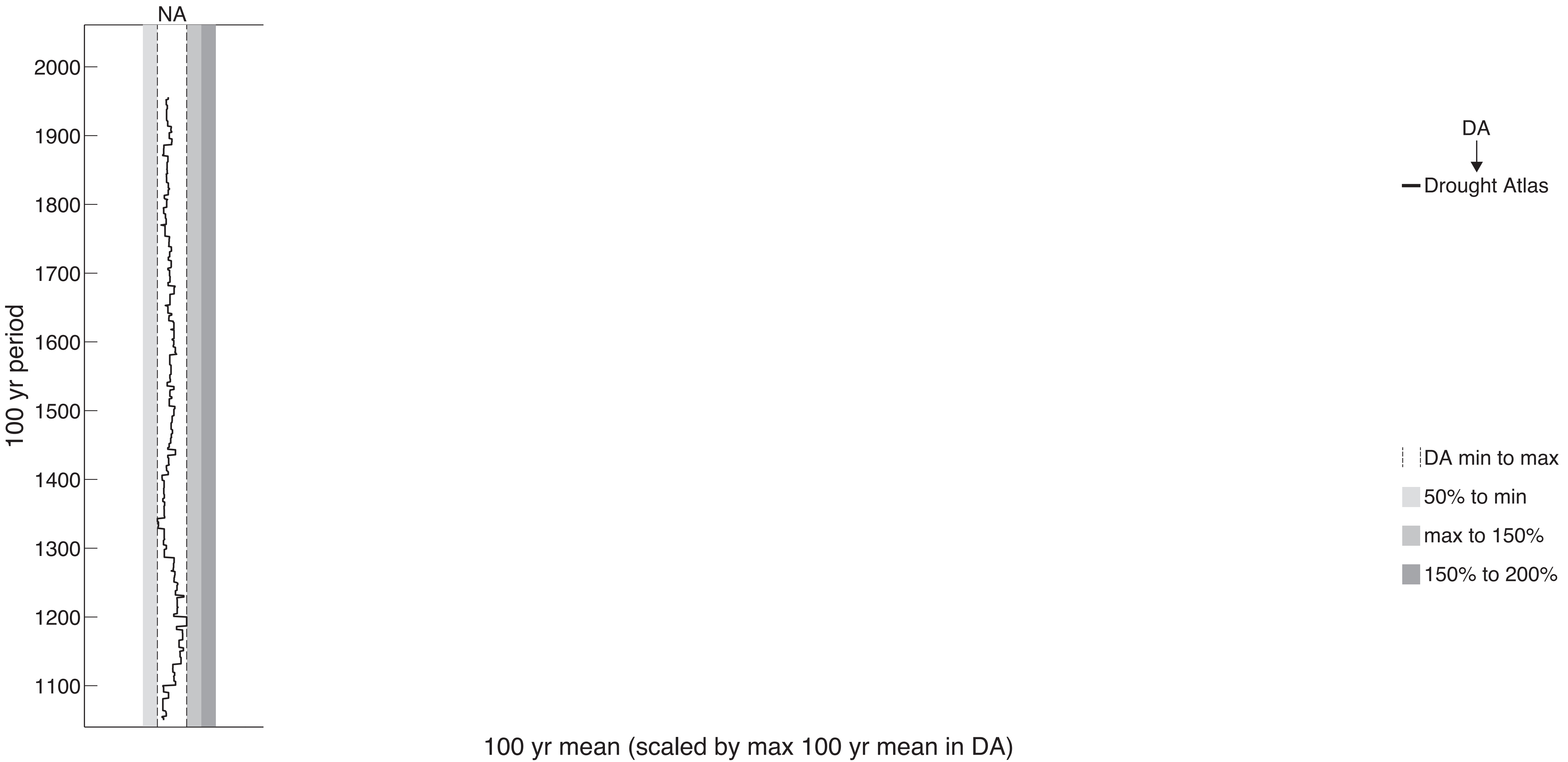
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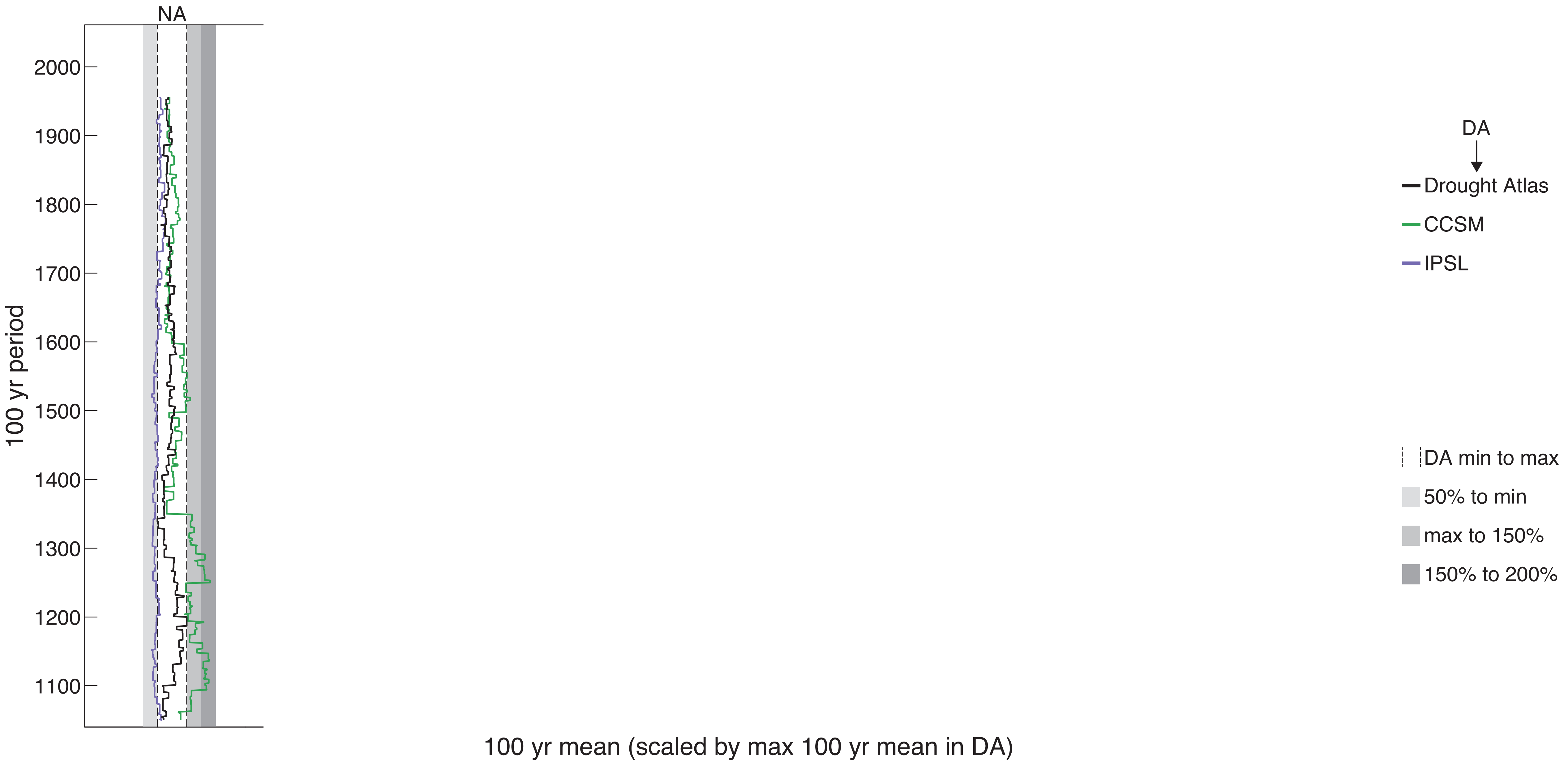
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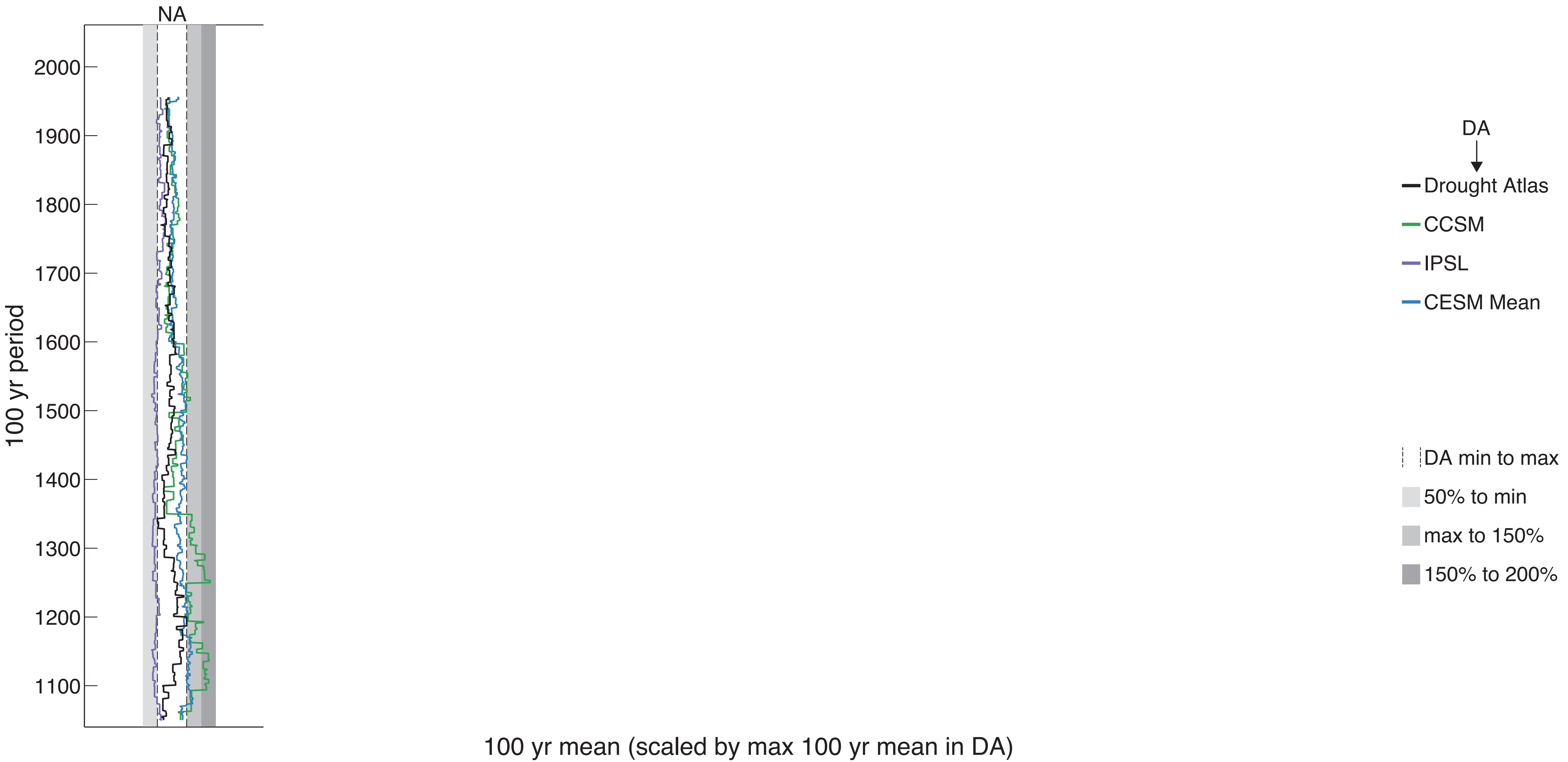
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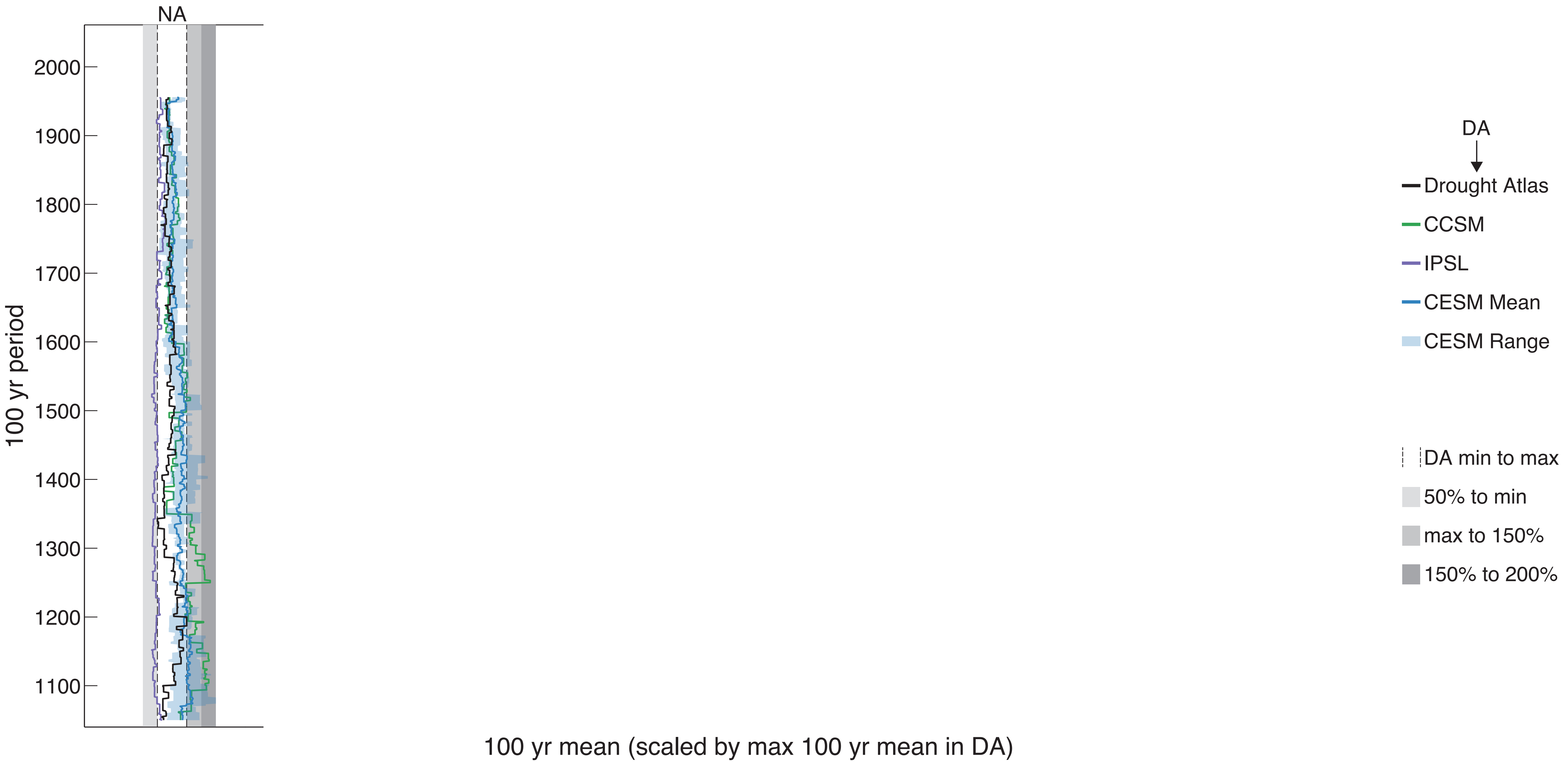
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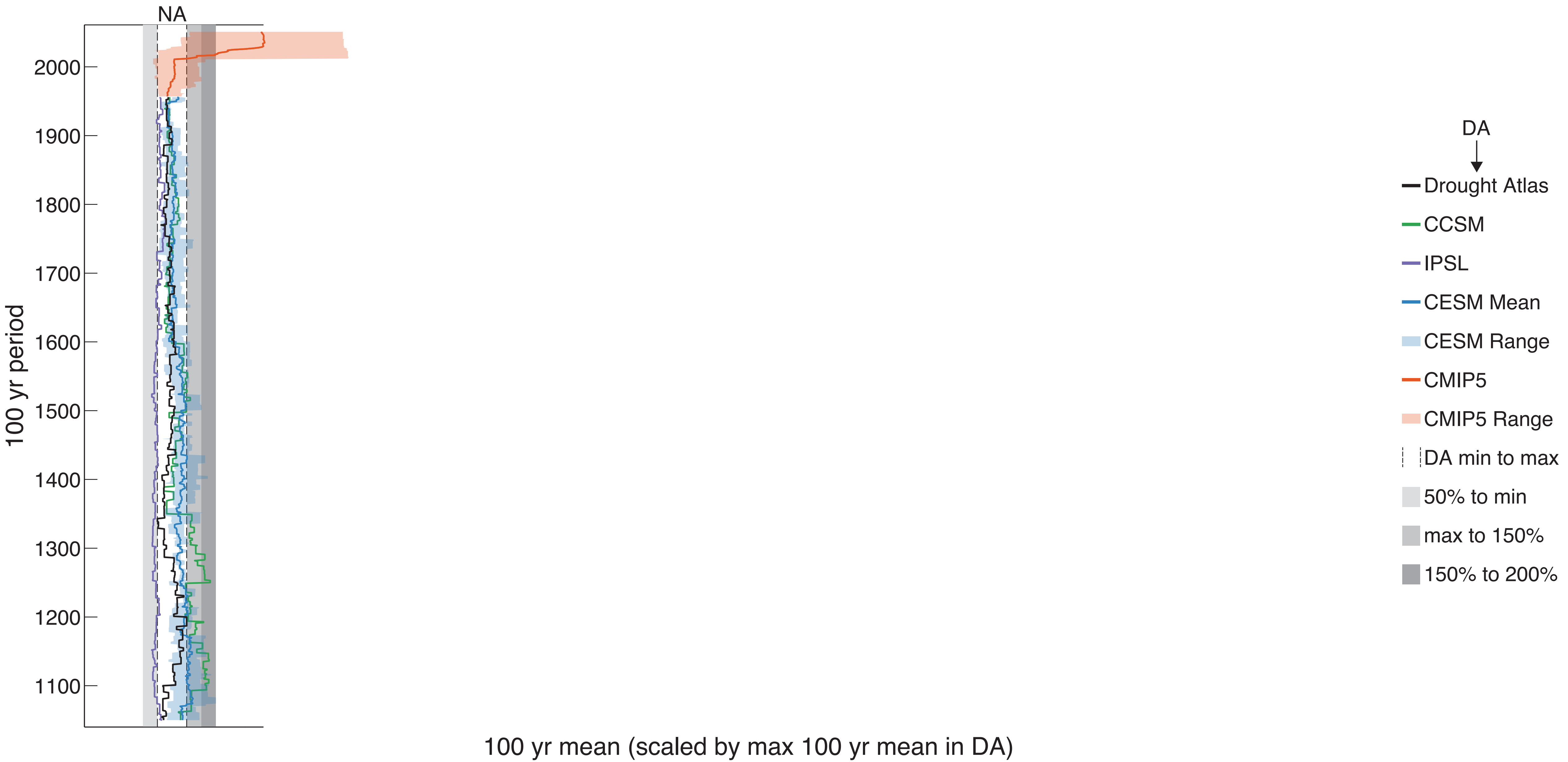
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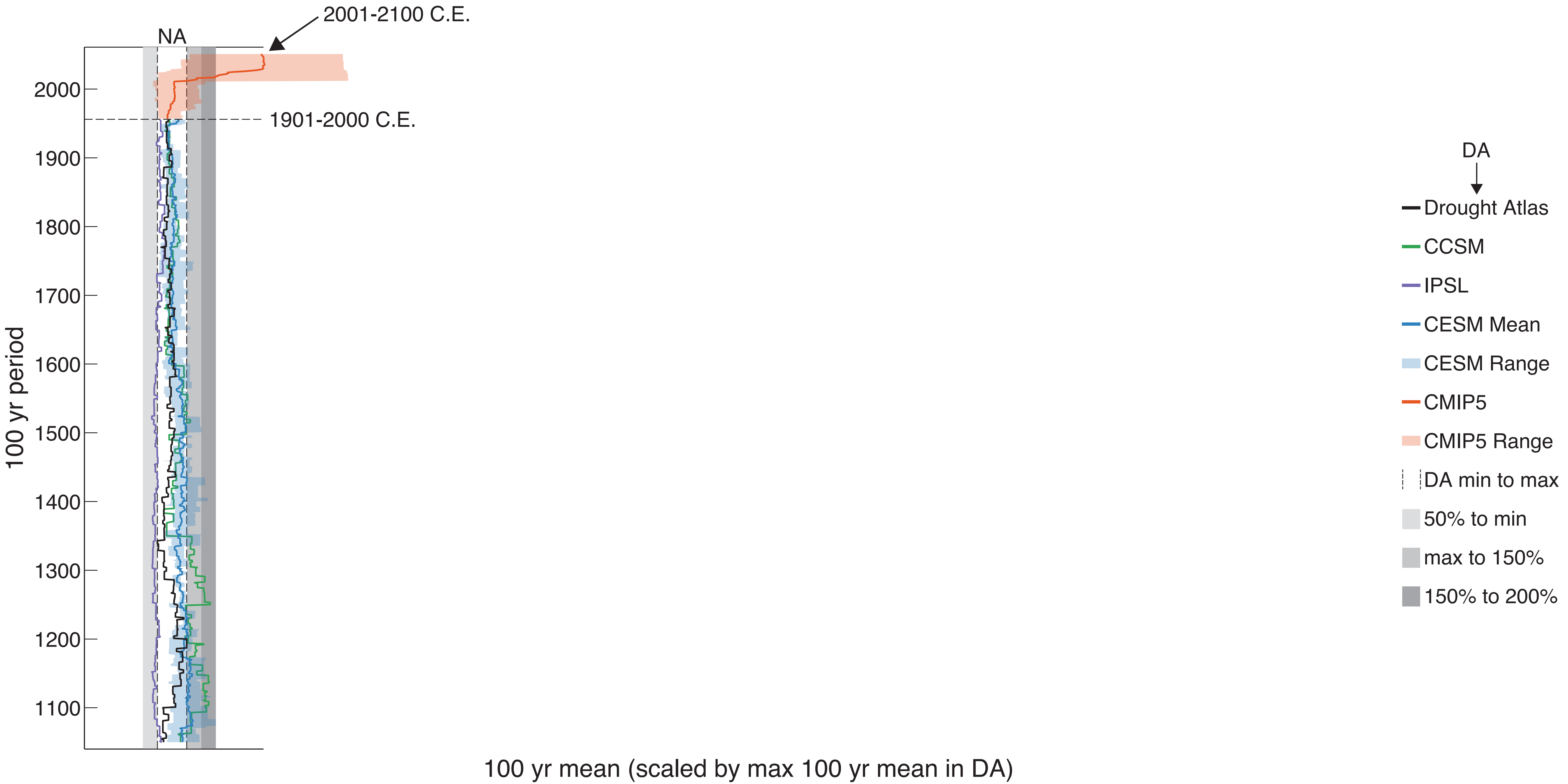
Megadroughts for every 100-yr period



Megadroughts for every 100-yr period



Megadroughts for every 100-yr period



Megadroughts for every 100-yr period

Severity

NA MA OW



Megadroughts for every 100-yr period

Severity

Size

NA

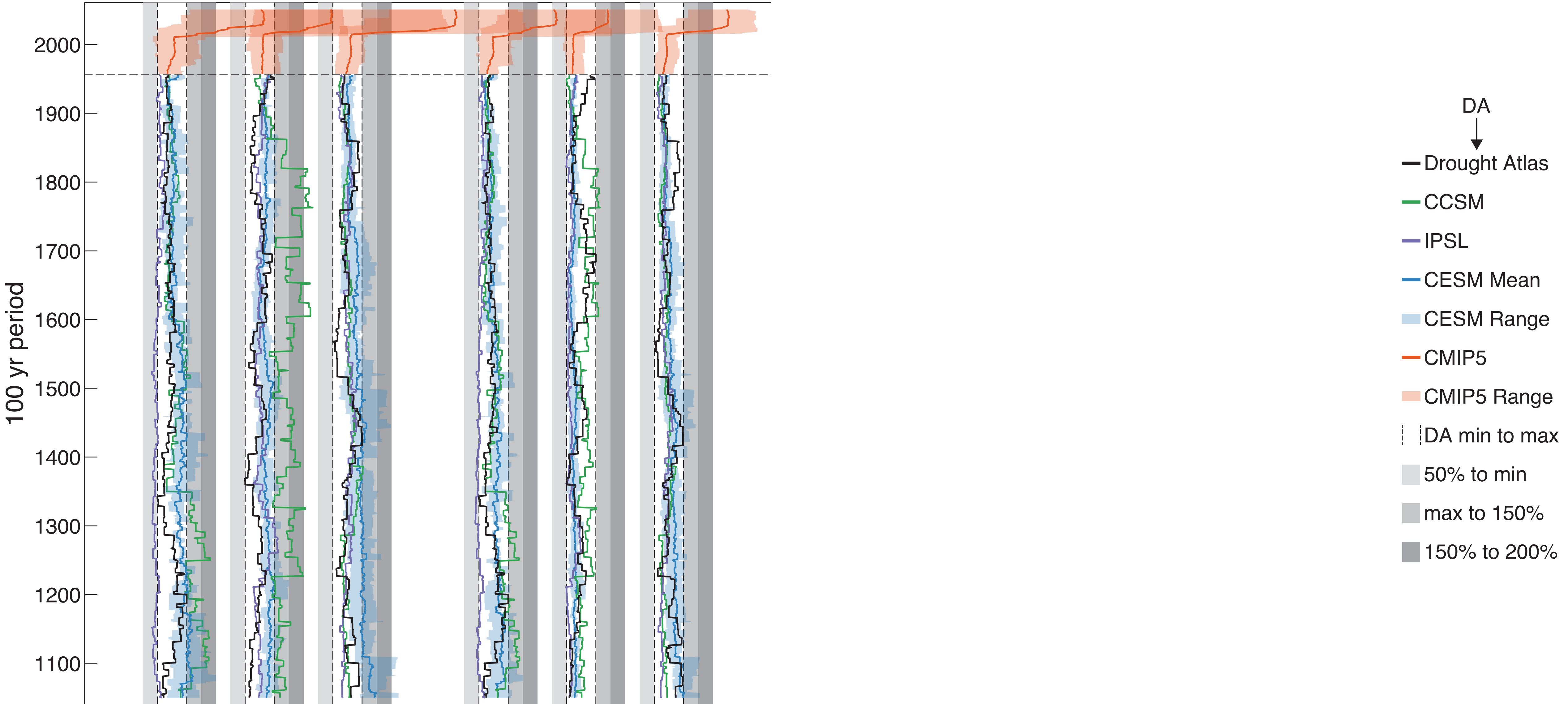
MA

OW

NA

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OW



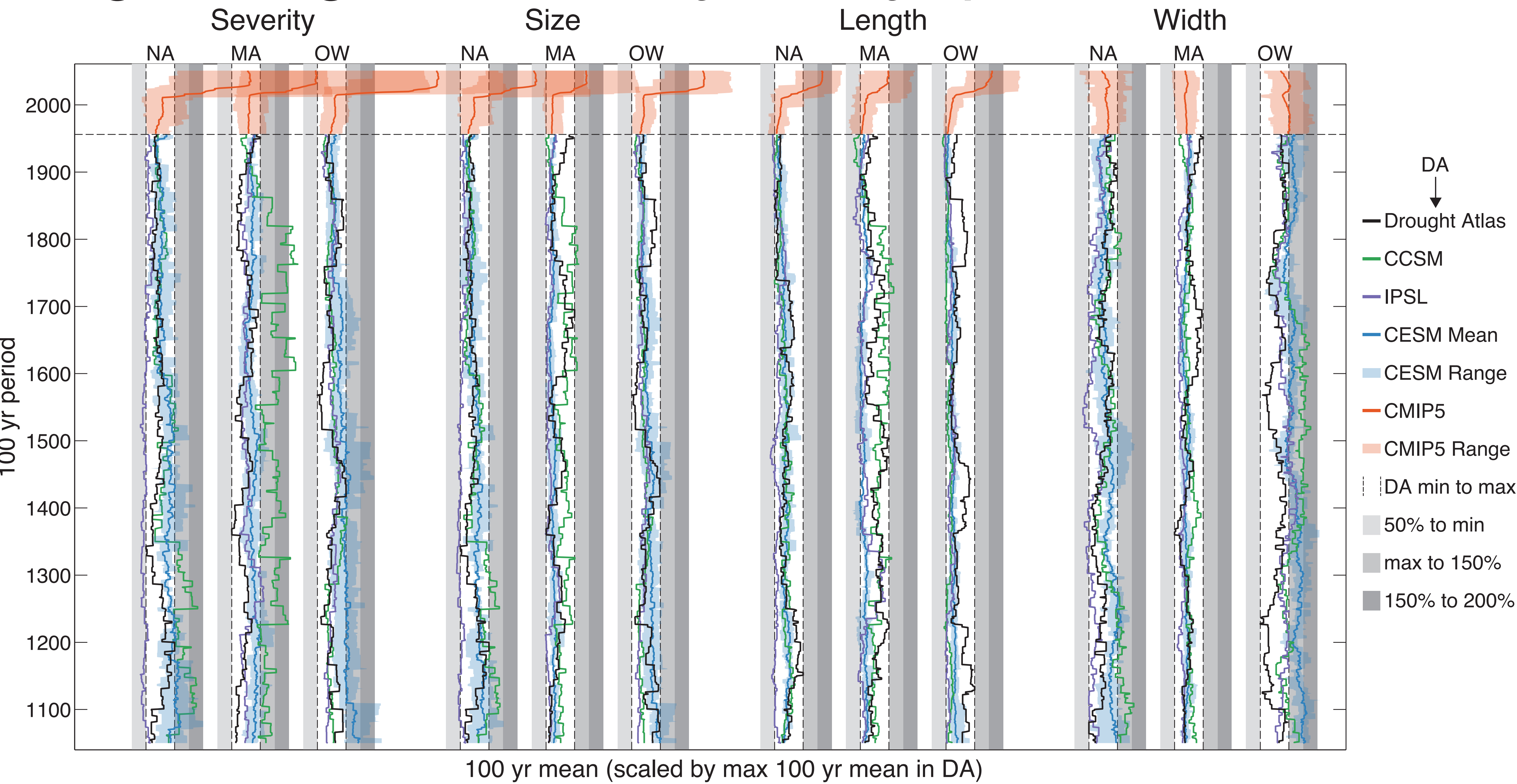
DA



- Drought Atlas
- CCSM
- IPSL
- CESM Mean
- CESM Range
- CMIP5
- CMIP5 Range
- - - DA min to max
- 50% to min
- max to 150%
- 150% to 200%

100 yr mean (scaled by max 100 yr mean in DA)

Megadroughts for every 100-yr period



Conclusions

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NATURE | LETTER



[日本語要約](#)

Northern Hemisphere hydroclimate variability over the past twelve centuries

[Fredrik Charpentier Ljungqvist](#), [Paul J. Krusic](#), [Hanna S. Sundqvist](#), [Eduardo Zorita](#),
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Conclusions

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- Characterized megadroughts over last millennium
- Analyzed the characteristics of megadroughts into future:
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 - Not everything changes about drought in the future