Hydroclimate Signals in Tree-Ring Chronologies Across Time and Space

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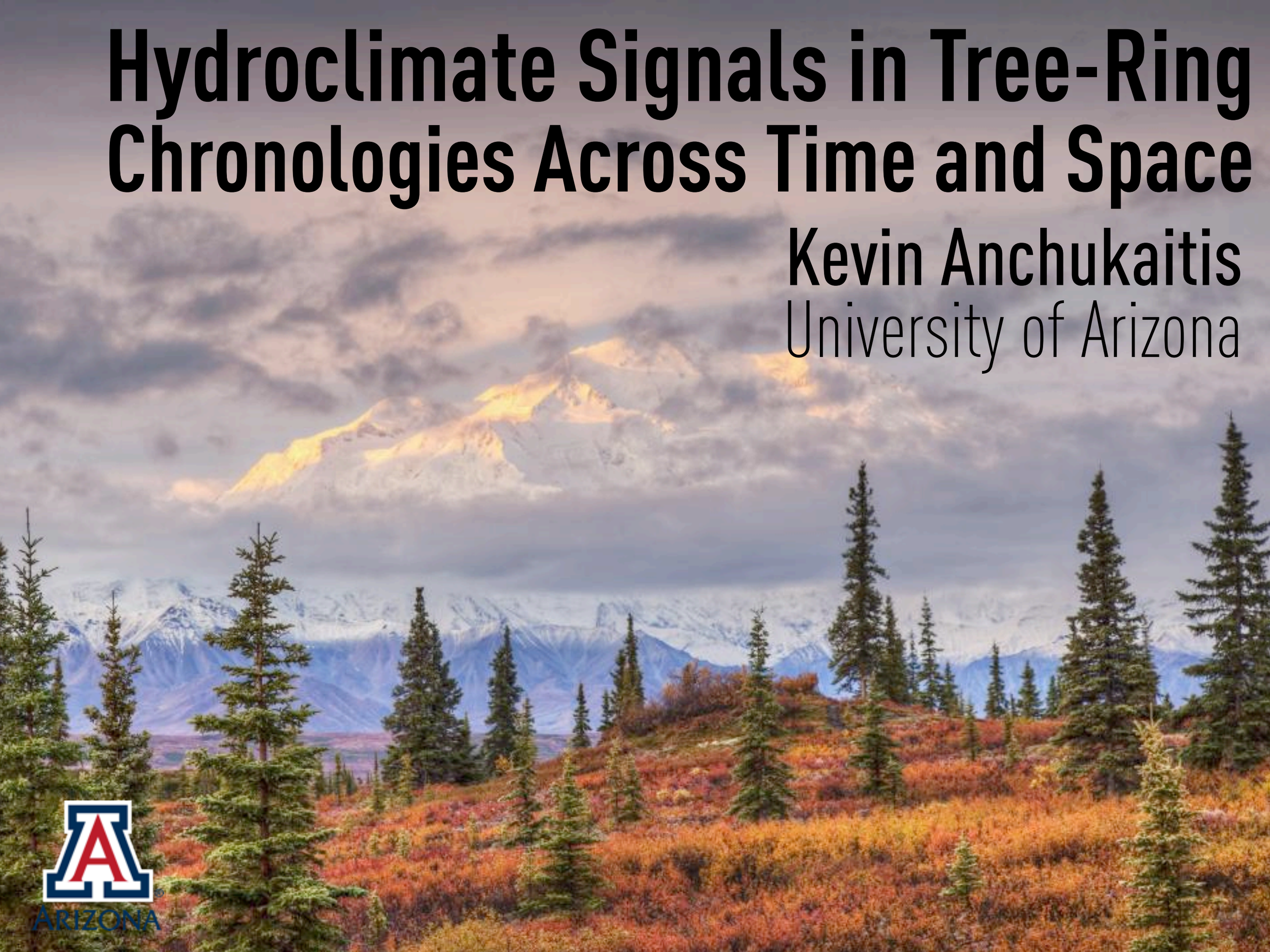
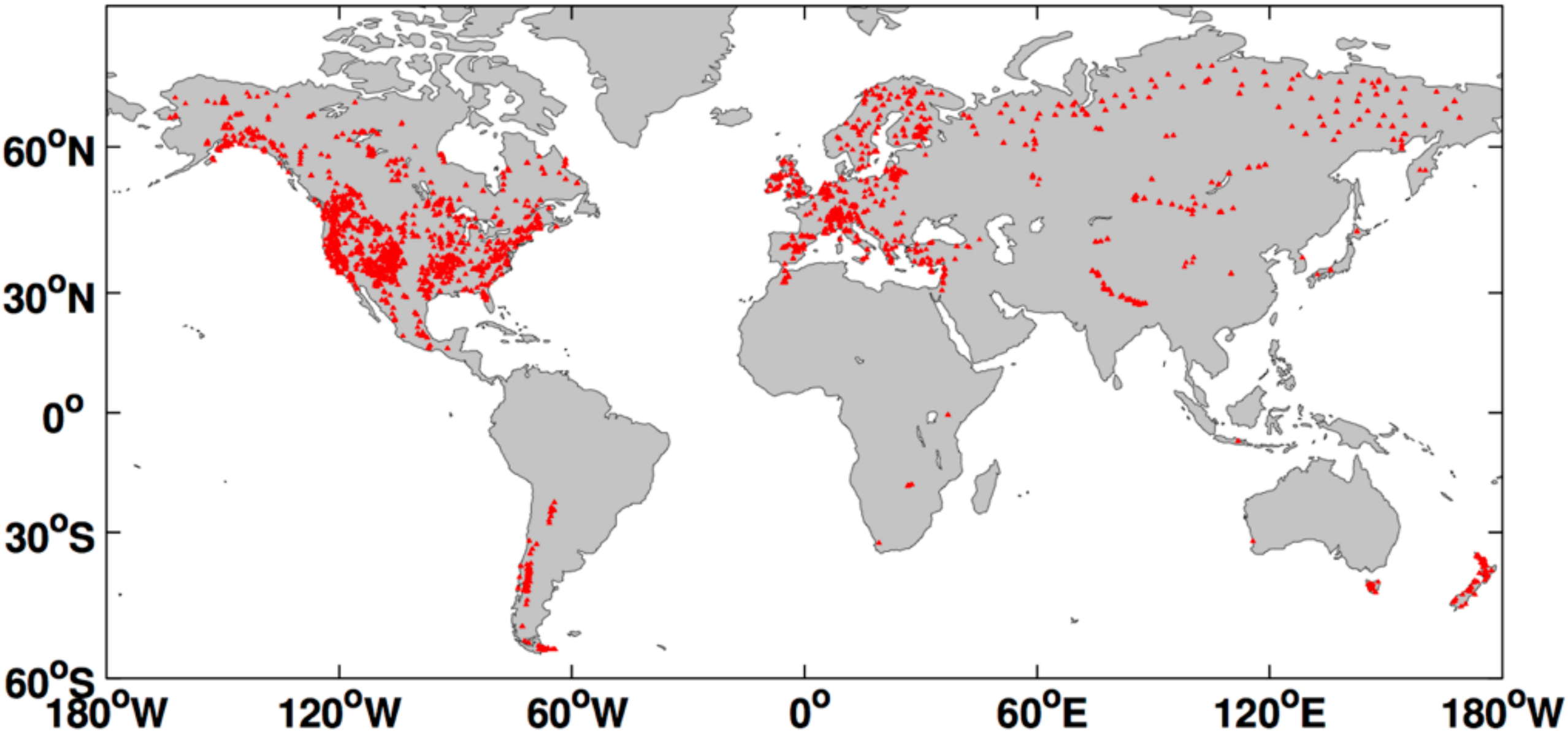
University of Arizona



climate response seasonality detrending and spectra


60°N
30°N
0°
30°S
60°S
180°W
120°W
60°W
0°
60°E
120°E
180°W

RECONSTRUCTION

CALIBRATION

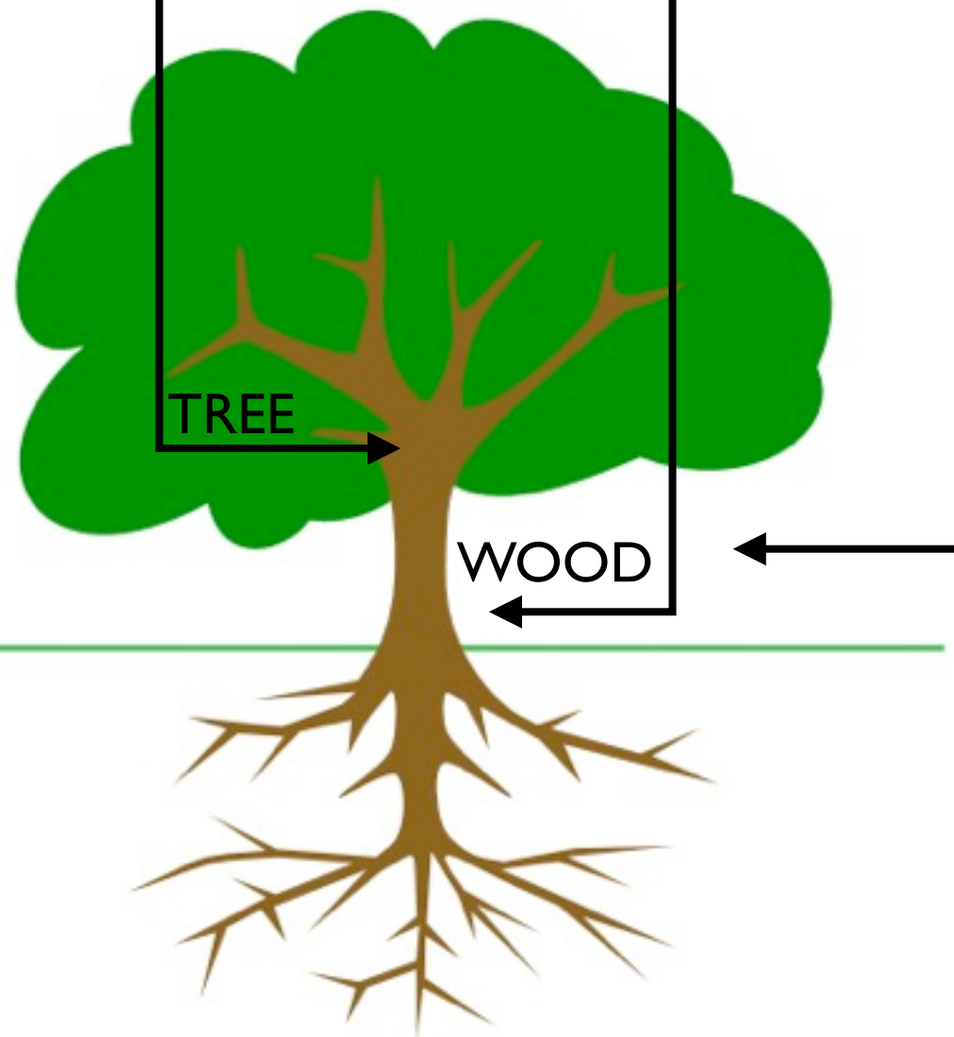
ENVIRONMENT

SENSOR

ARCHIVE

OBSERVATION

TEMPERATURE
PRECIPITATION
SOIL MOISTURE
SUNLIGHT
SNOW



RING WIDTH
MXD
EARLYWOOD
LATEWOOD
ISOTOPES

Evans, Tolwinski-Ward, Thompson, Anchukaitis, 2013

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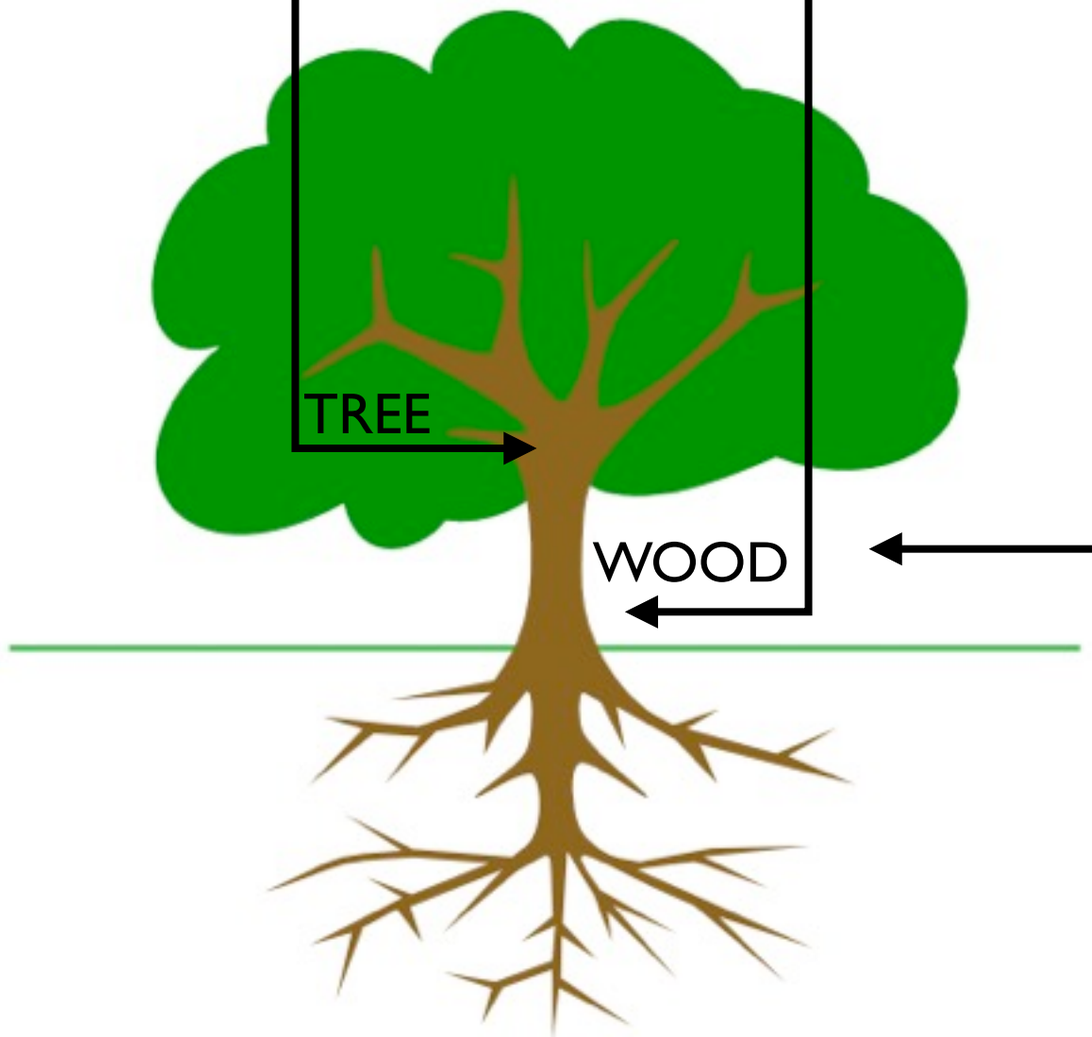

RING WIDTH
MXD
EARLYWOOD
LATEWOOD
ISOTOPES

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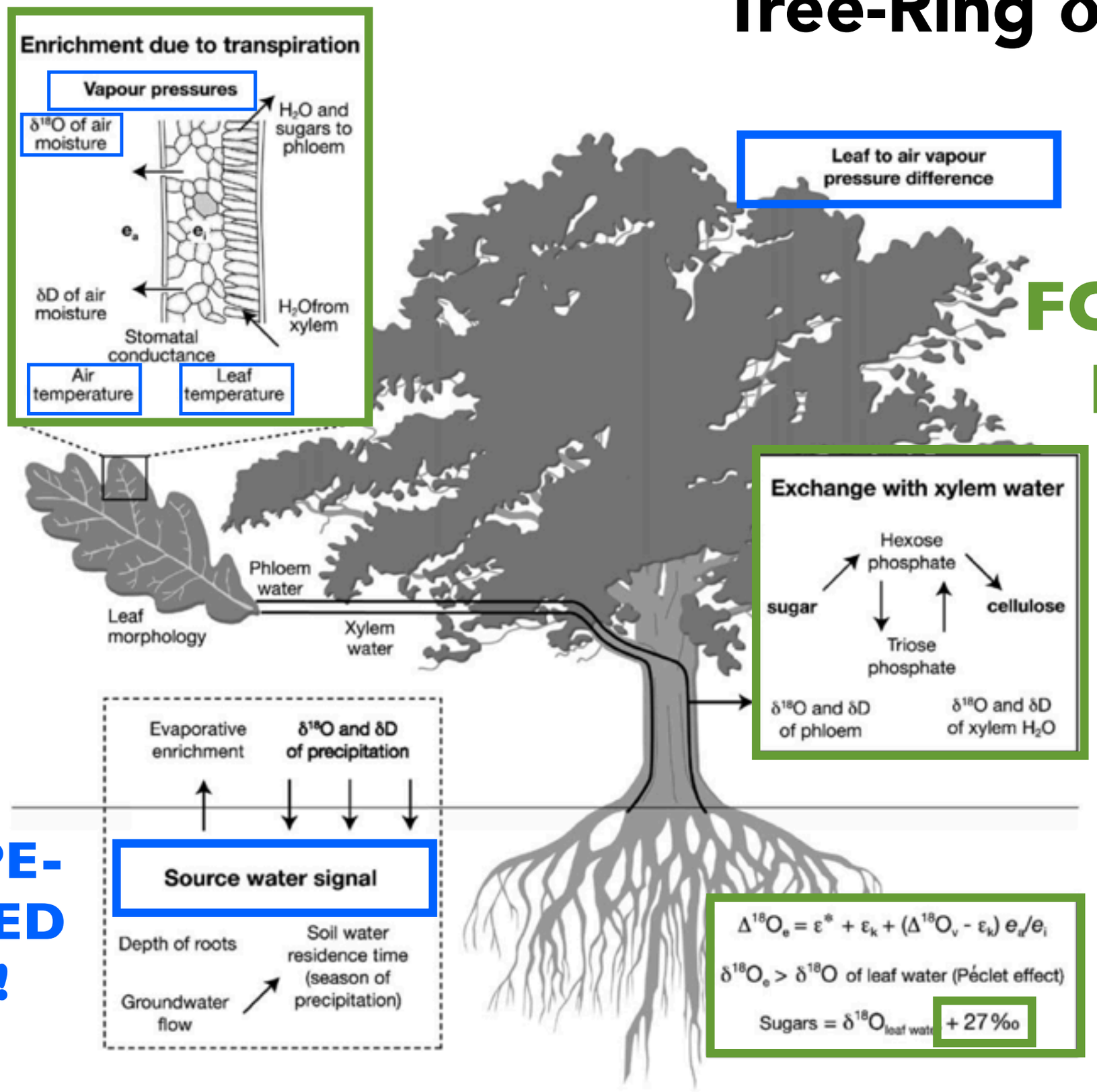
Tree-Ring $\delta^{18}O_{cellulose}$



FORWARD MODEL

ISOTOPE-ENABLED GCM !

McCarroll and Loader 2004, Barbour et al. 2004, Evans 2007, Sternberg et al. 2011

Environment to Observation (much) more complicated than an empirical ϵ_{bio}

Linear Aggregate Model of Tree Growth

(Cook 1985)

$$R_t = A_t + C_t + D_t^e + D_t^n + \epsilon_t$$

Ring width (or density) in year *t* is a function of the age of the tree, the climate, exogenous and endogenous disturbance, plus ‘noise’

Could also allow for lagged effects

Linear Aggregate Model of Tree Growth

(Cook 1985)

$$R_t = A_t + C_t + D_t^e + D_t^n + \epsilon_t$$

Try to *remove* age and retain climate signal

try to account for with a mix of site and tree selection and replication

Ring width (or density) in year *t* is a function of the age of the tree, the climate, exogenous and endogenous disturbance, plus 'noise'

Could also allow for lagged effects

$$C_t$$

What is the dominant hydroclimate signal in tree-ring chronologies?

Palmer Drought Severity Index

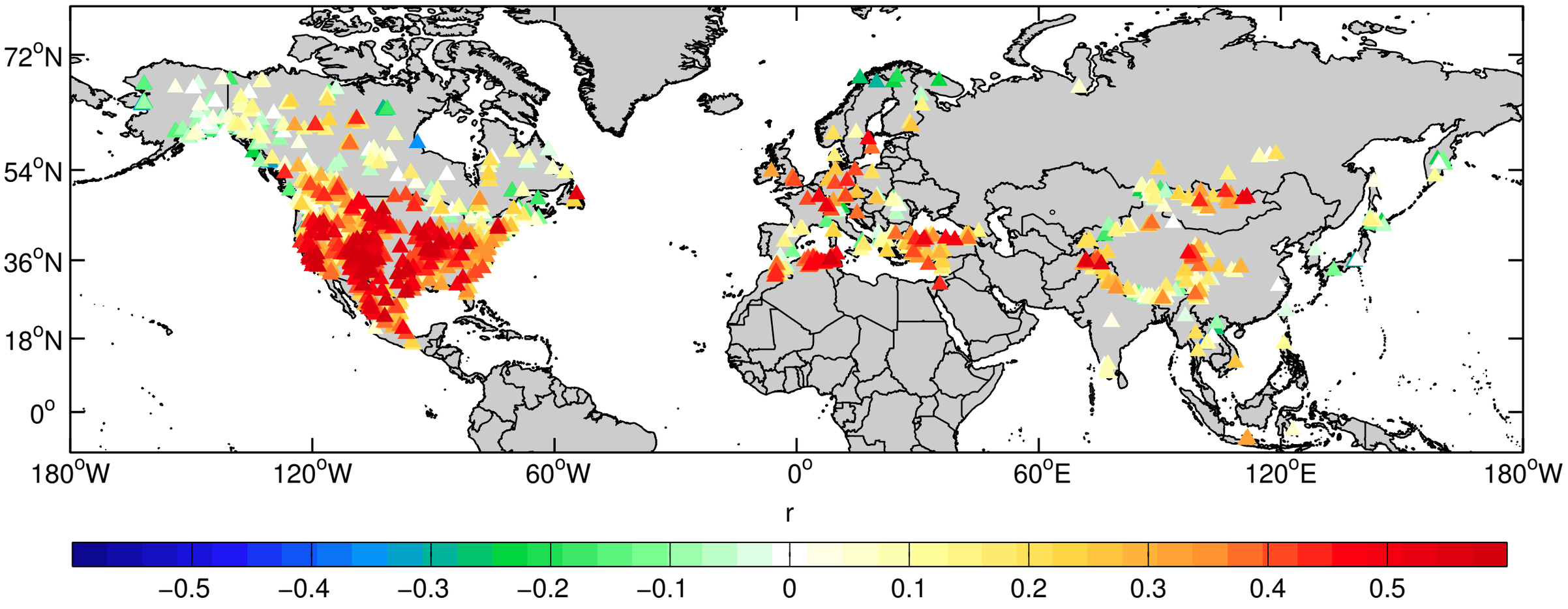
PDSI

Positive values (+) are wet

Zero is Normal for that Location

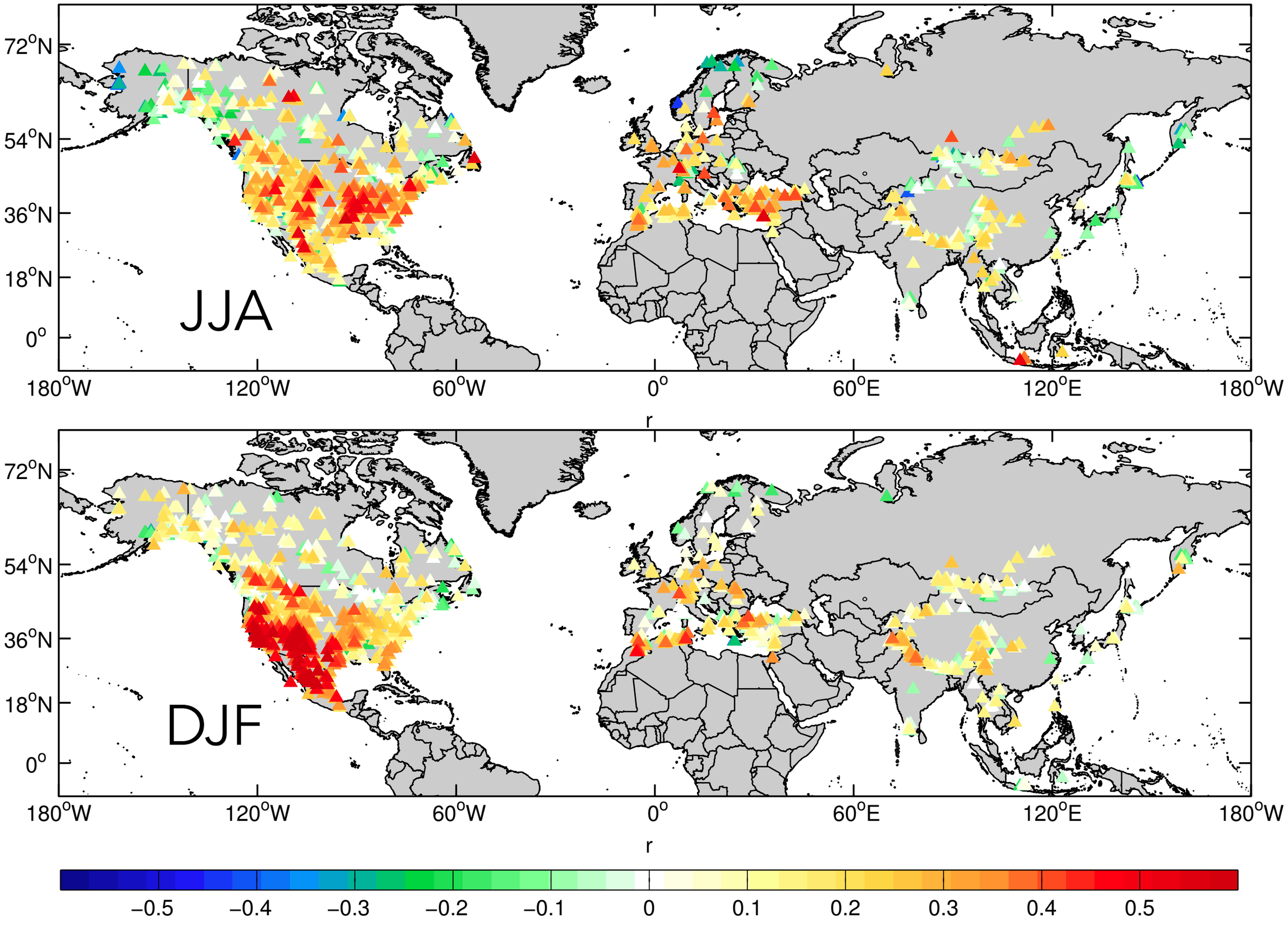
Negative values (–) are dry

chronology vs. local JJA PDSI

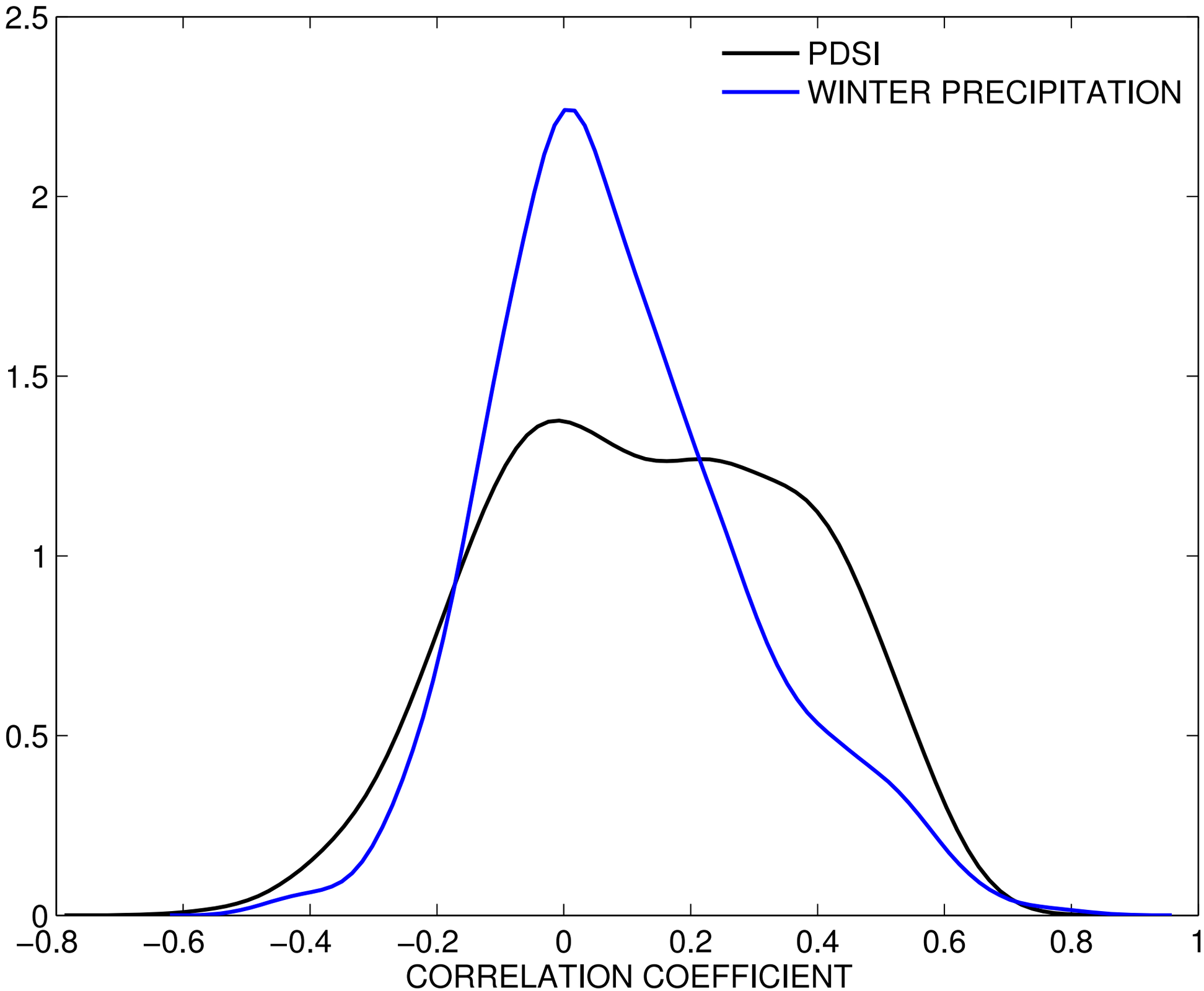


data sources: Cook et al. 2004, 2009, 2010, 2015, & in preparation; Touchan, Anchukaitis et al. 2014; Touchan et al. in preparation, Anchukaitis et al. in preparation

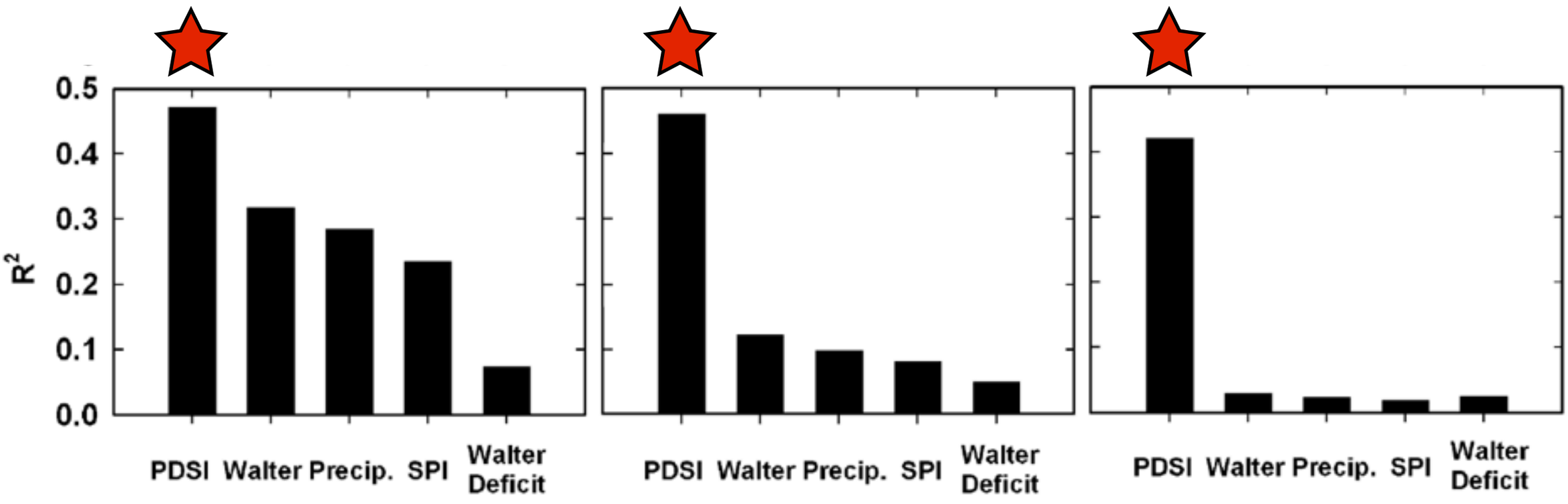
chronologies vs. precipitation



Overall, the global tree ring network has a somewhat stronger relationship to PDSI



PDSI in many (most?) cases explains more variance in tree-ring width than other hydroclimate metrics ...

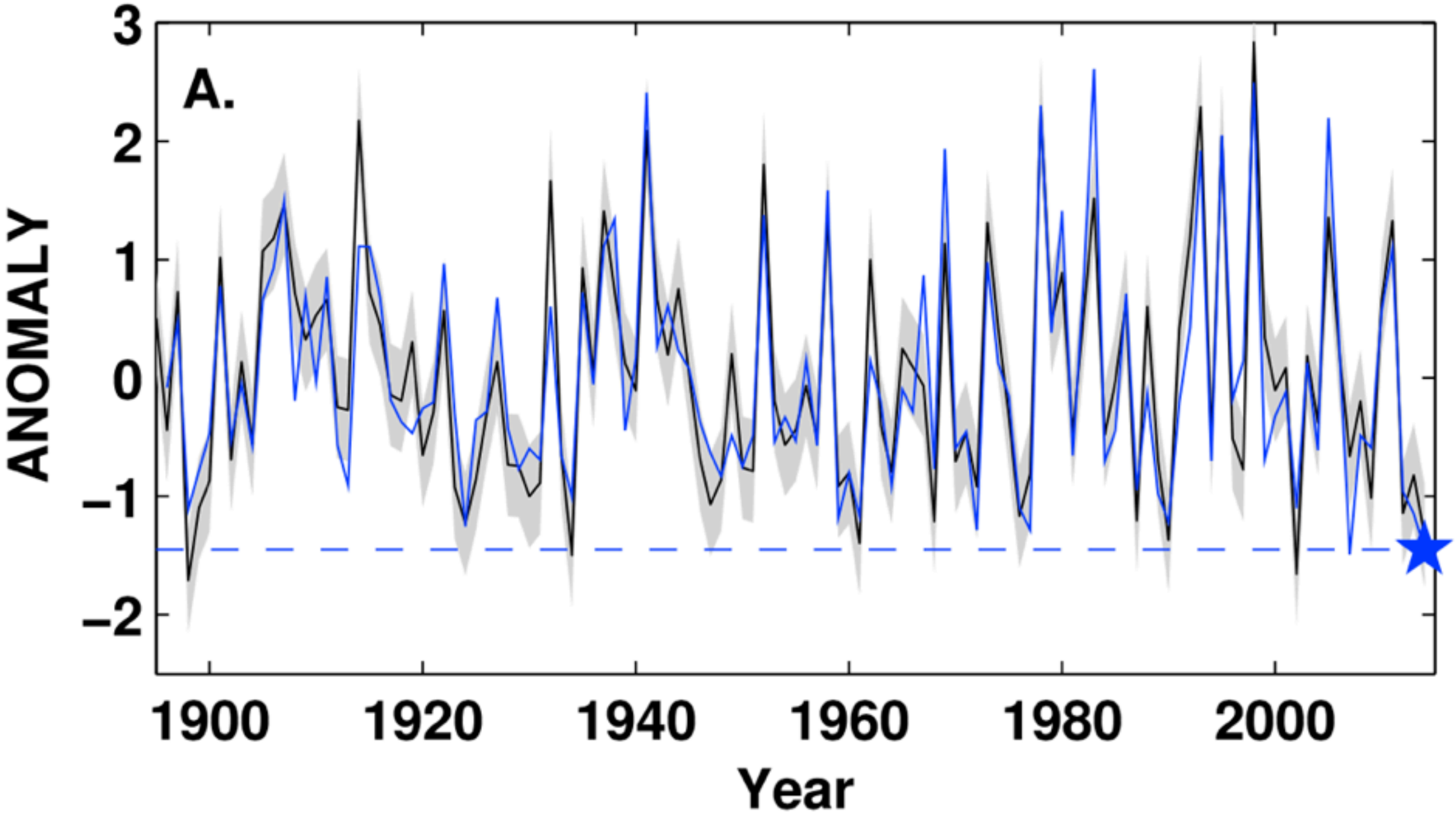


water year calendar year summer

Kempes et al. 2008 for *Pinus edulis*

… but not always …

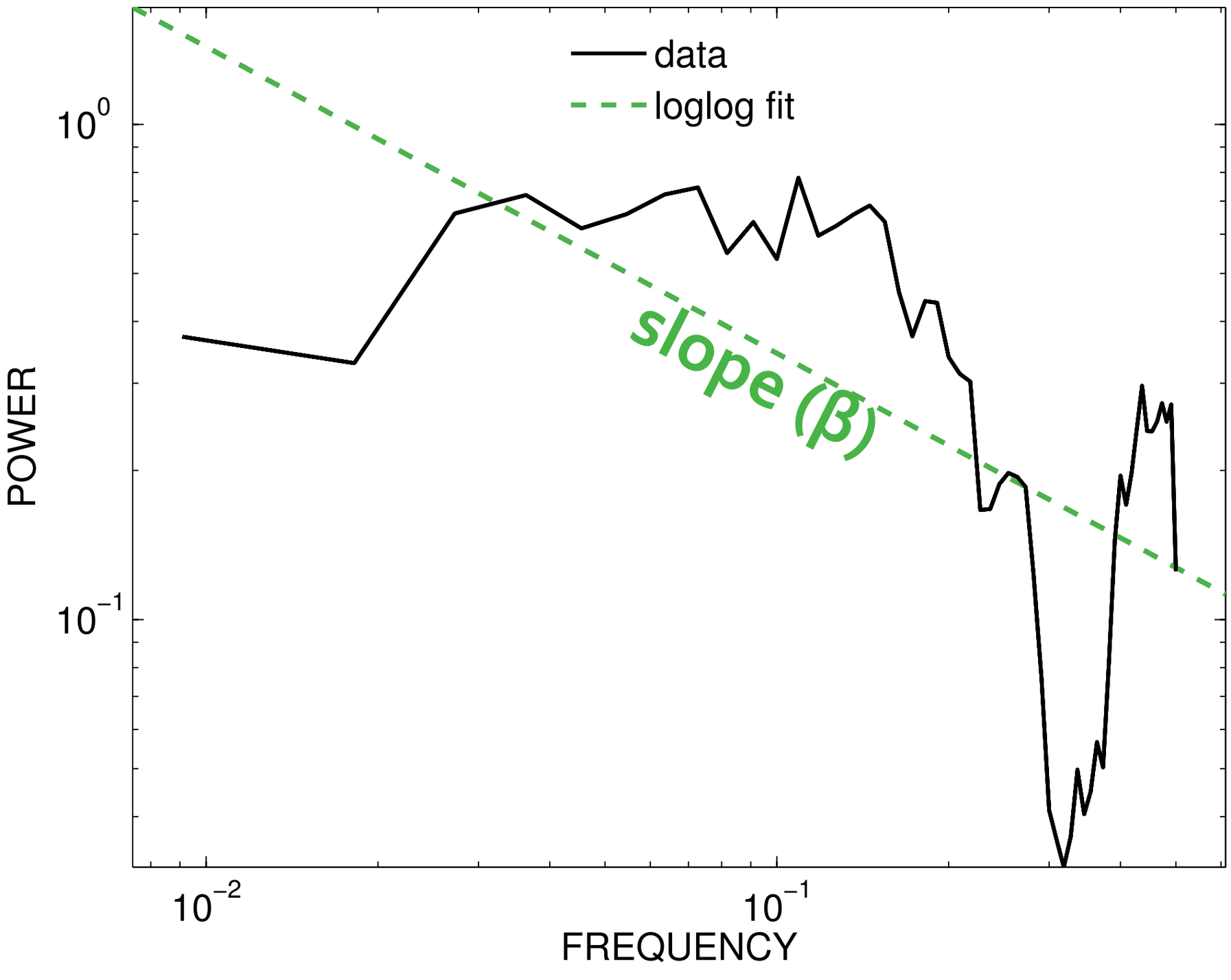
California winter precipitation from blue oaks

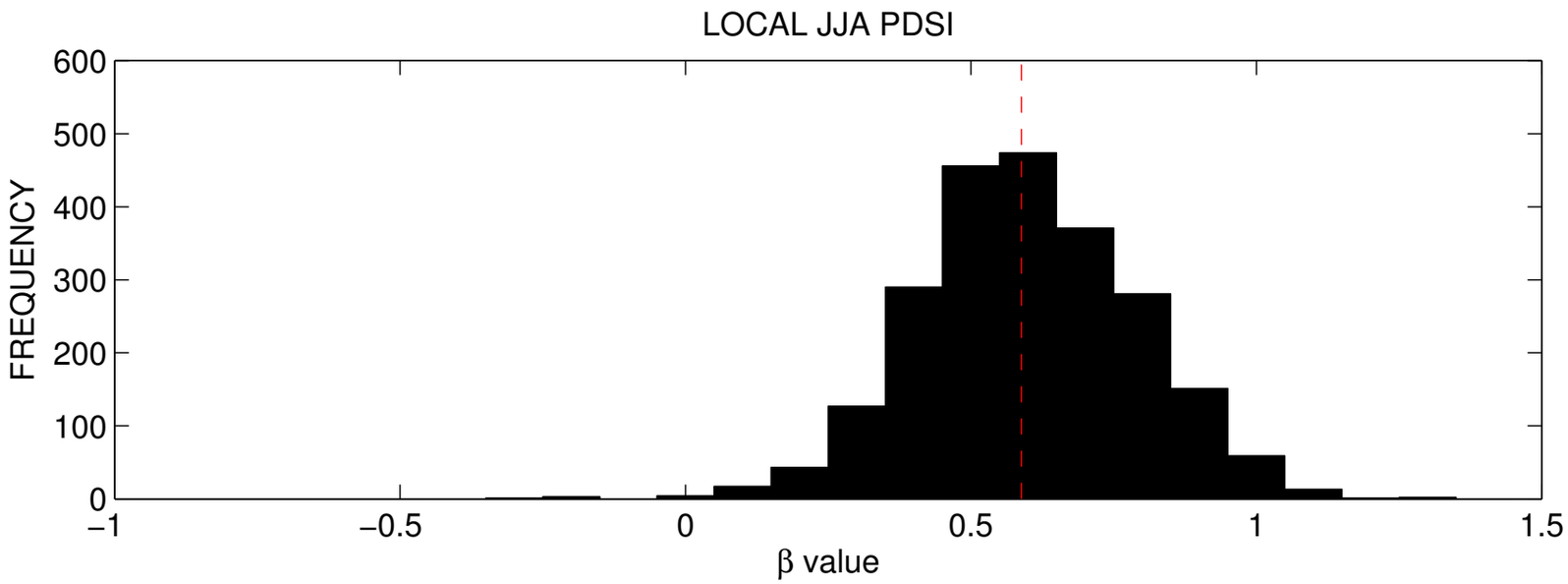


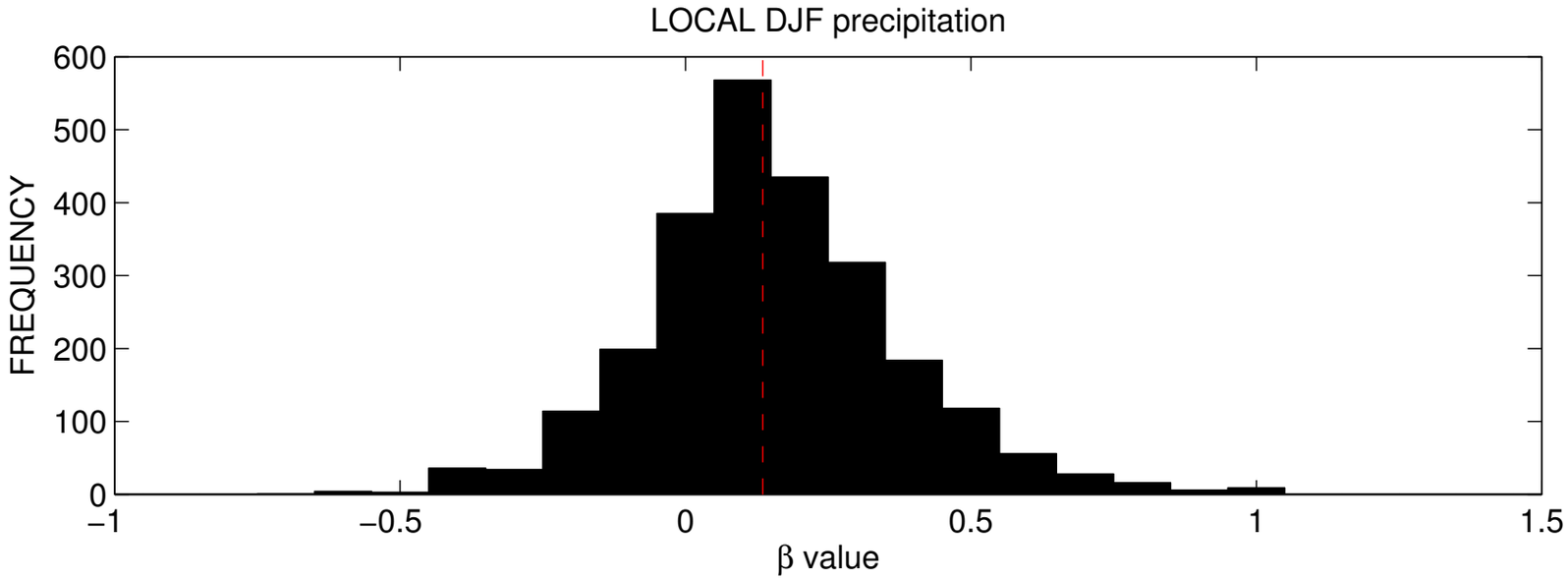
Griffin and Anchukaitis 2014

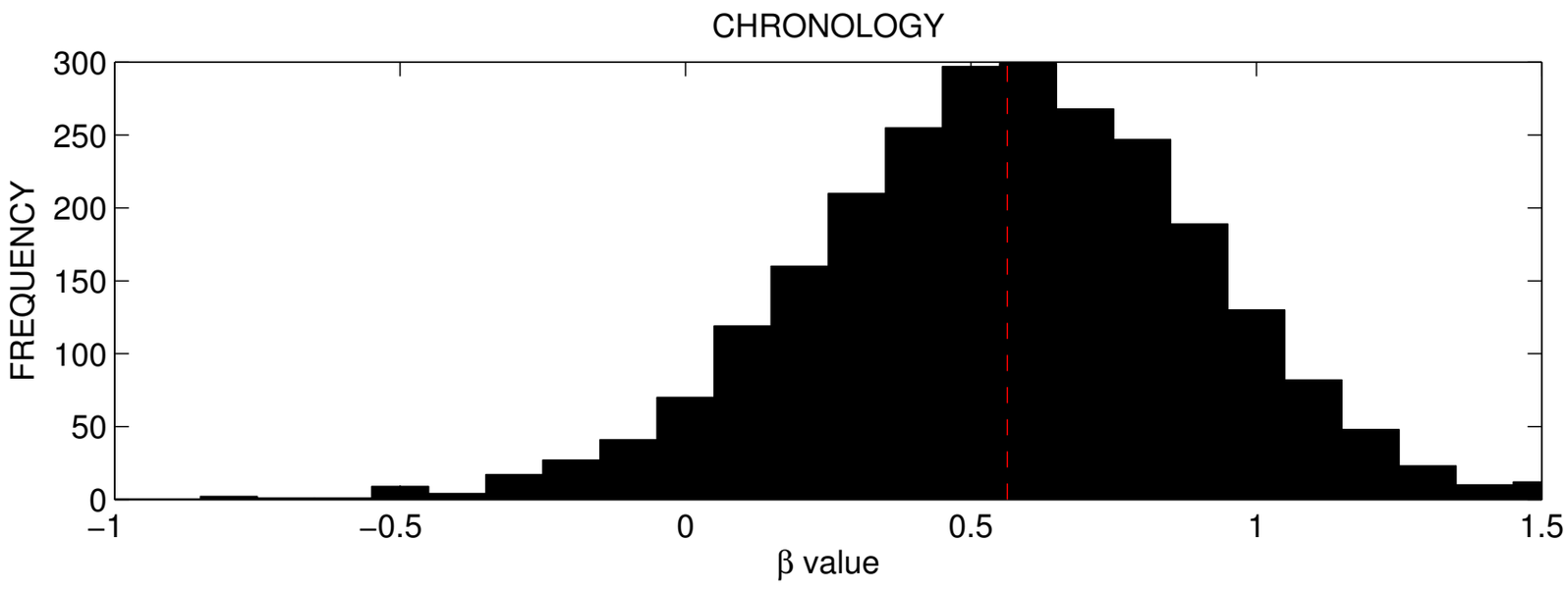
Are tree-ring chronologies 'spectrally biased', sensu Franke et al. 2013?

Least squares fit to the chronology and climate power spectra in loglog space




LOCAL JJA PDSI
FREQUENCY
600
500
400
300
200
100
0
−1
−0.5
0
0.5
1
1.5
β value


LOCAL DJF precipitation
FREQUENCY
600
500
400
300
200
100
0
−1
−0.5
0
0.5
1
1.5
β value


CHRONOLOGY
FREQUENCY
300
250
200
150
100
50
0
−1
−0.5
0
0.5
1
1.5
β value

No *systematic* bias in tree-ring chronology power spectra vs. summer (JJA) PDSI, at least up to centennial scale although chronologies show much larger dispersion

Possible reasons: tree-ring detrending and standardization, non-PDSI related variance (other climate signal or multivariate) in chronologies, PDSI not the best or first-order control, errors in observational PDSI, etc.

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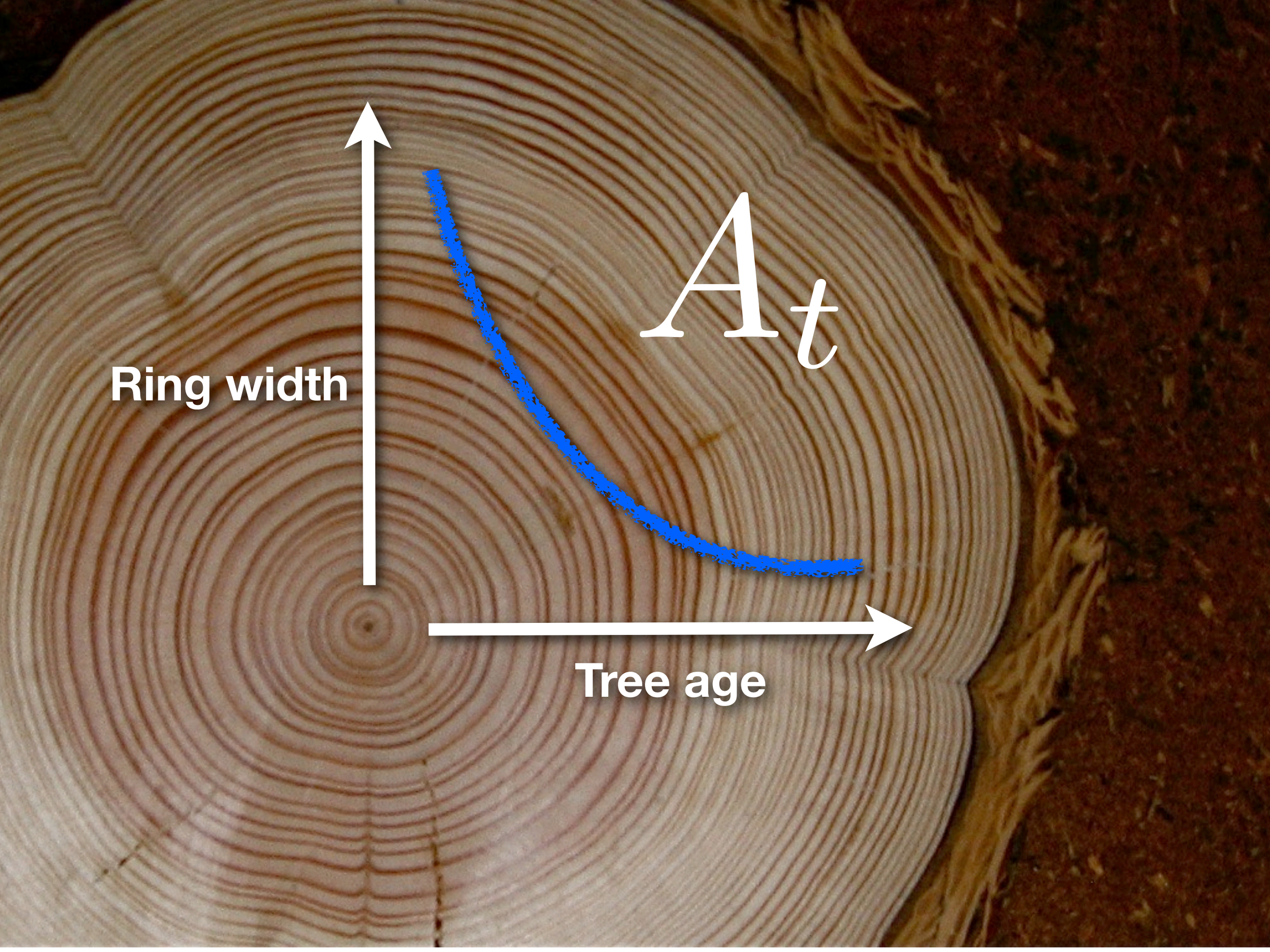

Ring width
A_t
Tree age

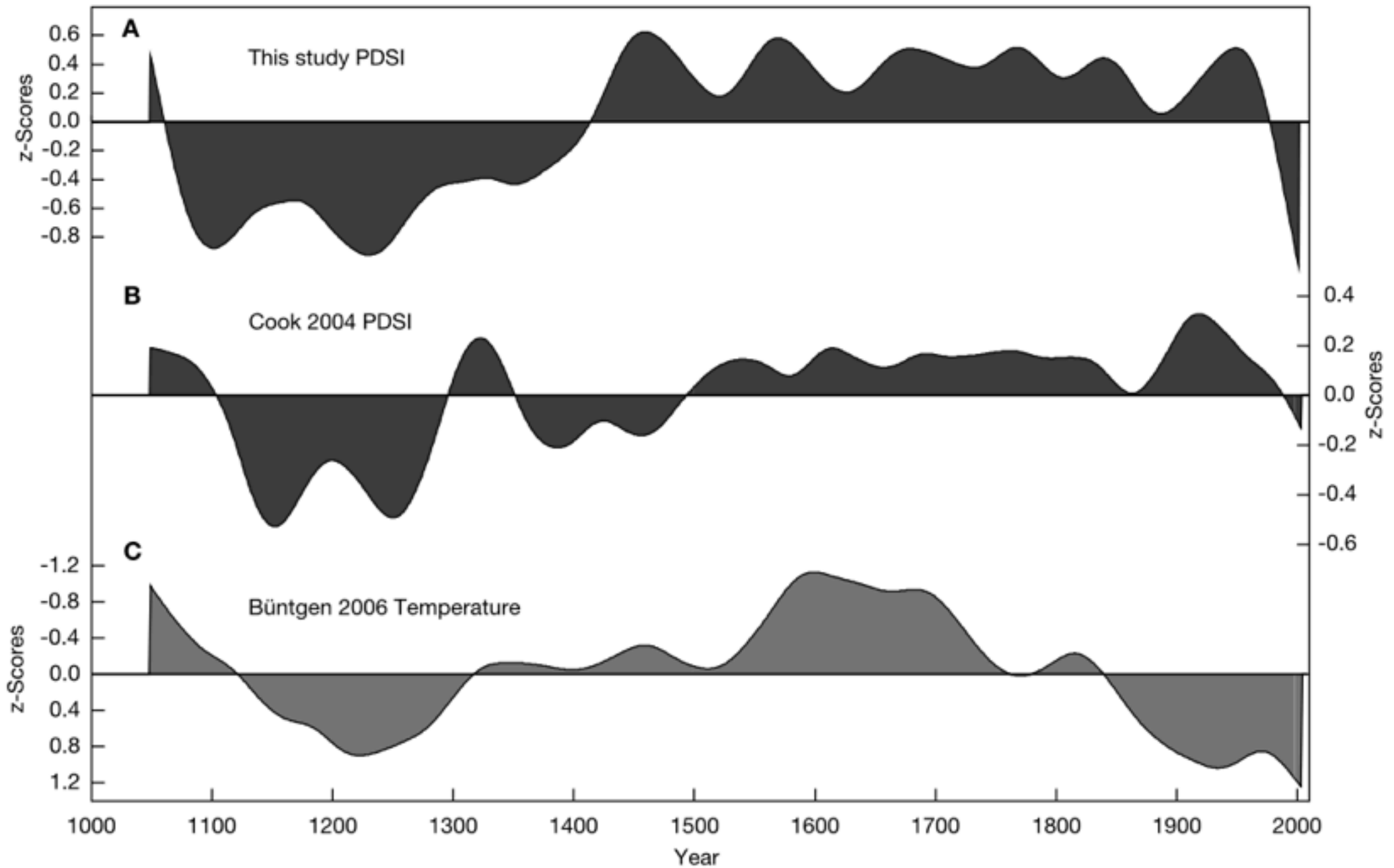
The Segment Length Curse

'This 'curse' is related to the fact that the **maximum wavelength of recoverable climatic information is ordinarily related to the lengths of the individual tree-ring series used to construct the millennia-long chronology.'**

'Alternative schemes of chronology development are described that seek to exorcise the segment length curse. **While they show some promise**, none is universal in its applicability and this problem still remains largely unsolved.'

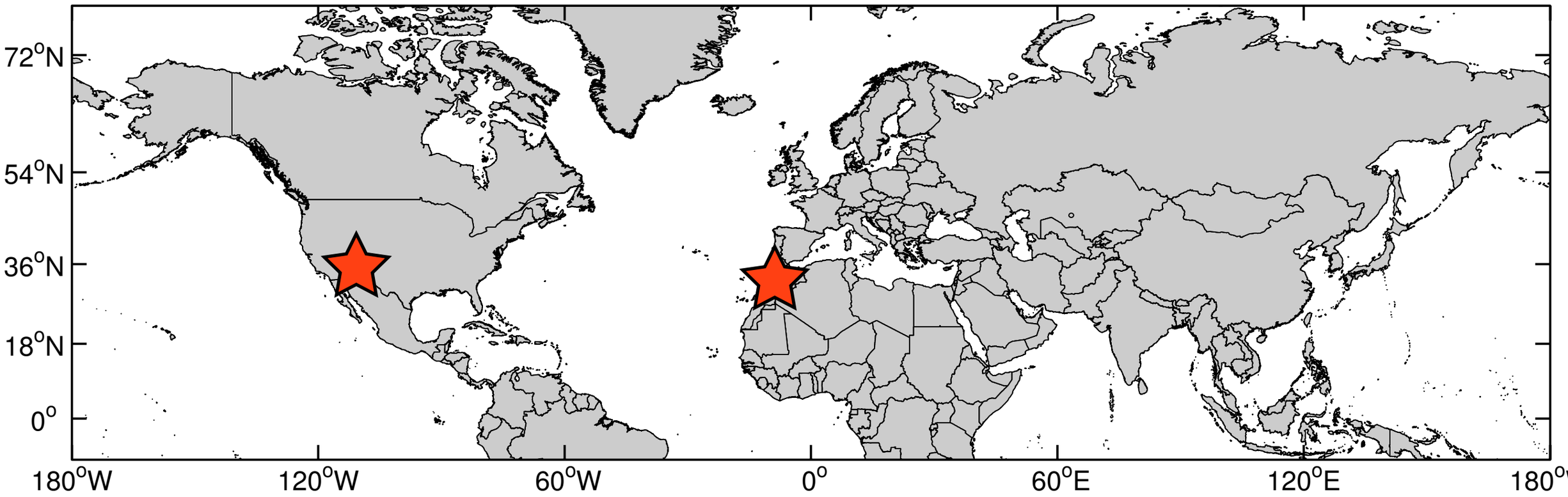
Ed Cook et al. 1995

Regional curve standardization (RCS) applied to Moroccan tree-ring series suggest a persistently dry Medieval Epoch



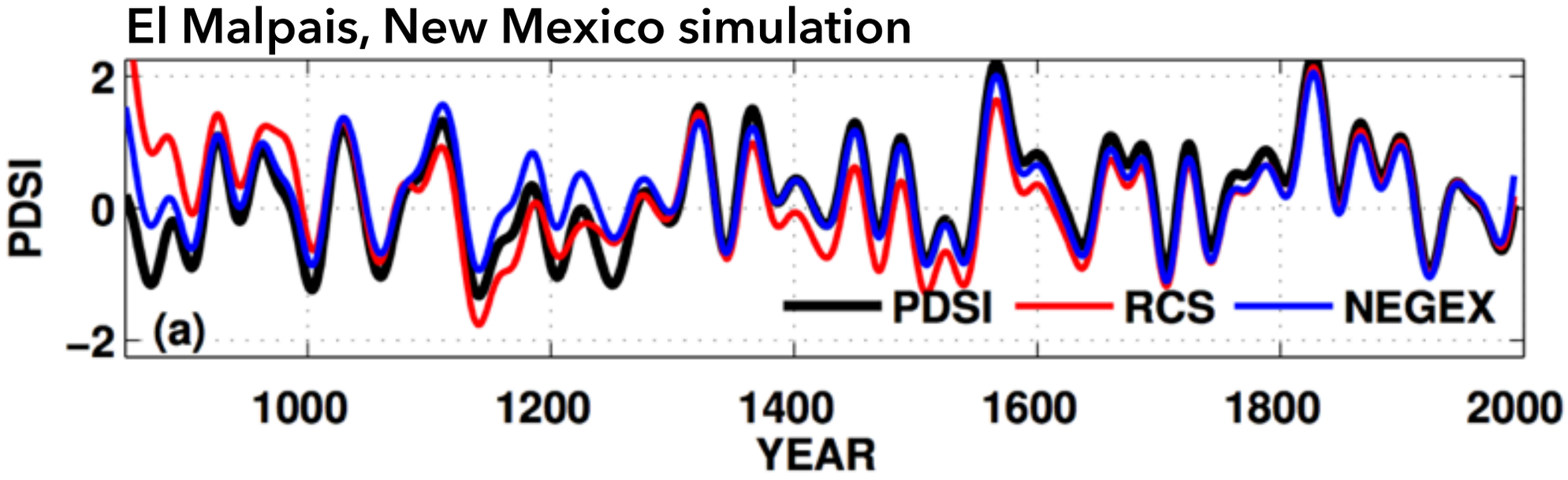
Esper et al. 2007

Pseudoproxy studies of regional curve standardization detrending at moisture-sensitive tree-ring sites



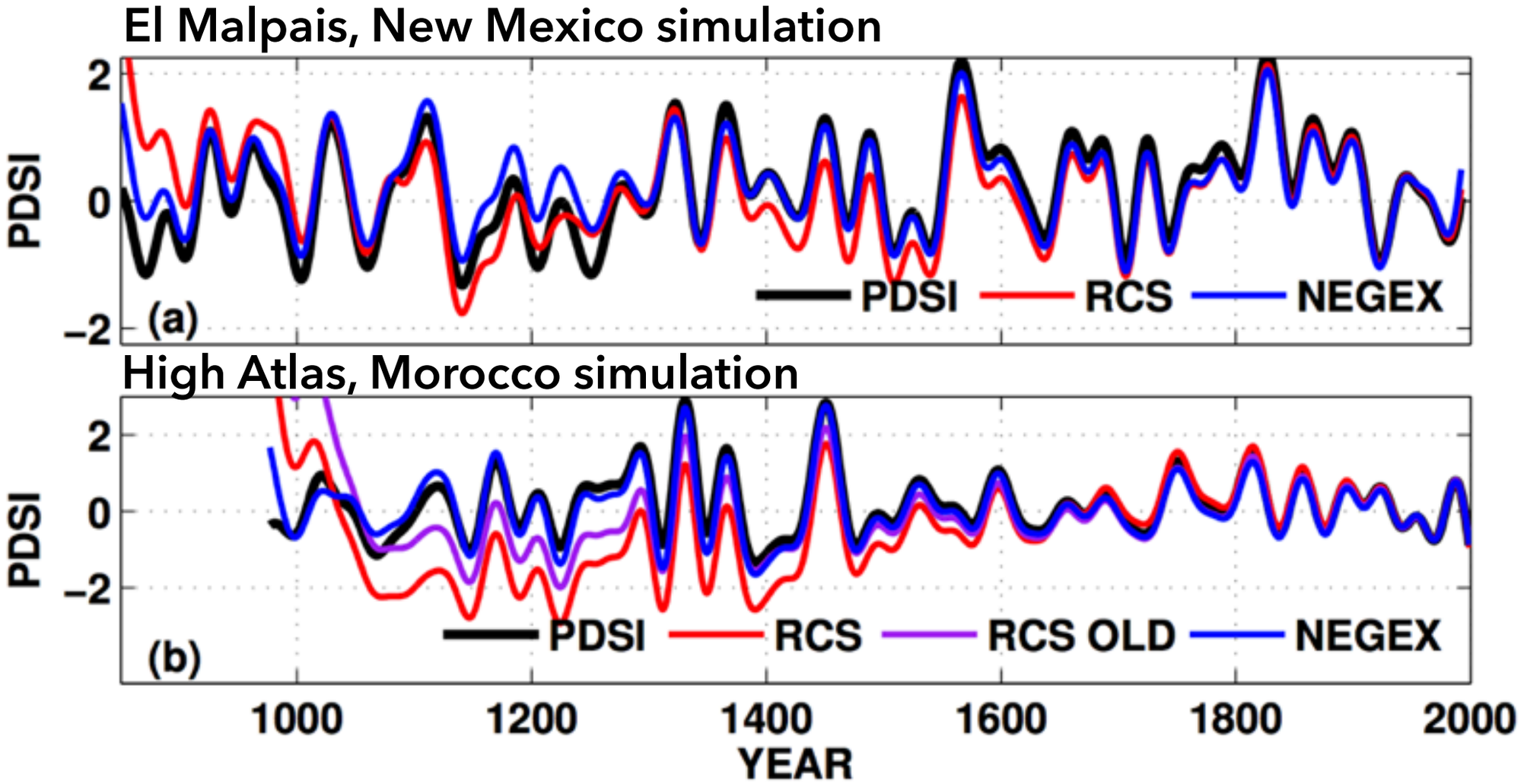
Pseudoproxy experimental design

Extract growth curves from raw tree-ring width data → Impose curves on pseudoclimate signal to generate simulated width series → Test detrending and standardization methods for retrieving known pseudoclimate signal



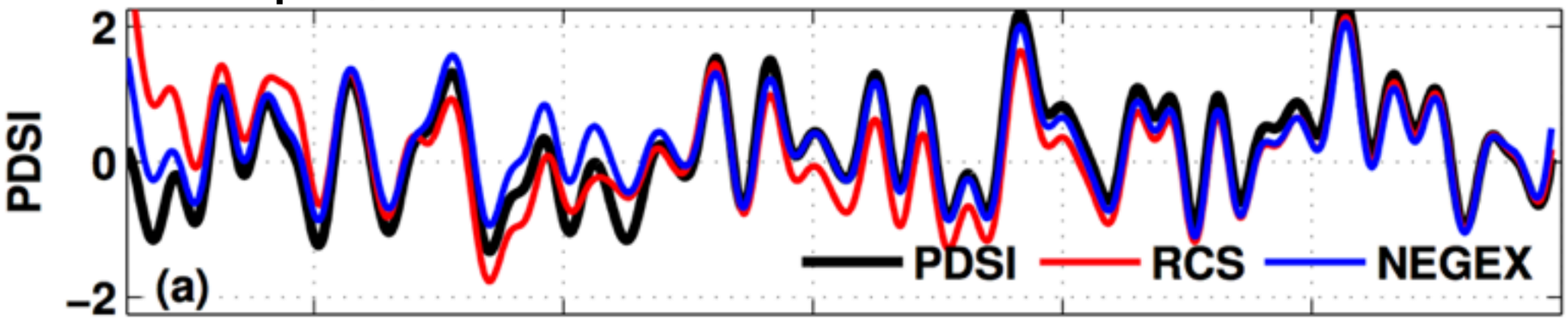
why do both these solutions work?

segments are long and a single curve is reflective of growth trend through times

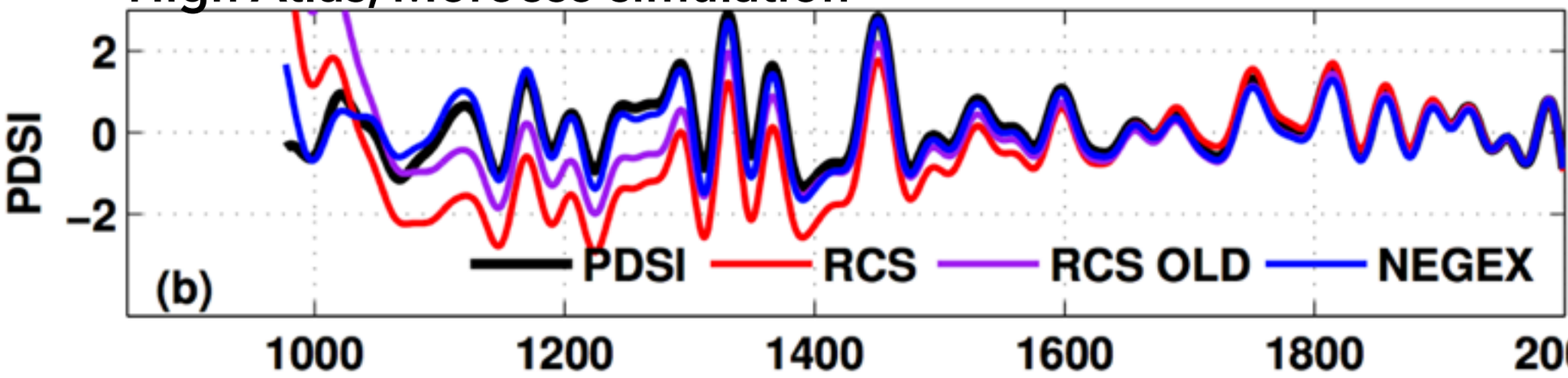


why does traditional detrending work?
segments are long relative to timescale of modeled climate variability

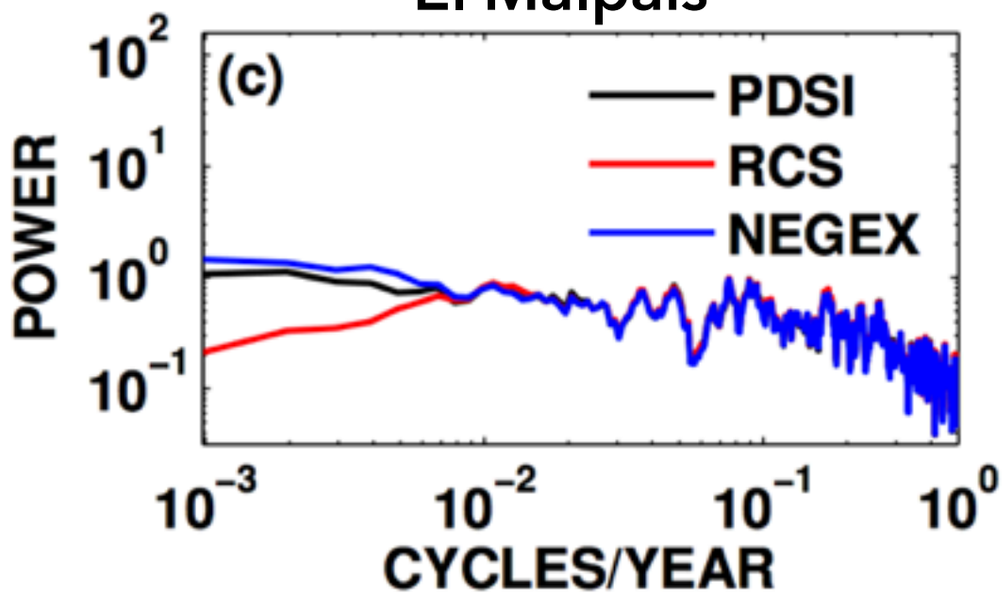
El Malpais, New Mexico simulation



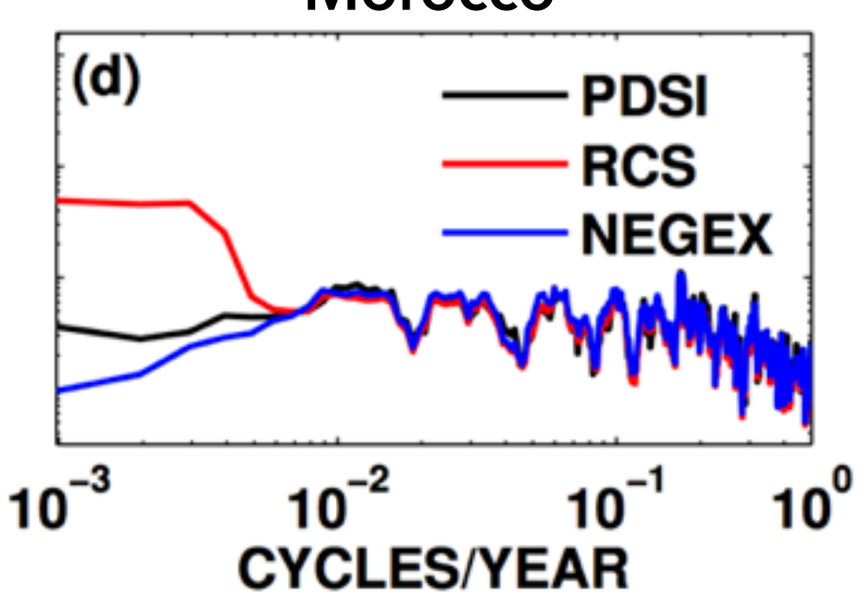
High Atlas, Morocco simulation



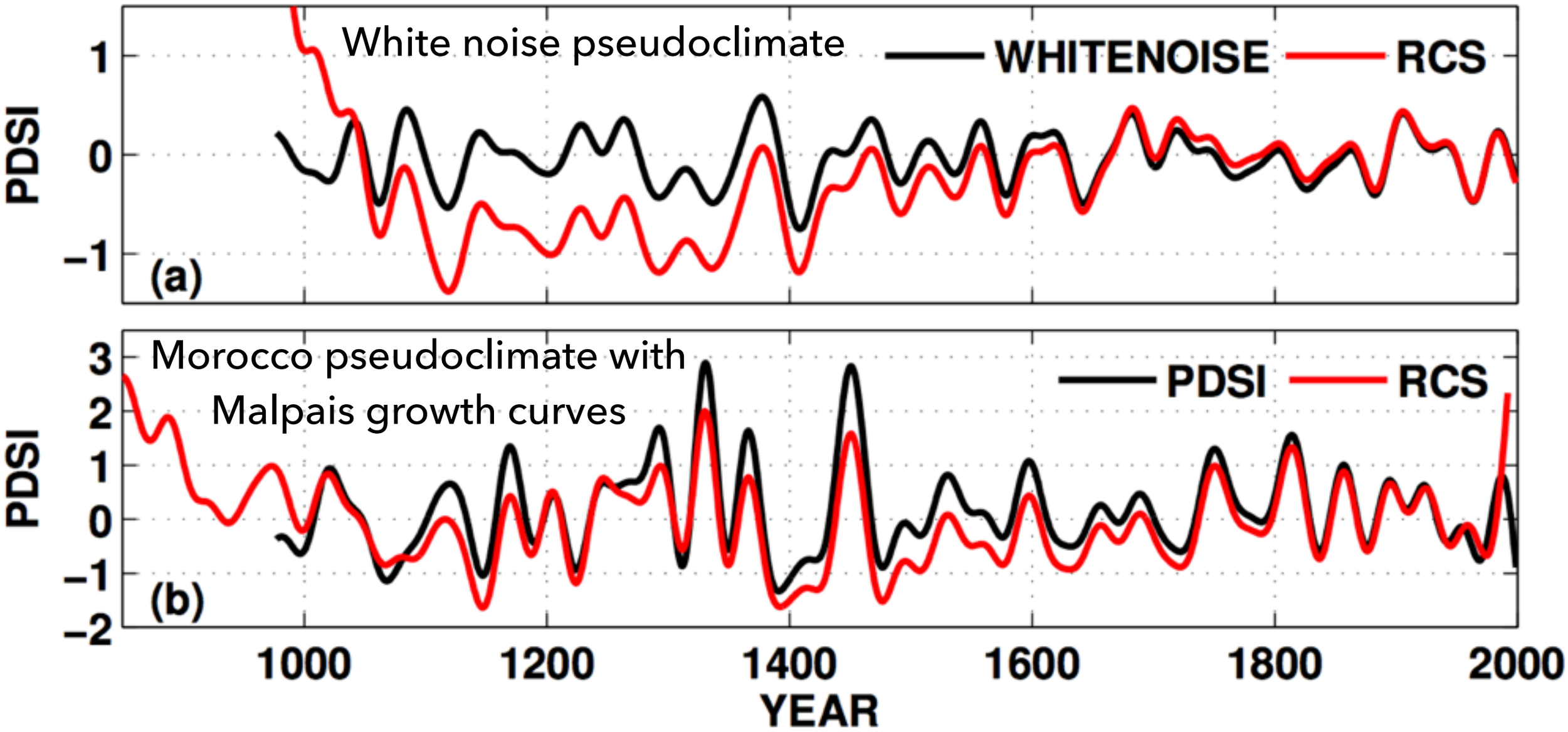
El Malpais



Morocco



High Atlas, Morocco alternative simulations



RCS bias in Morocco arises because of growth curves (older trees != younger trees)

Take home messages

Trees are not rain gauges. They contain filtered, seasonally biased, sometime multivariate signals across space and through time.

Detrending is the great ‘known unknown’, but we can’t simply assume trees *do or do not capture* certain wavelengths nor can we assume a particular spectrum of hydroclimate variability

Model/data comparison requires knowledge of biological basics + process-based understanding - **mashing together proxies of different timescales, seasonalities, etc. is unlikely to yield deeper understanding.**