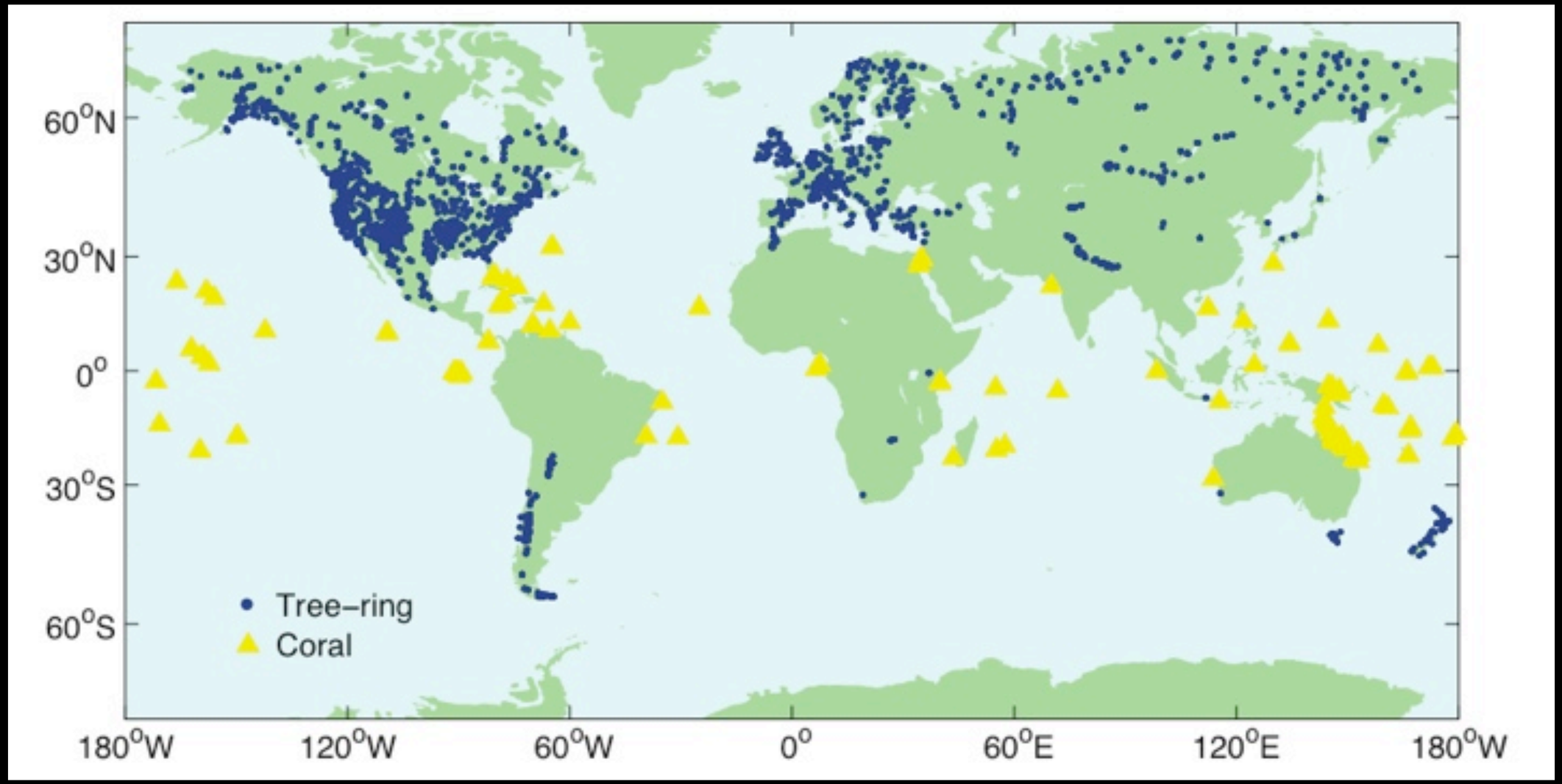
What can we learn from the Monsoon Asia Drought Atlas [MADA]?

Kevin Anchukaitis

Edward Cook, Brendan Buckley, Rosanne D'Arrigo, Benjamin Cook, Gordon Jacoby, Andrew Bell, Dan Penny, Jess Tierney, Roland Fletcher, Johann Jungclaus, Caspar Ammann, Rob Wilson, Caroline Ummenhofer, Jonathan Barichivich, & Le Canh Nam

NSF ATM 0402474
NSF AGS 0908971

Relatively few long high-resolution terrestrial **tropical** proxies



NOAA WDC, December 2007

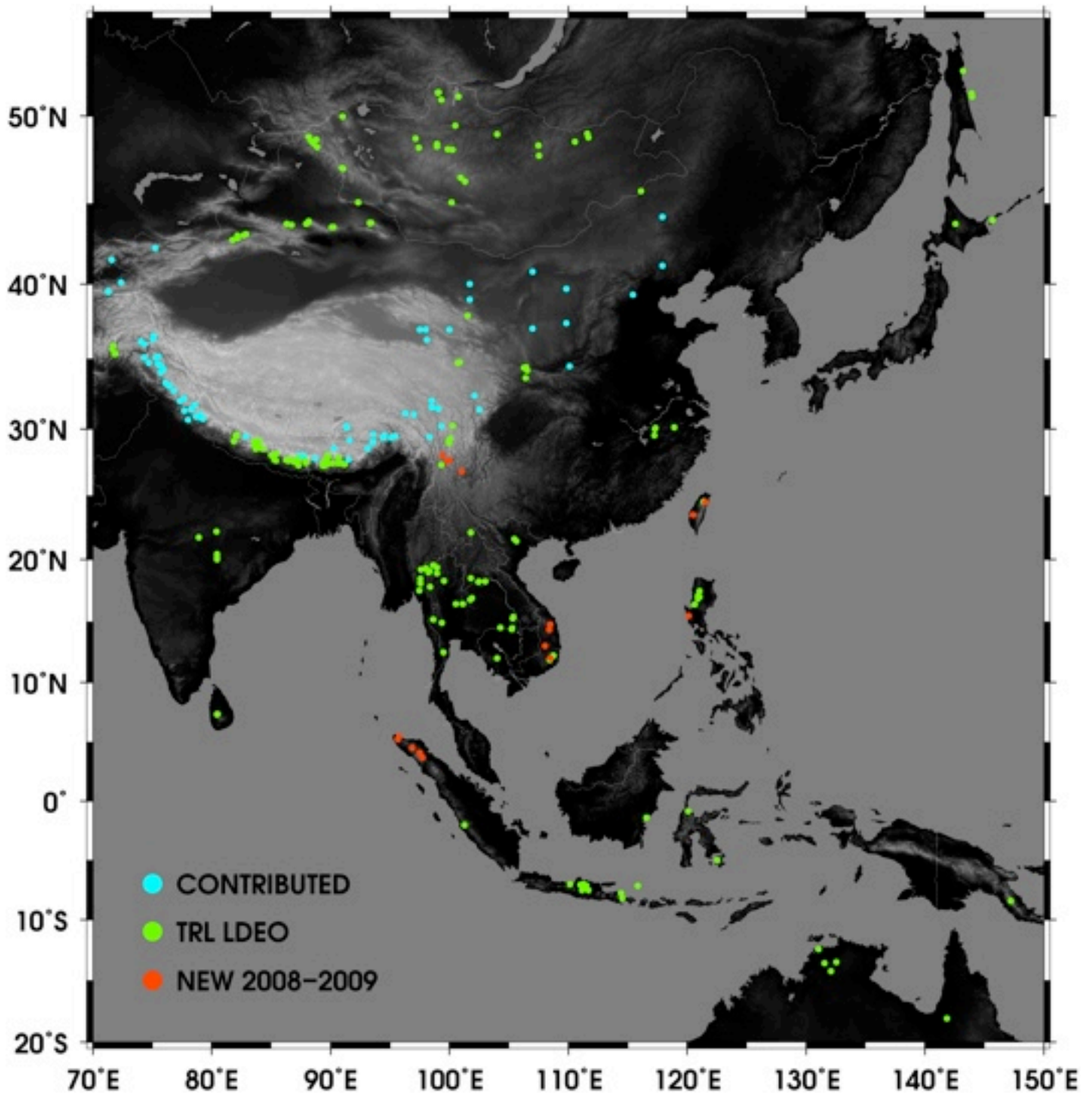
Tropical marine proxies from corals, sediments
terrestrial from speleothems and laminated lake sediments

Photo by Andy Nelson, Christian Science Monitor

755 mm
847 mm
809 mm
770 mm
823 mm
787 mm
901 mm
840 mm

Photo by Andy Nelson, Christian Science Monitor

THE MONSOON ASIA DROUGHT ATLAS [MADA]



A **327 chronology** tree-ring network from Vietnam, the Philippines, Pakistan, Kyrgistan, India, Sri Lanka, Nepal, Bhutan, Thailand, Laos, Cambodia, Malaysia, Indonesia, Australia, New Guinea, Vanuatu, China, Taiwan, Mongolia, Russia, Korea, and Japan.

Used to reconstruct gridded seasonal (MAM, **JJA**, SON, DJF) Palmer Drought Severity Index (**PDSI**) over **534 individual 2.5 degree grid cells back to A.D. 1000.**

Cook et al., Science, 2010

NSF Paleoclimate ATM 0402474

THE MONSOON ASIA DROUGHT ATLAS [MADA]

A **327 chronology** tree-ring network = makes this type of data product possible

Our target field: **Palmer Drought Severity Index** (PDSI) over 534 individual 2.5 degree grid cells from Dai and Trenberth with Queen's Case [v1] or Regularized Expectation Maximization [v1.1] for missing value imputation

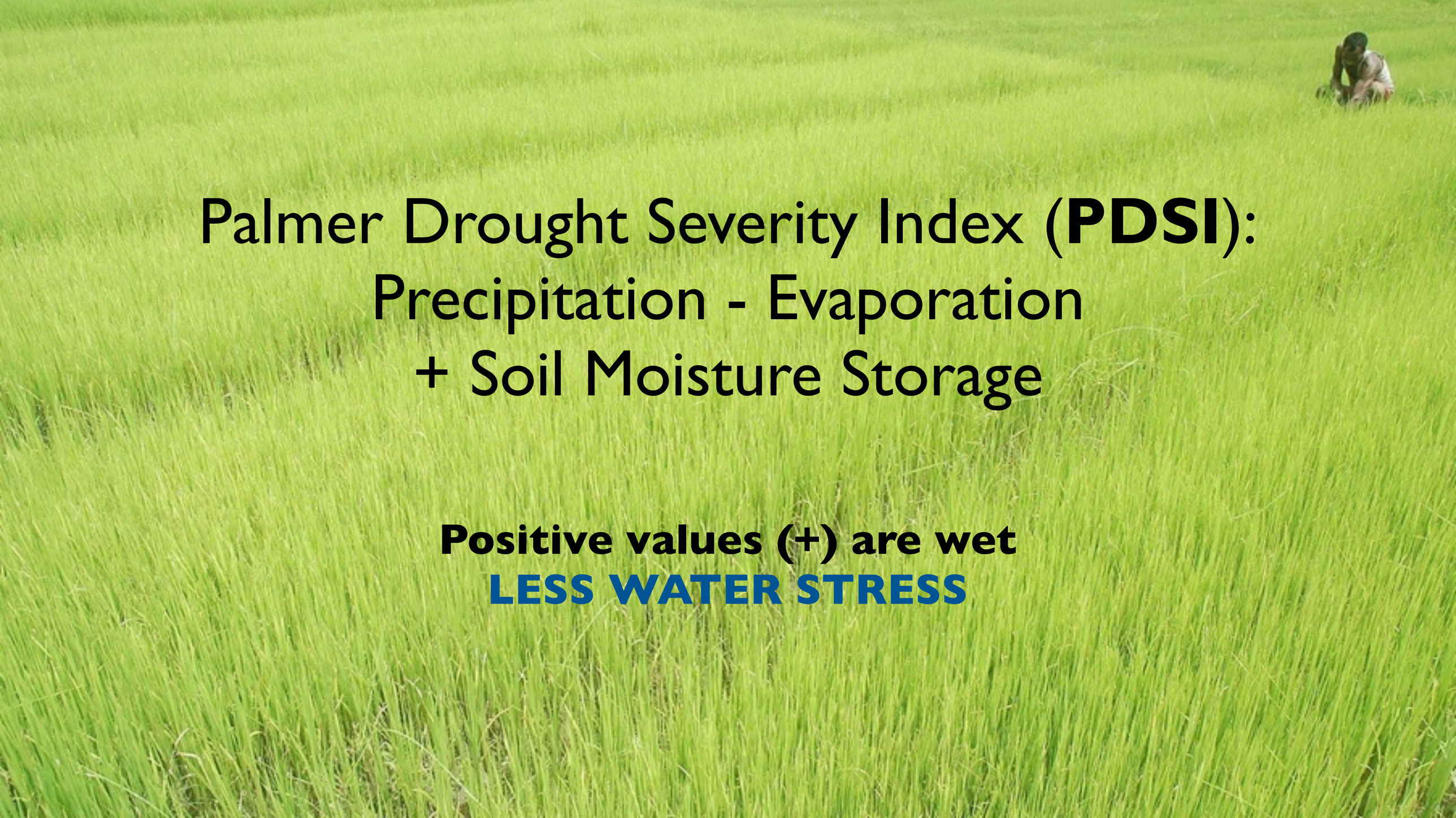
Point-to-Point Regression Approach [Cook et al. 1999], 24 member ensemble varying search radius and chronology weighting

Calibration and out-of-sample **validation** during the instrumental period

Extended validation over India (long instrumental records) and **historical support** for prehistoric droughts

Cook et al., Science, 2010

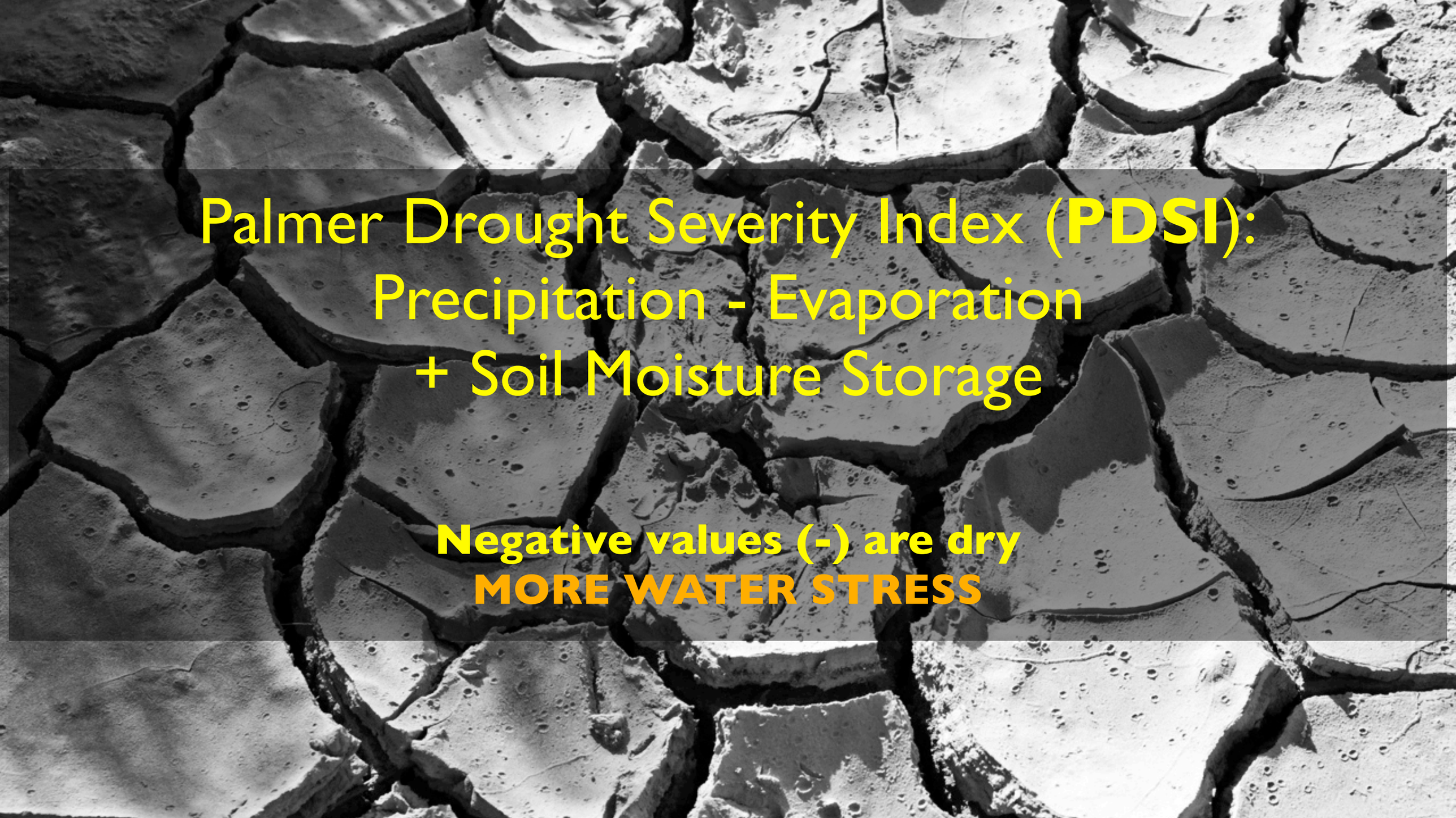
NSF Paleoclimate ATM 0402474



Palmer Drought Severity Index (**PDSI**):
Precipitation - Evaporation
+ Soil Moisture Storage

Positive values (+) are wet

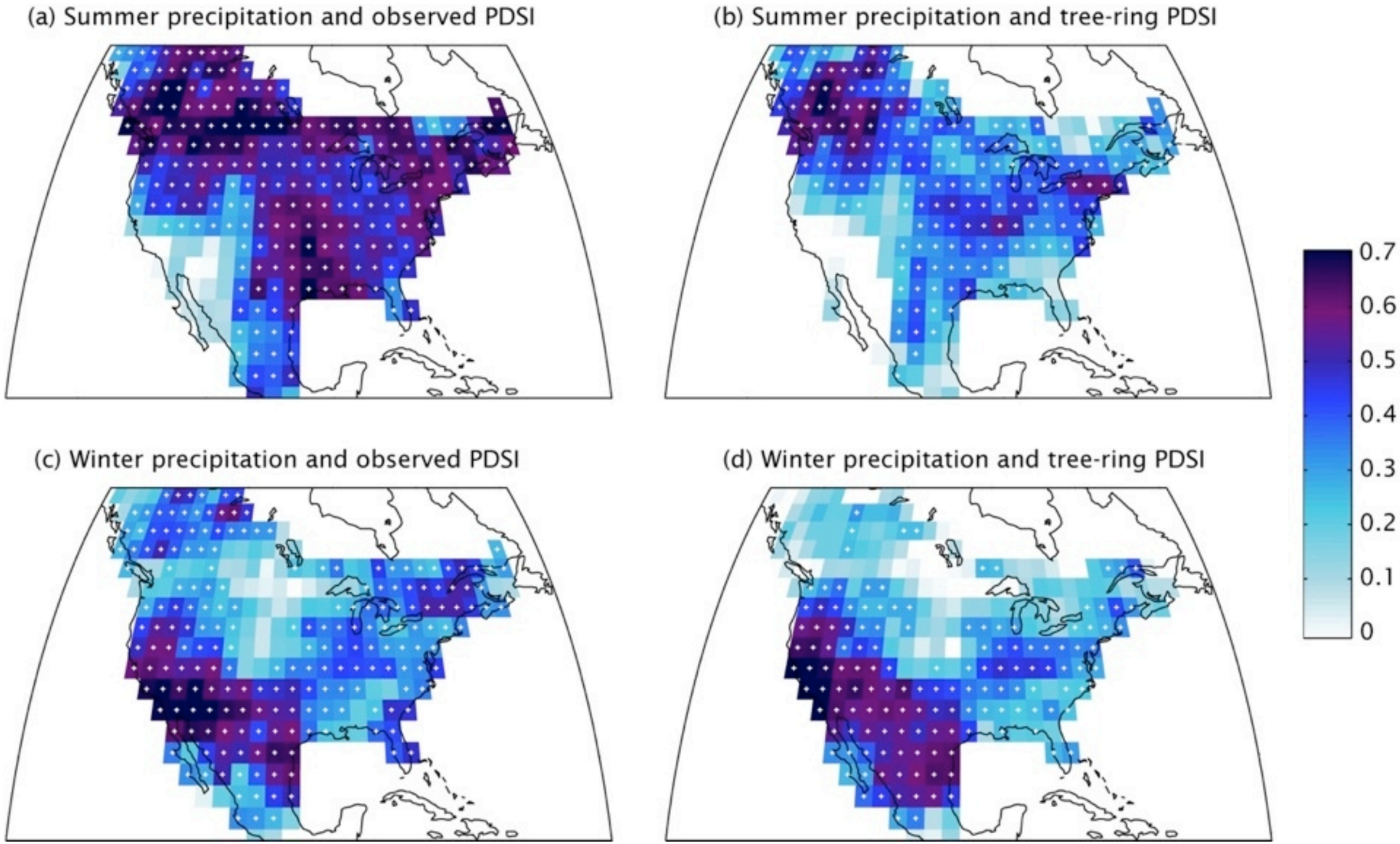
LESS WATER STRESS



Palmer Drought Severity Index (**PDSI**):
Precipitation - Evaporation
+ Soil Moisture Storage

Negative values (-) are dry
MORE WATER STRESS

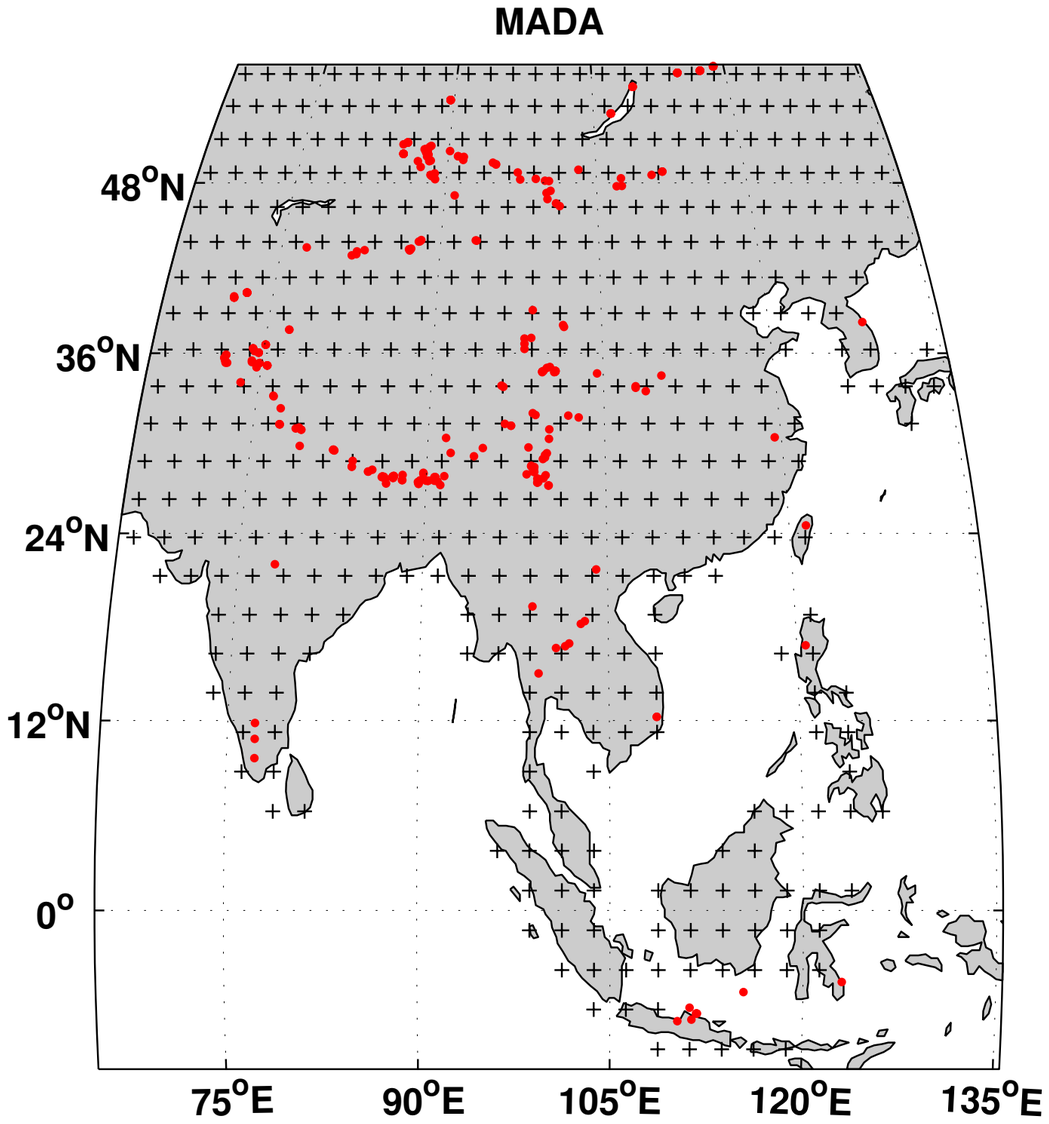
Why PDSI and why point-to-point (P2P) regression?

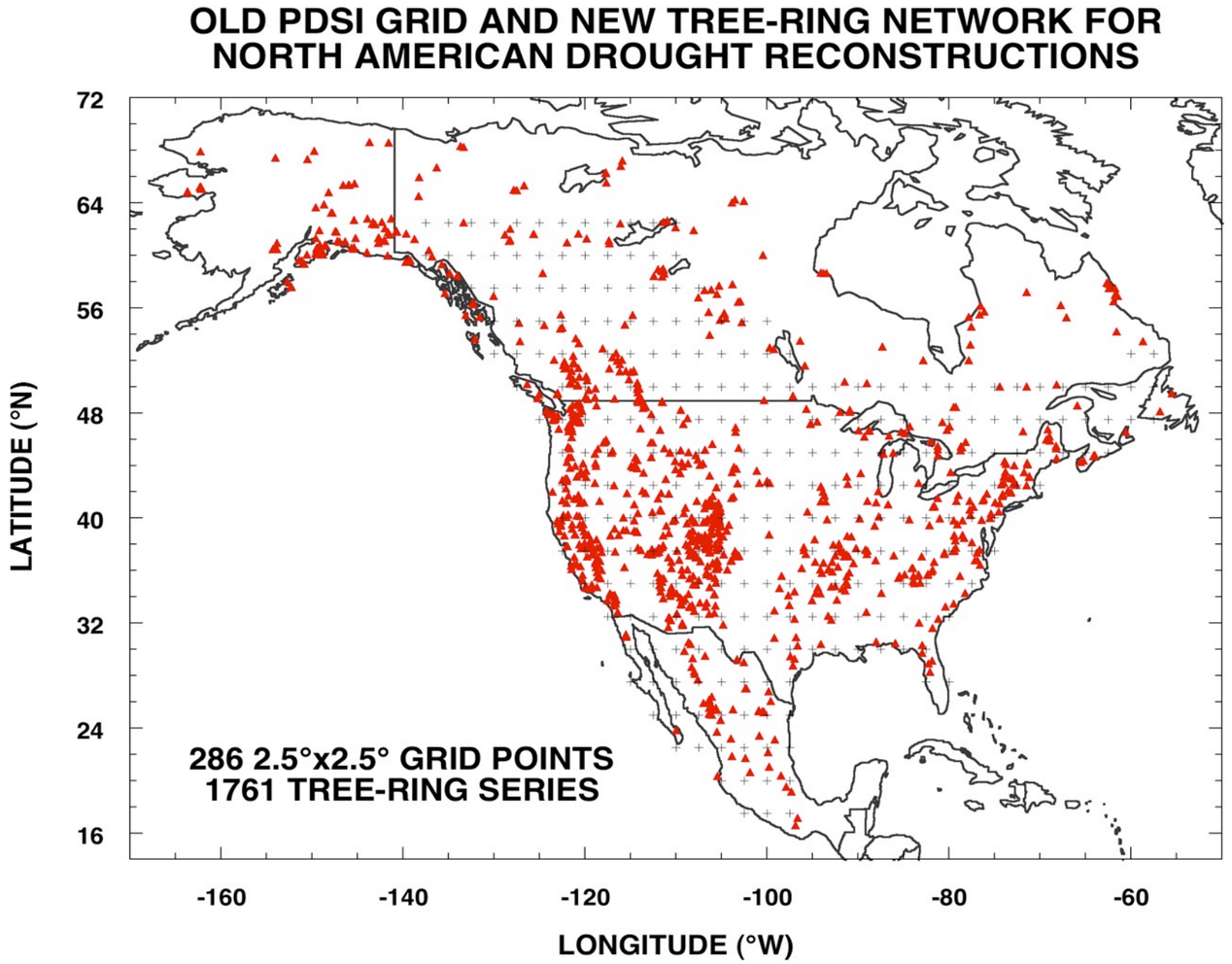


St. George et al. 2010

PDSI allows an 'apples-to-apples' comparison across diverse hydroclimate regions

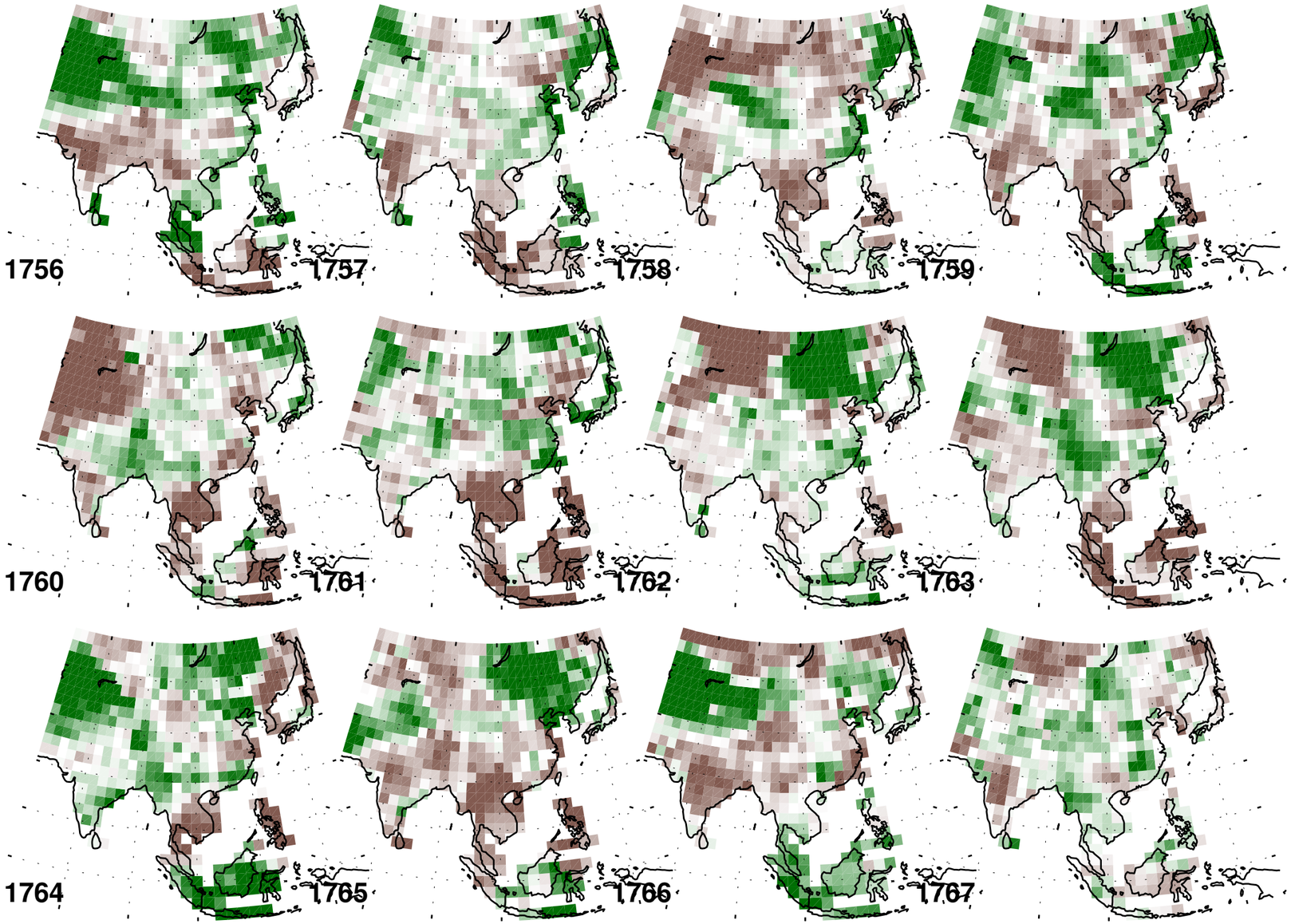
Why PDSI and why point-to-point (P2P) regression?





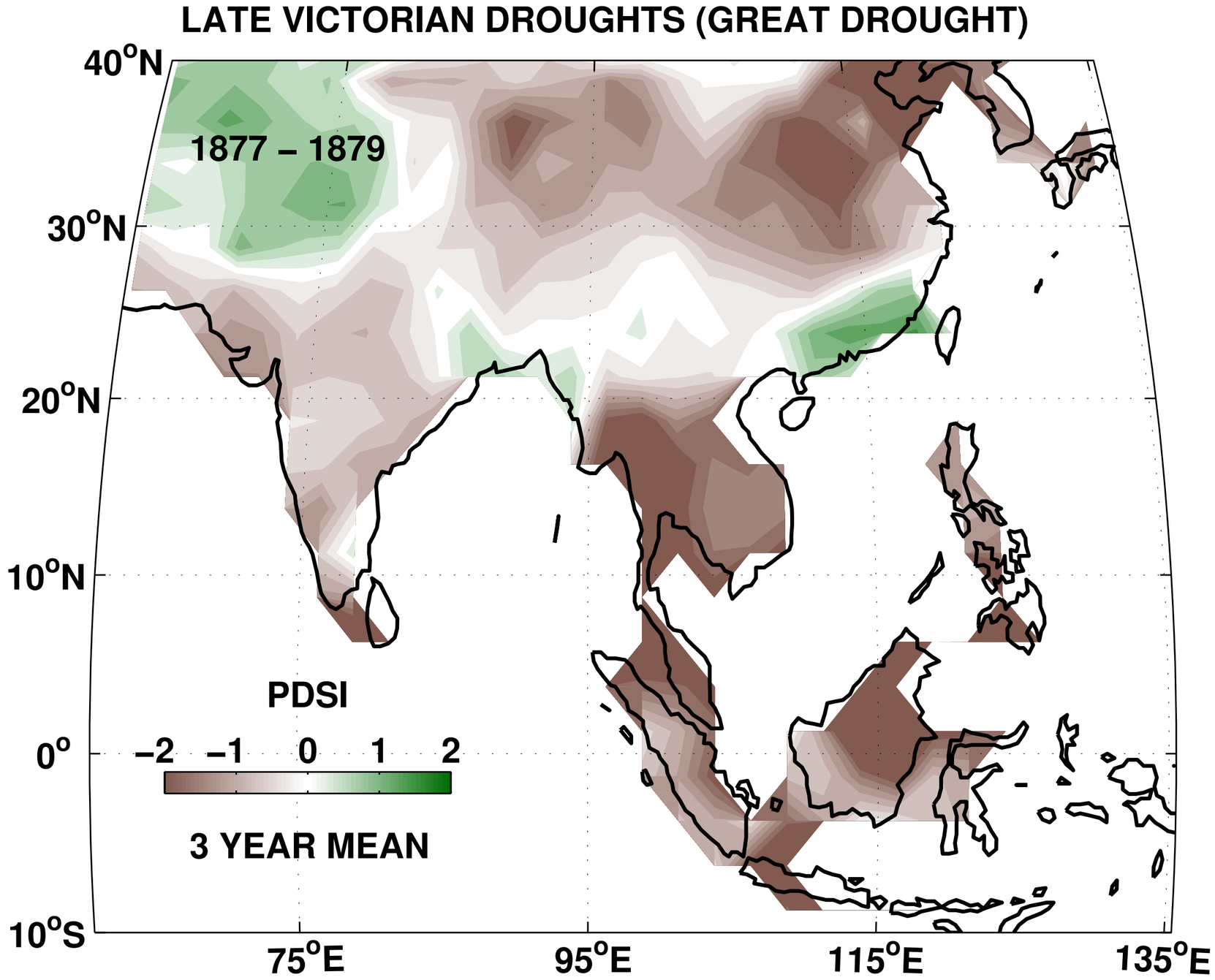
Reduced space approaches over the whole MADA domain including PCR, RegEM Ridge, RegEM TTLS all failed to capture important gradients and in some cases created clear artifacts compared to site-wise, well-validated single chronology reconstructions

The ‘Strange Parallels’ Drought, 1756-1768

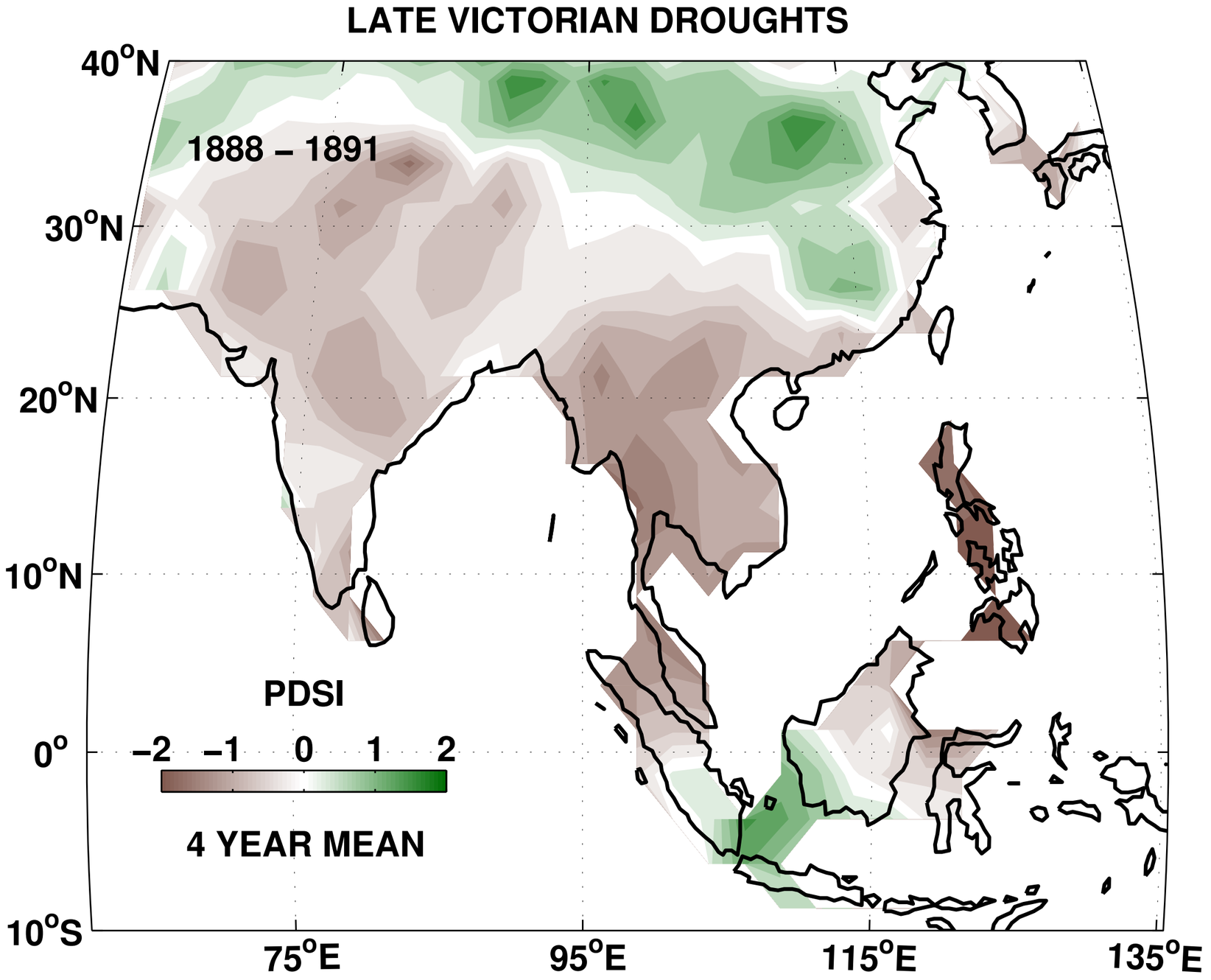


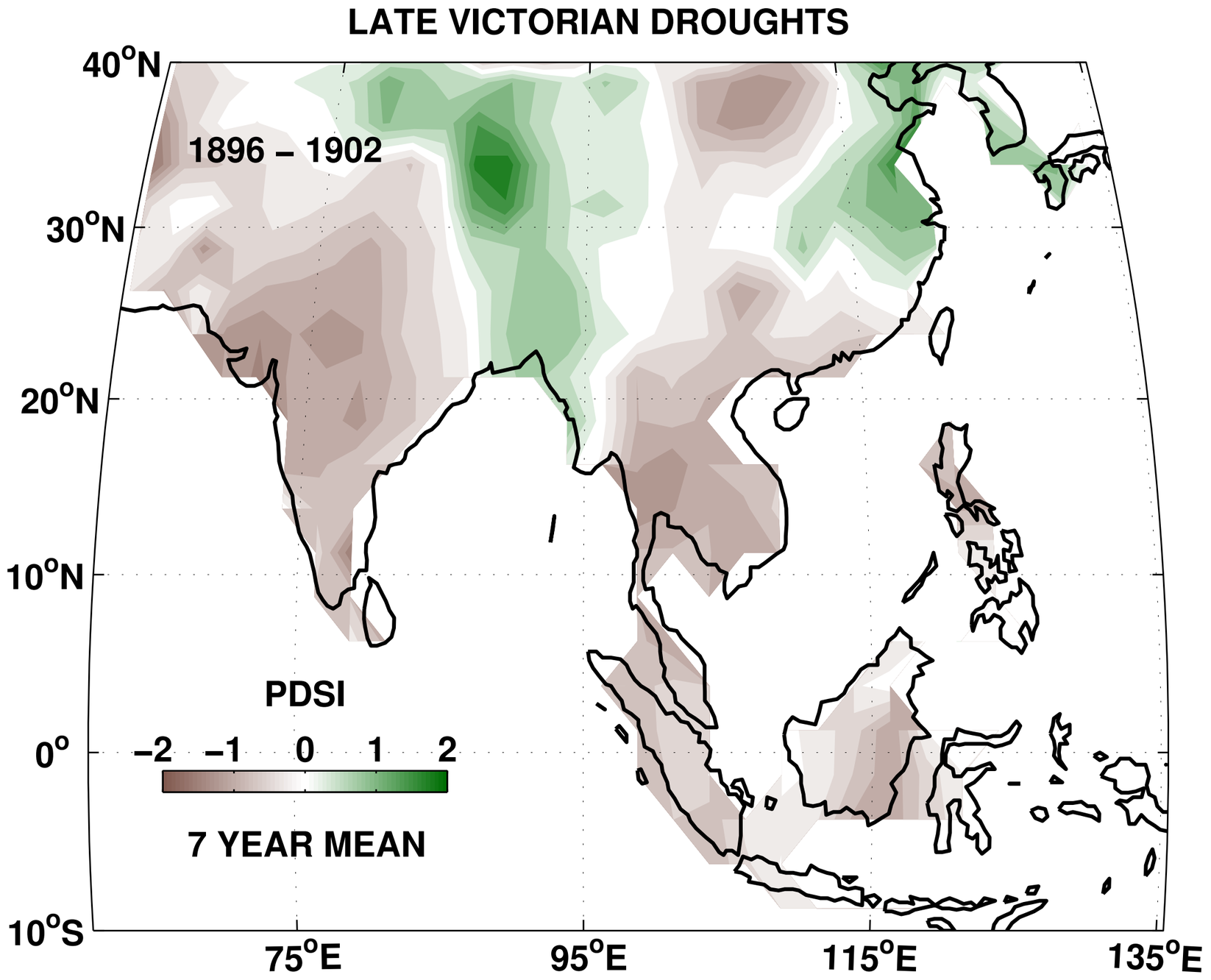
The **MADA** (like the **NADA** before it and the **OWDA**, **SADA**, and **NWADA** to come) provides gridded, annual resolution maps of drought that can be directly compared to model and instrumental data

Late Victorian Holocausts and the Great Drought

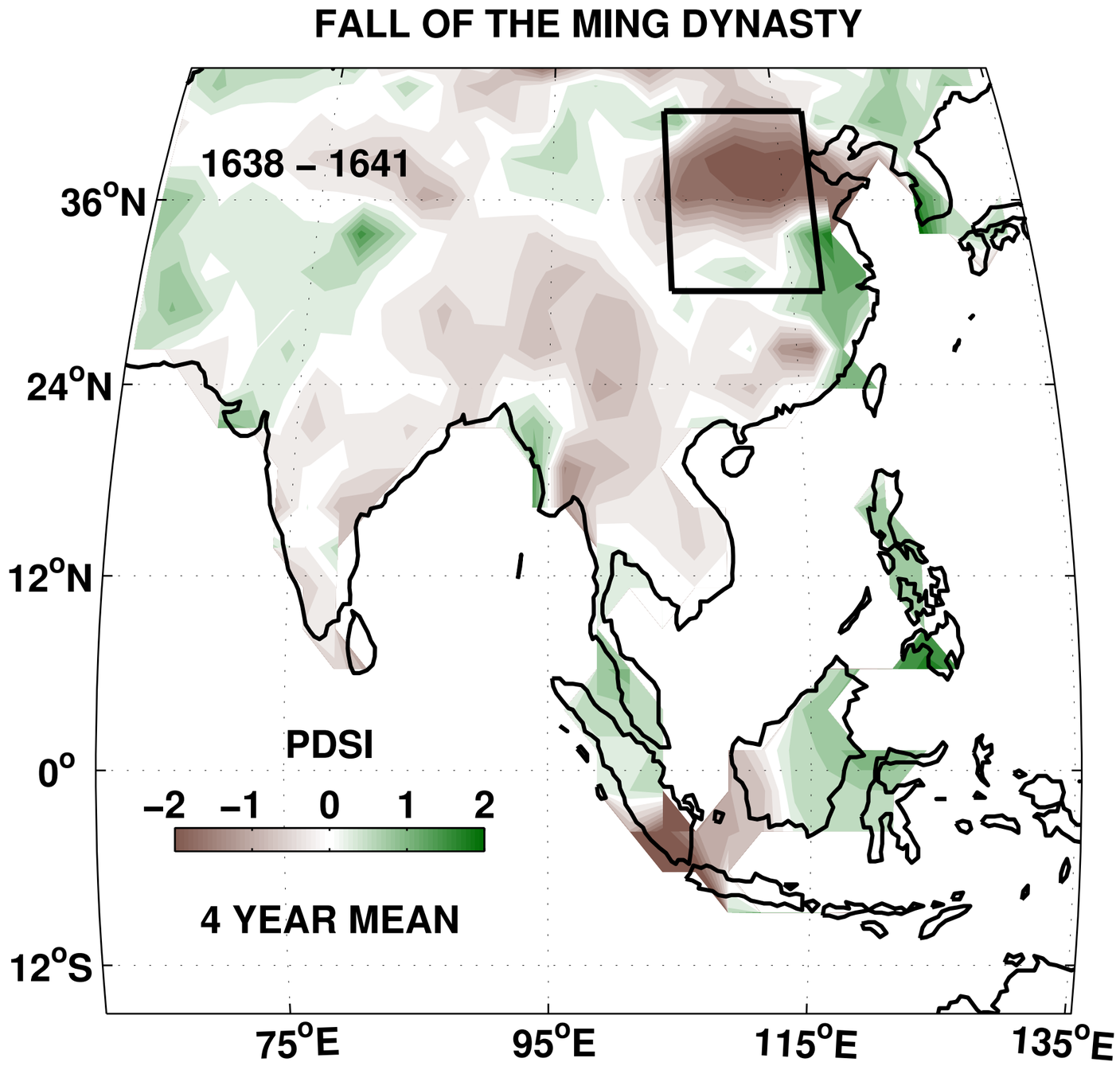


Cook et al., Science, 2010

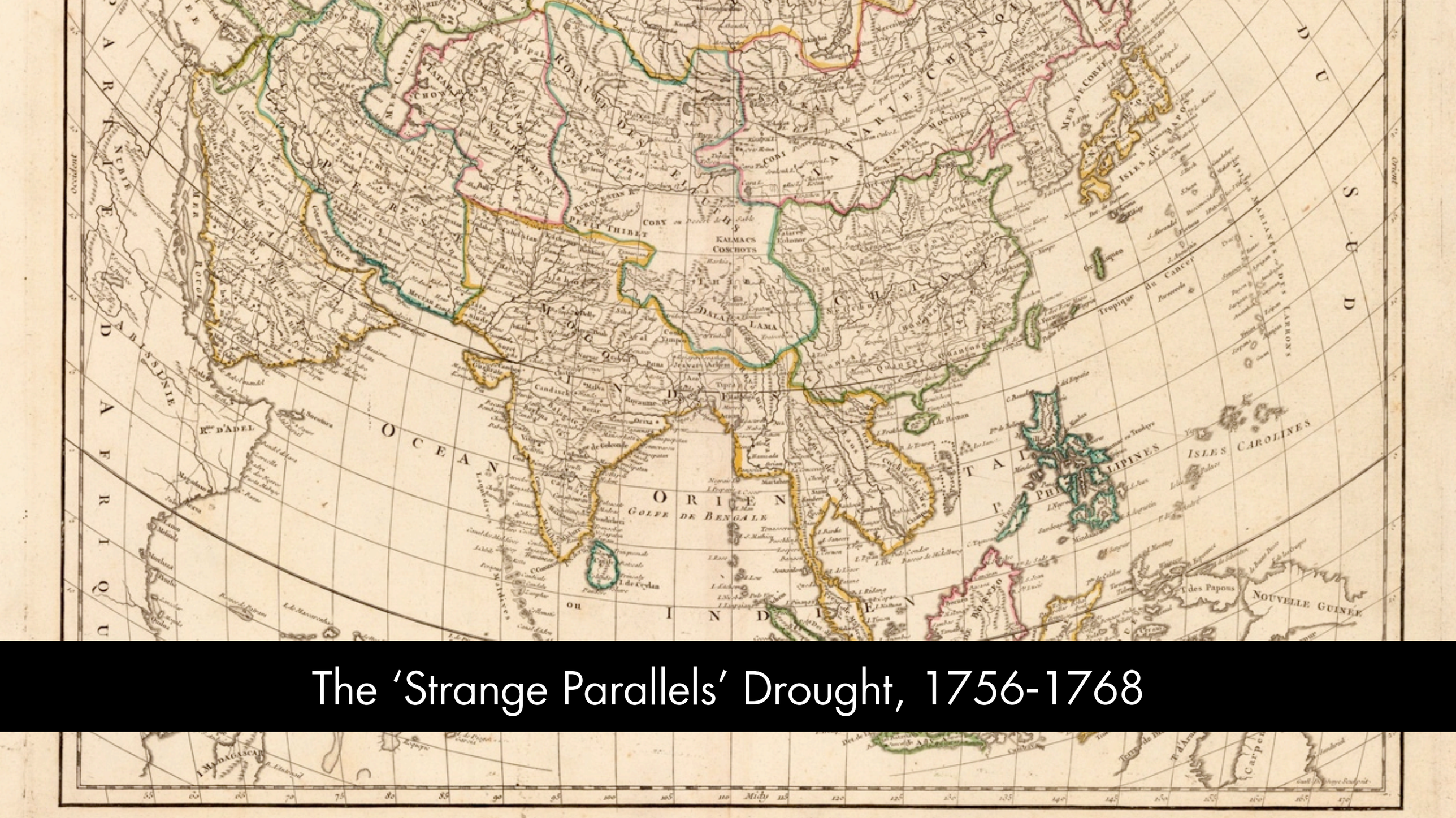

LATE VICTORIAN DROUGHTS
1888 – 1891
40°N
30°N
20°N
10°N
0°
10°S
75°E
95°E
115°E
135°E
PDSI
−2 −1 0 1 2
4 YEAR MEAN


LATE VICTORIAN DROUGHTS
1896 – 1902
40°N
30°N
20°N
10°N
0°
10°S
75°E
95°E
115°E
135°E
PDSI
−2 −1 0 1 2
7 YEAR MEAN

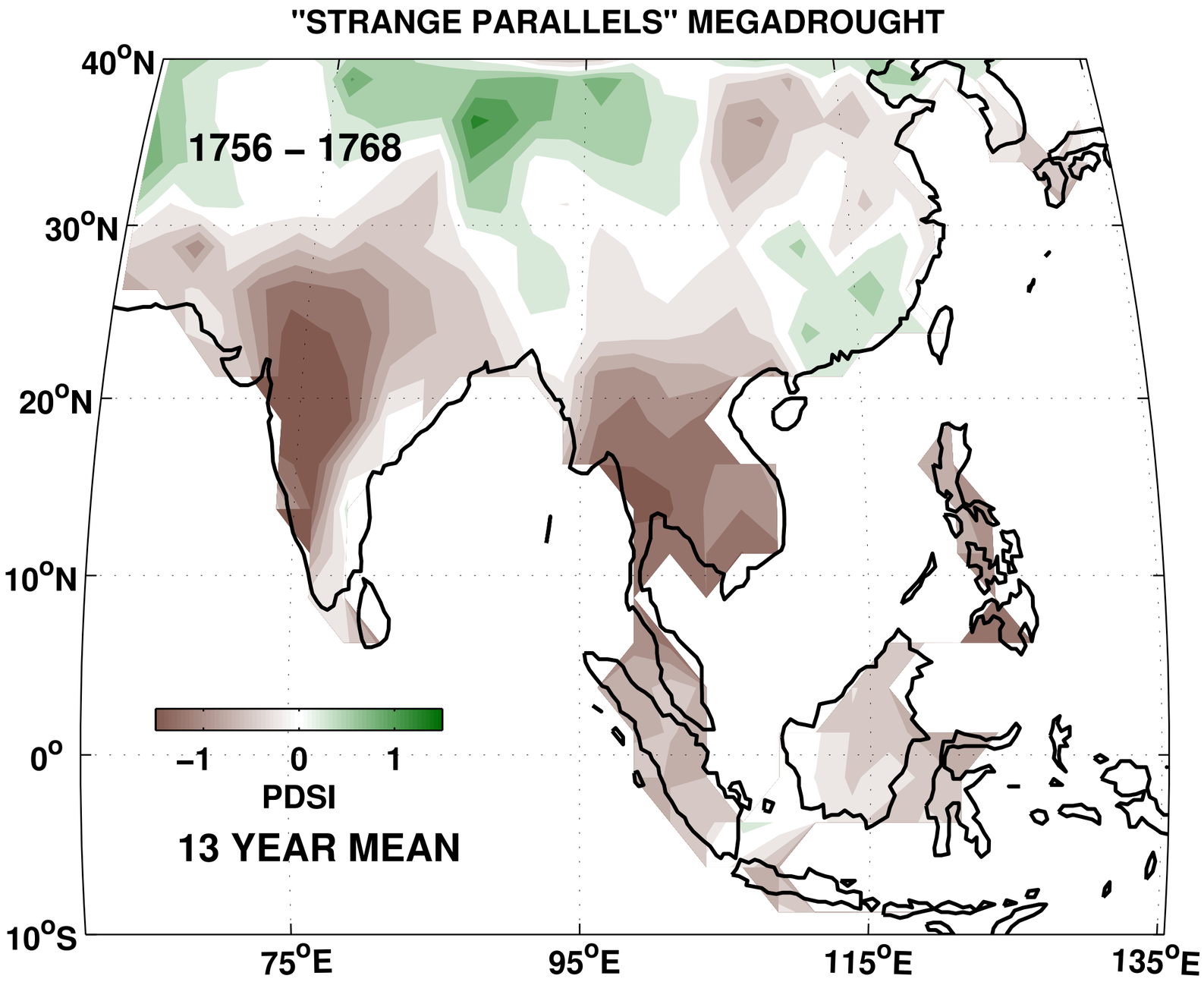
The Fall of the Ming Dynasty, 1644 CE



Cook et al., Science, 2010



The ‘Strange Parallels’ Drought, 1756-1768

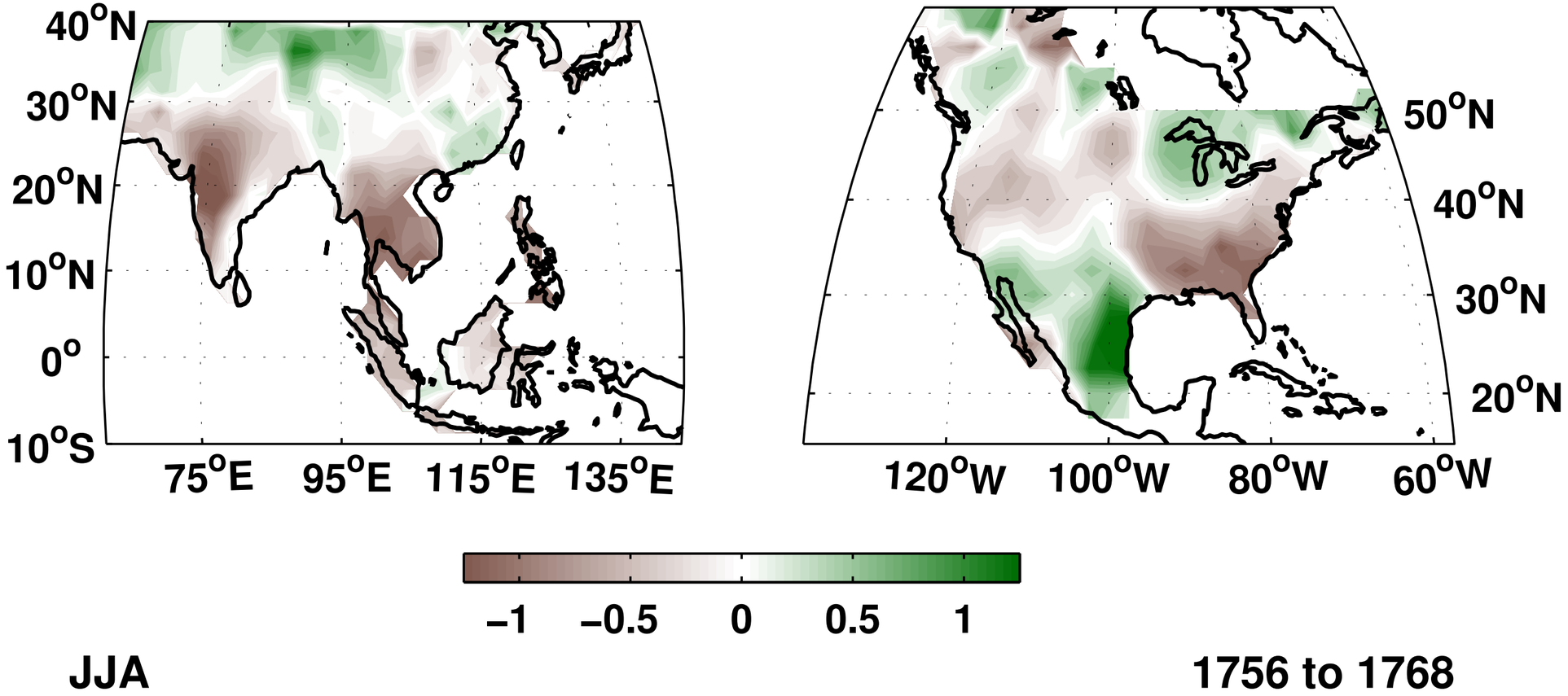


Cook et al., Science, 2010

STRANGE PARALLELS DROUGHT

MADA [Cook et al. 2010]

NADA [Cook et al. 2004]

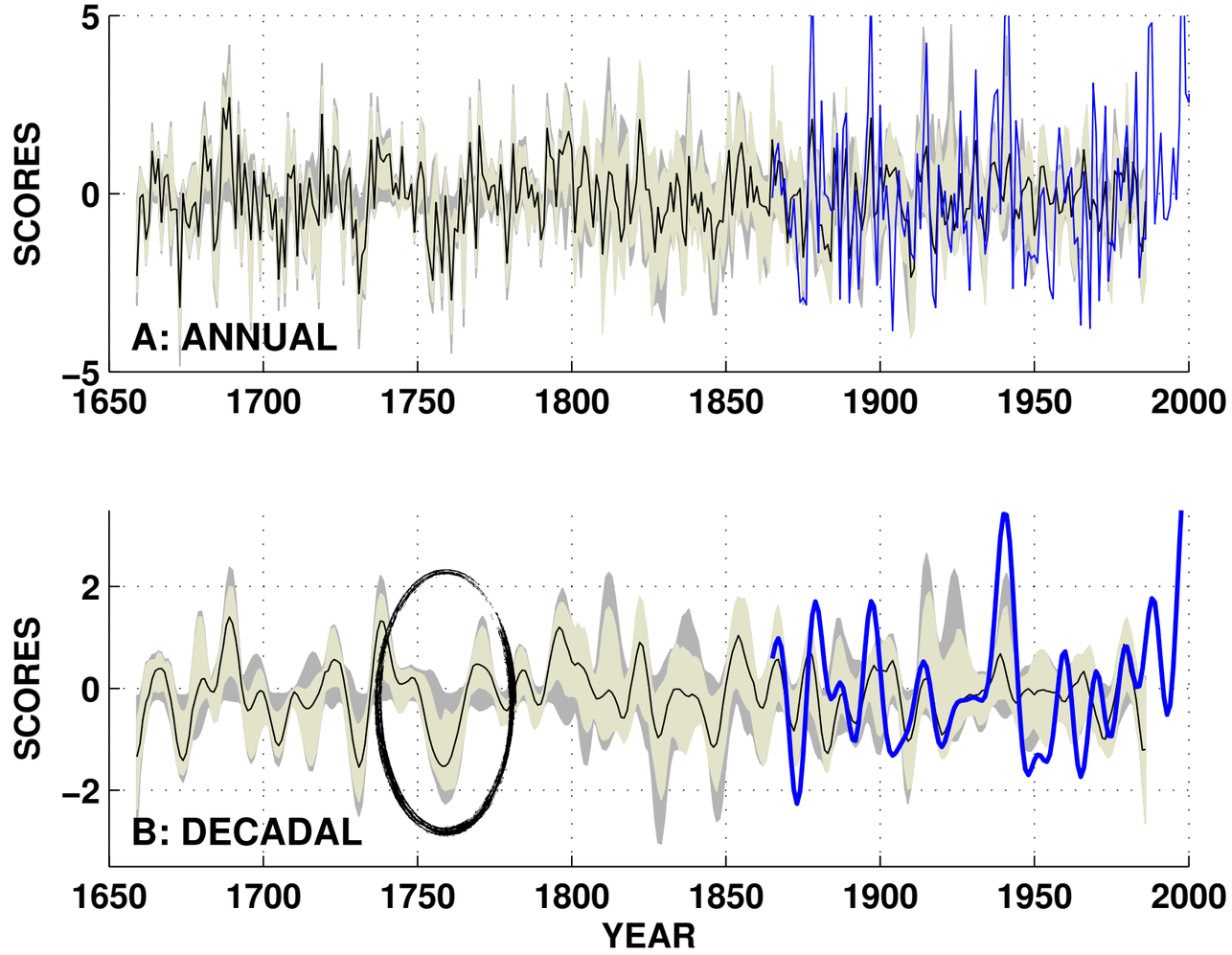


JJA

1756 to 1768

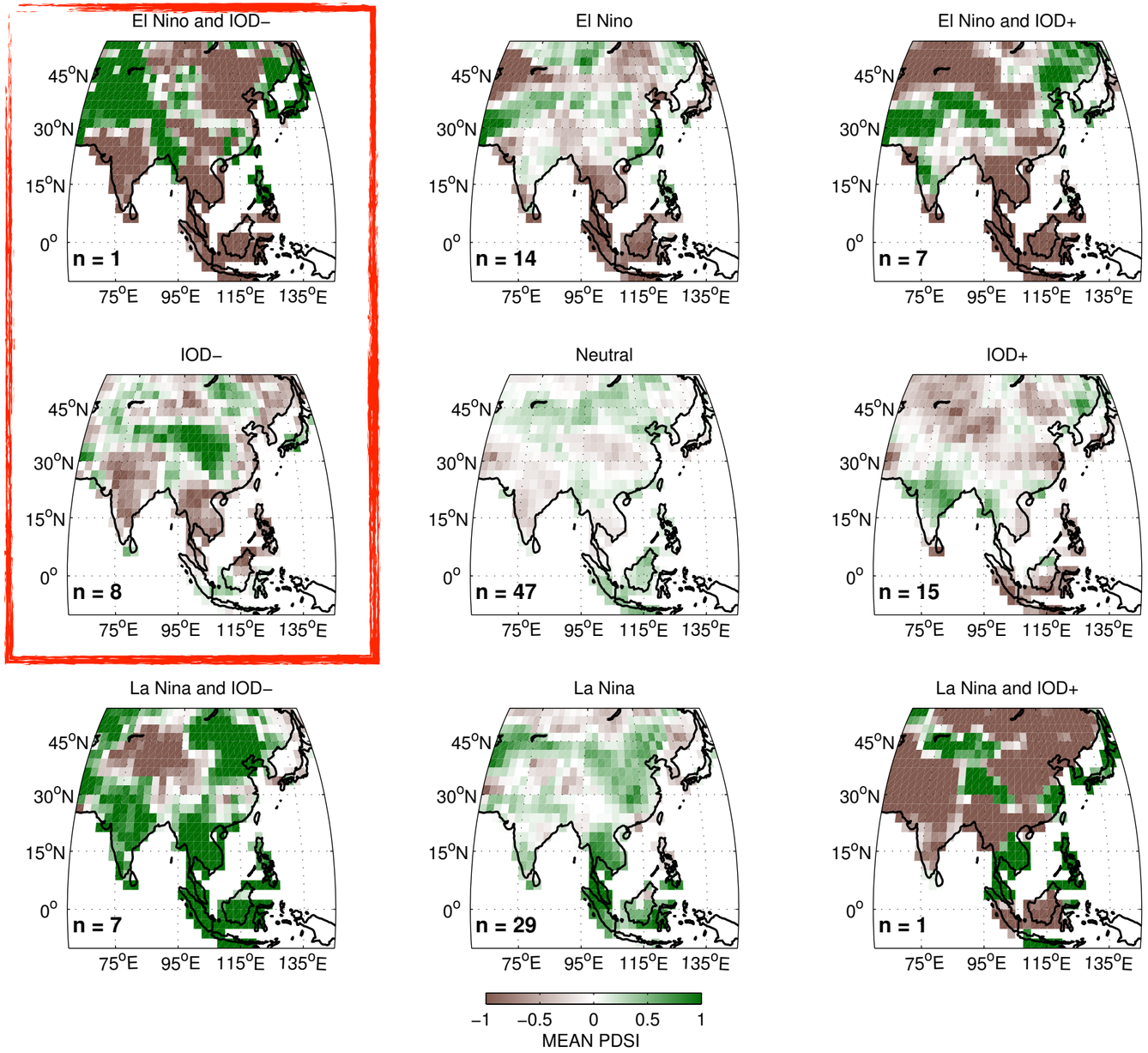
‘Strange Parallels’ a more classic ‘El Nino’ type drought? Dry throughout tropical Asia, Pacific Northwestern United States; North American monsoon region anomalously wet

Anchukaitis et al. in preparation



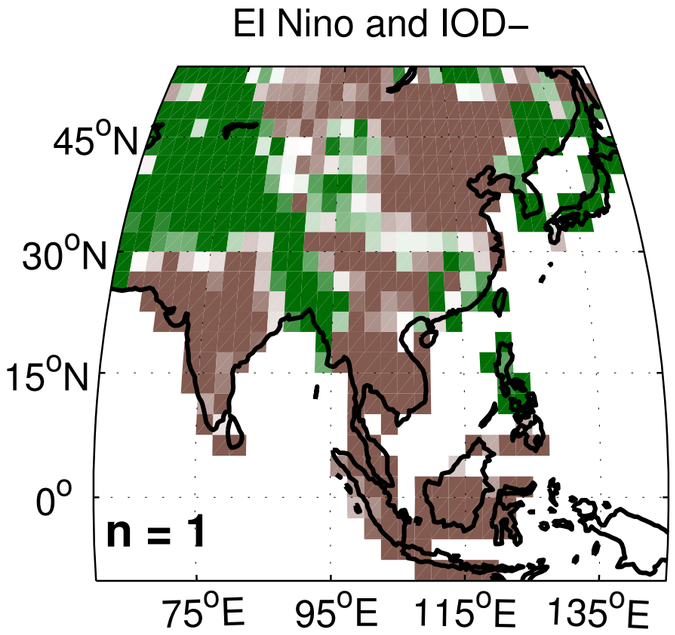
Ensemble Indian Ocean Basin Mode SST reconstruction using corals suggests colder Indian Ocean during 'Strange Parallels'

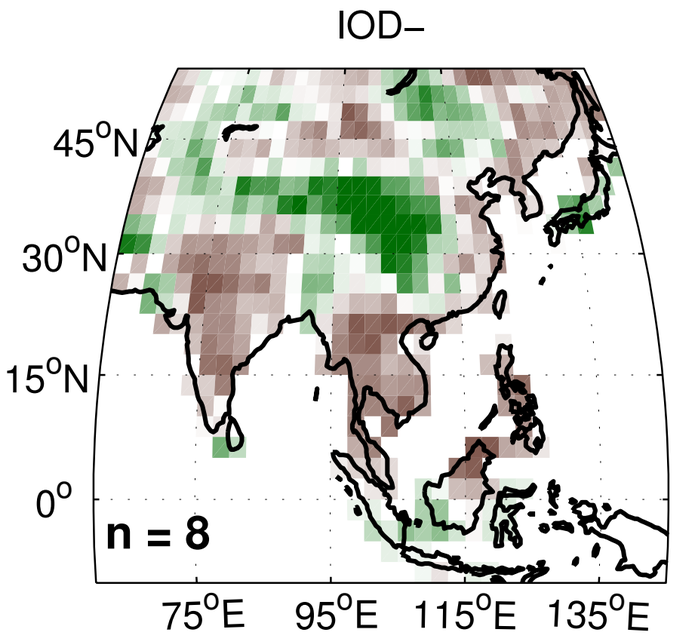
Anchukaitis et al. in preparation



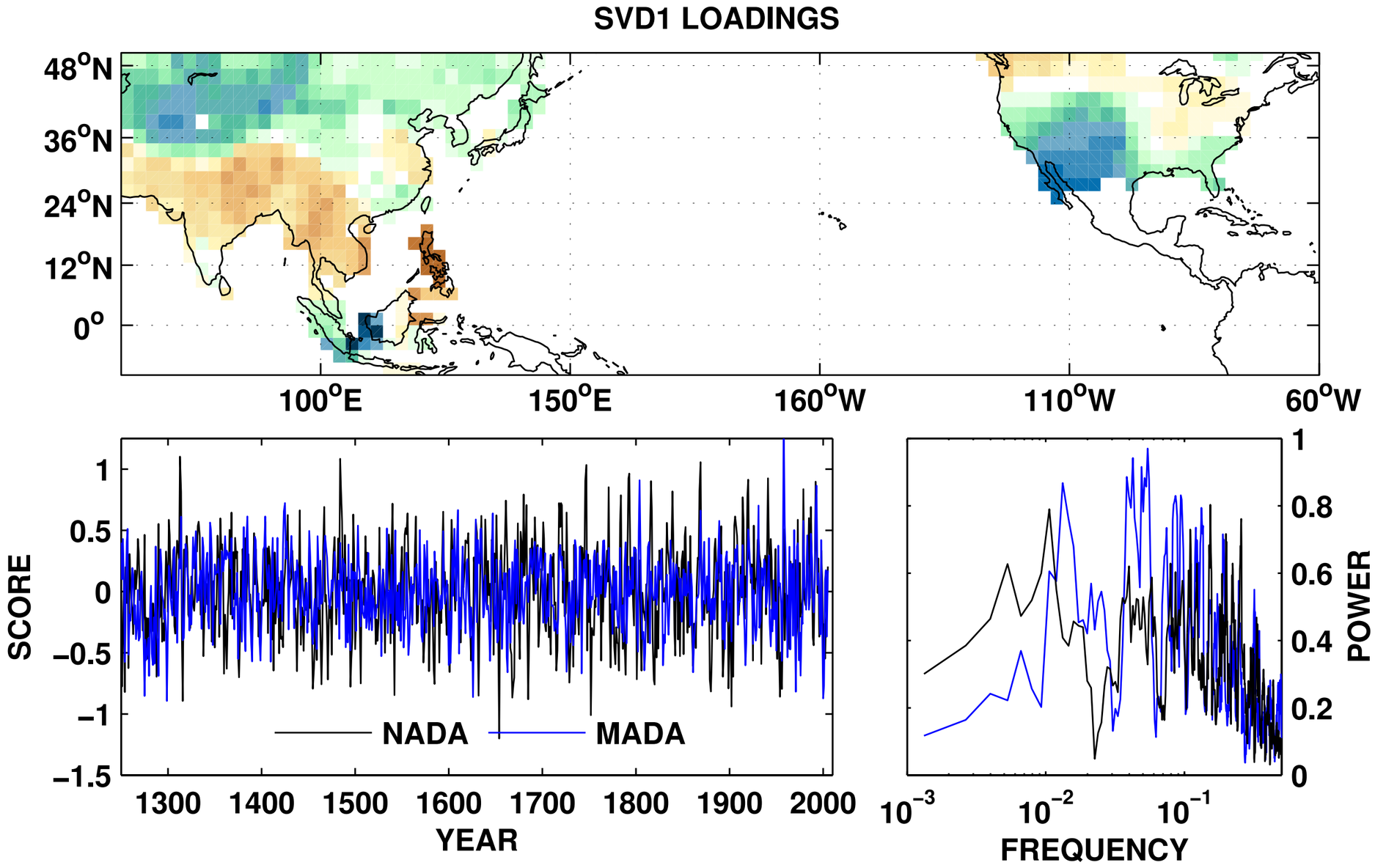
Meyers-Ummenhofer plots composite Australasian climate fields by ENSO/IOD years

Meyers et al. 2007, Ummenhofer et al. 2009, Ummenhofer et al. in preparation, Anchukaitis et al. in preparation





The Strange Parallels drought has a spatial 'fingerprint' associated with a negative Indian Ocean Dipole or cold Indian Ocean SSTs, and perhaps with concurrent El Nino conditions.



Leading coupled MADA-NADA mode has an ENSO fingerprint

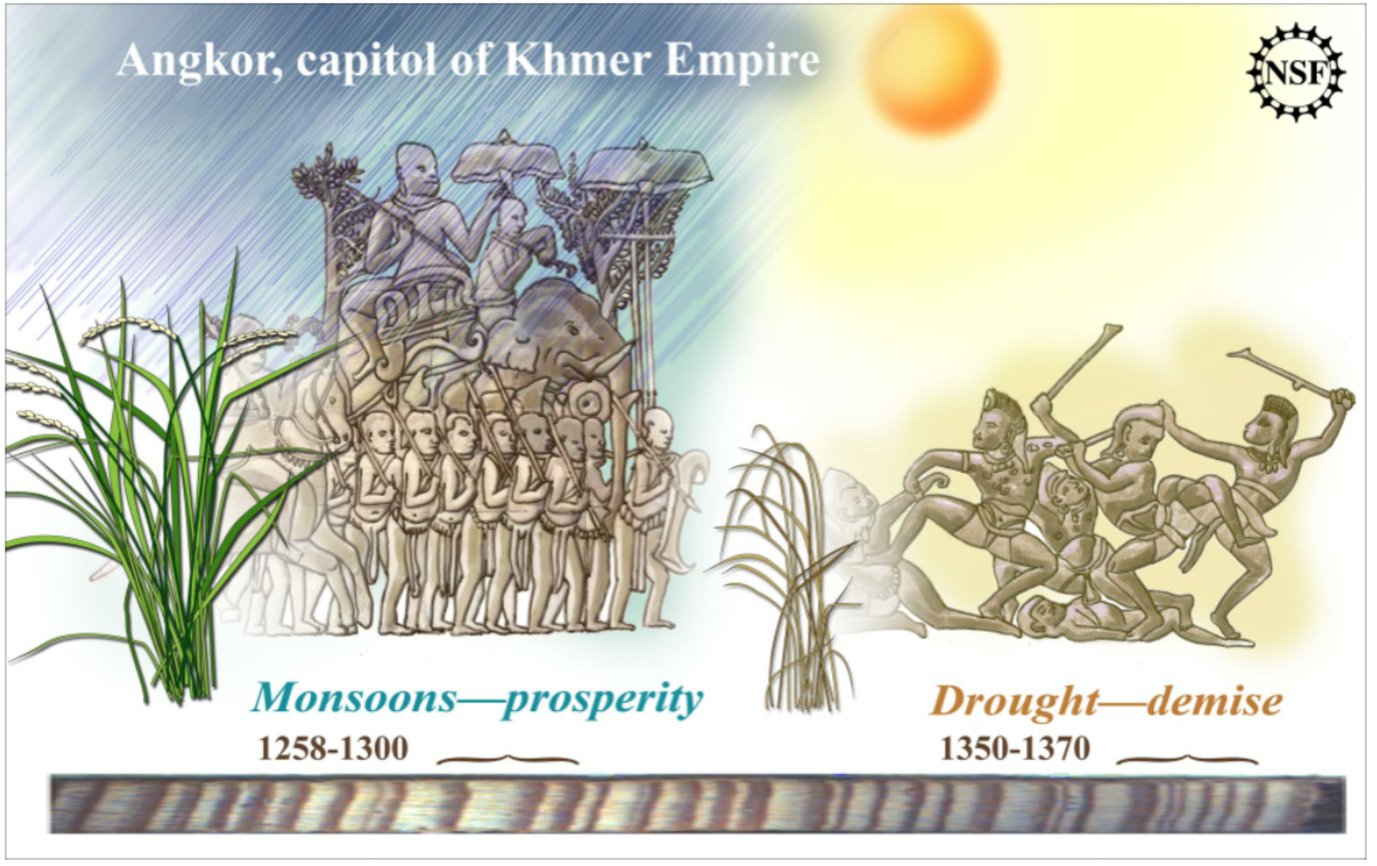
SVD/CCA: Bretherton et al. 1992

Climate as a contributing factor in the demise of Angkor, Cambodia

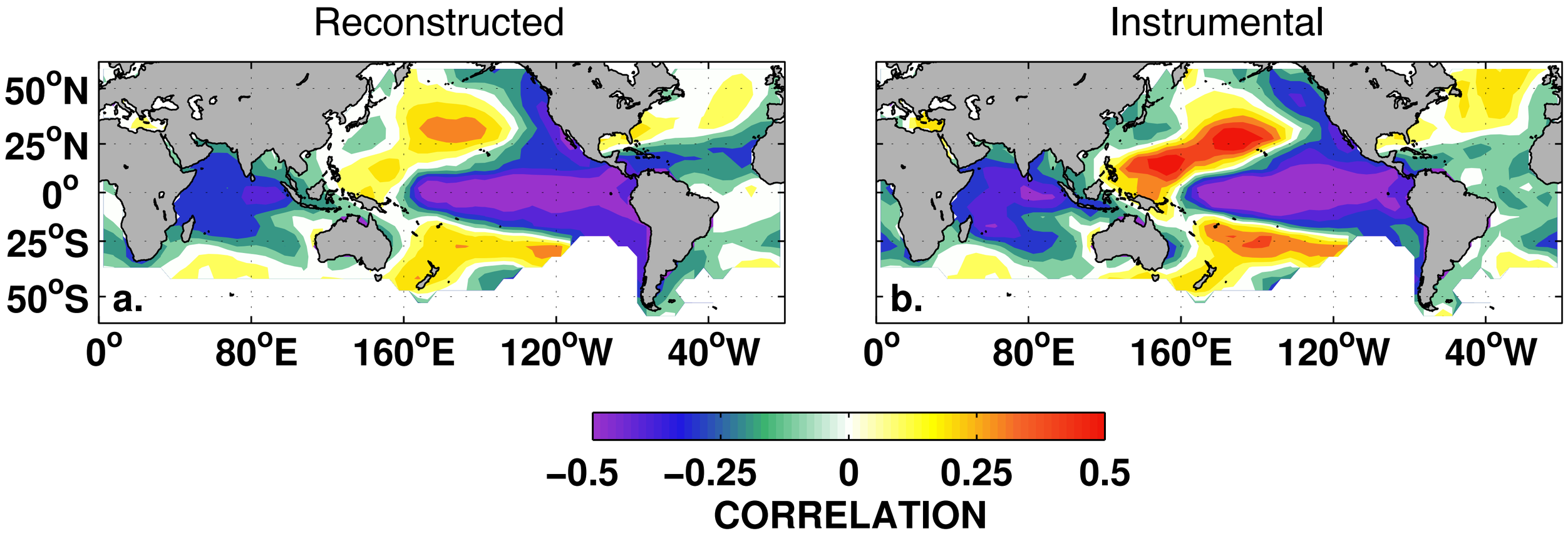
Brendan M. Buckley[a,1], Kevin J. Anchukaitis[a], Daniel Penny[b], Roland Fletcher[c], Edward R. Cook[a], Masaki Sano[d], Le Canh Nam[e], Aroonrut Wichienkeeo[f], Ton That Minh[e], and Truong Mai Hong[g]

[a]Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, 10964; [b]School of Geosciences, University of Sydney, Sydney, Australia; [c]Department of Archaeology, University of Sydney, Sydney, Australia; [d]Department of Agriculture, Ehime University, Ehime, Japan [e]Bidoup Nui Ba National Park, Lam Dong Province, Vietnam; [f]Department of History, Chiang Mai Rajabhat University, Chiang Mai, Thailand; and [g]Nong Lam University, Ho Chi Minh City, Vietnam

Edited by Joyce Marcus, University of Michigan, Ann Arbor, MI, and approved February 26, 2010 (received for review October 15, 2009)

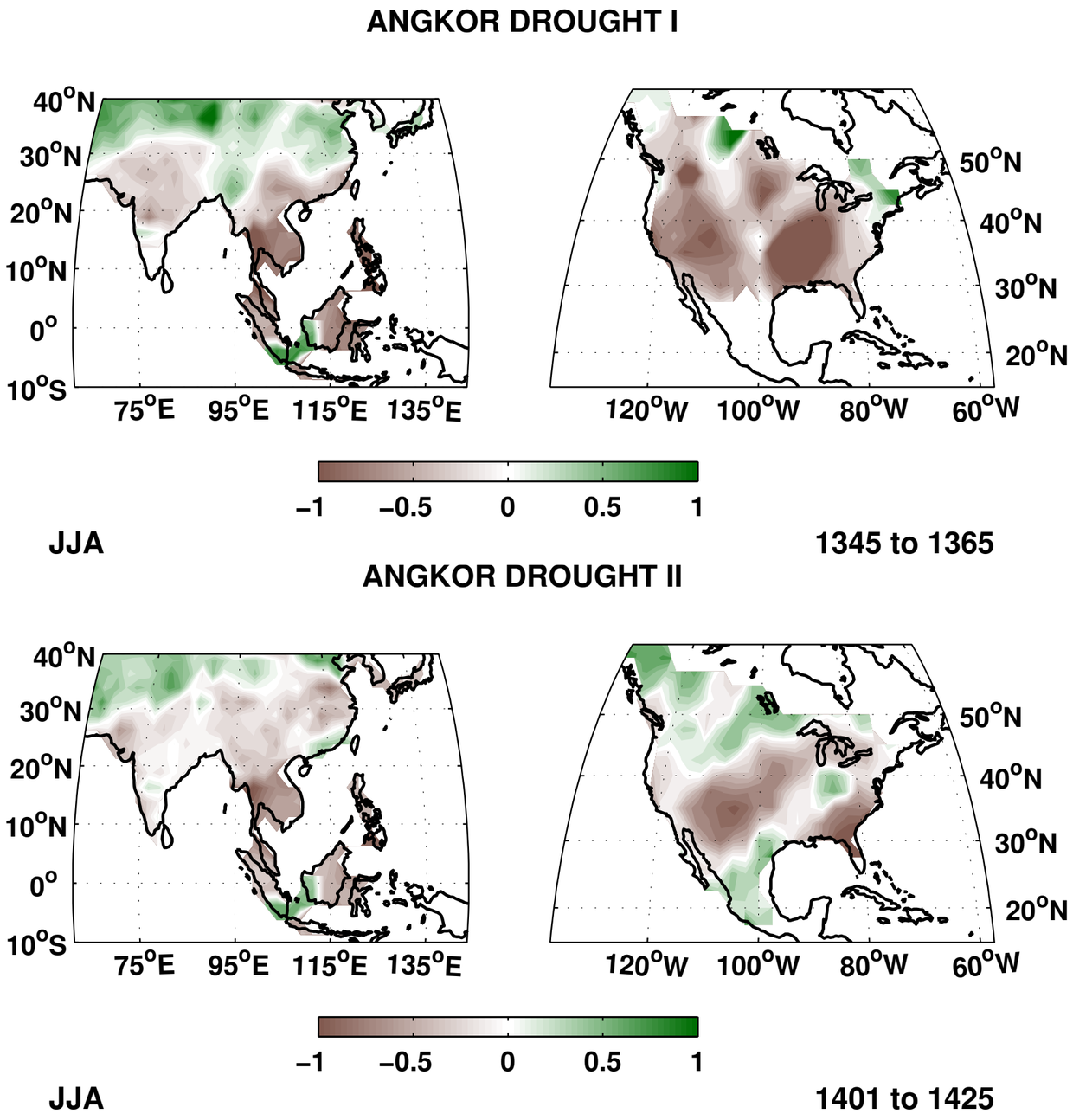


Bidoup Nui Ba reconstruction correlated with tropical Pacific SSTs



Also, the Interdecadal Pacific Oscillation (IPO; Meehl and Hu, 2006): multi-decadal variability over most of the Pacific. Involves tropical to mid-latitude air-sea interactions, wind-forced Ocean Rossby waves near 20°N - 25°S.

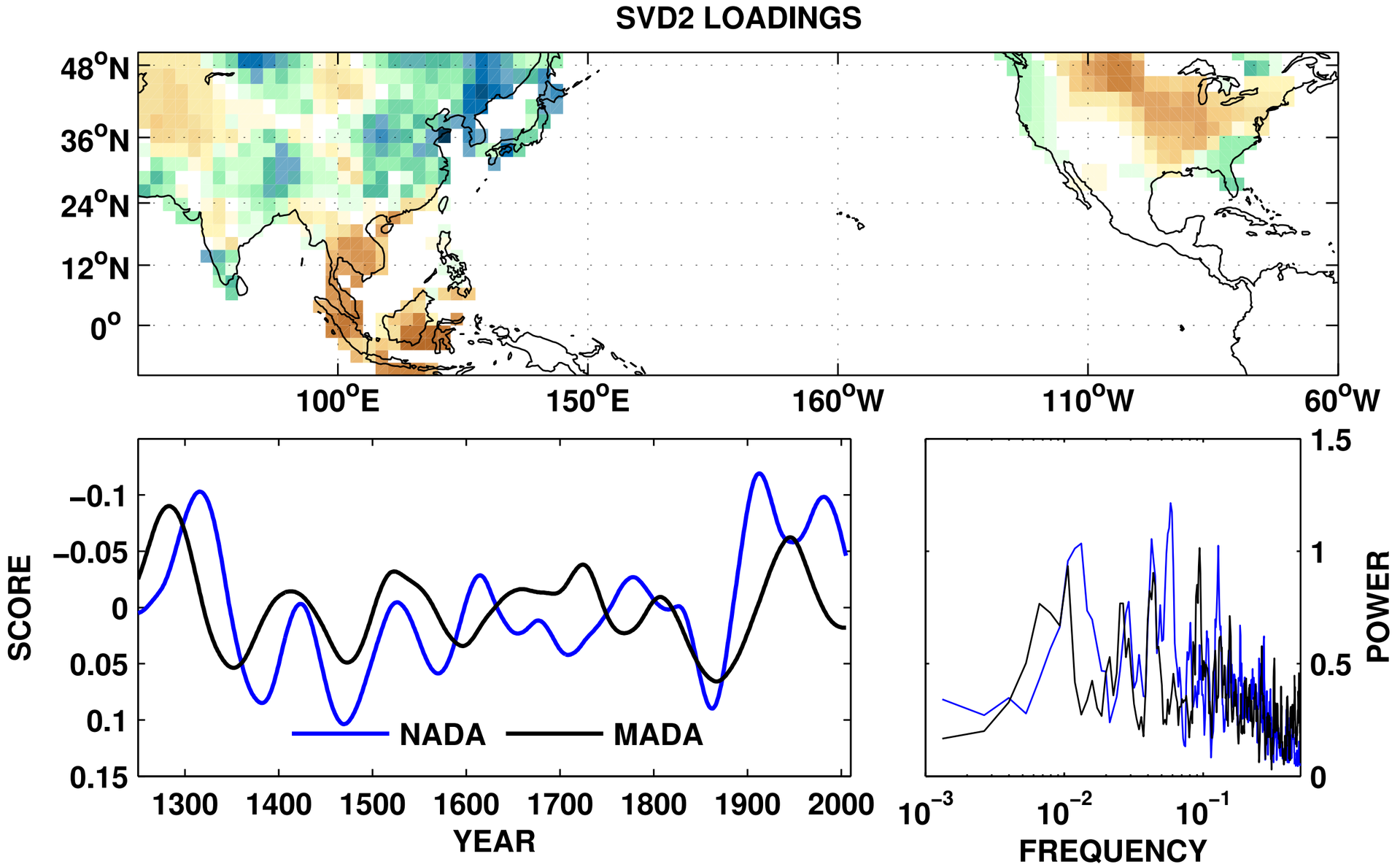
Buckley et al. PNAS 2010



So **both** North America and tropical Asia experience multi-decadal drought conditions during the late Medieval period, in contrast to the canonical patterns related to ENSO or the IPO that typically predict opposite signed anomalies on either side of the Pacific

NADA: *Cook et al.. 2004;* **MADA**: *Cook et al. 2010*

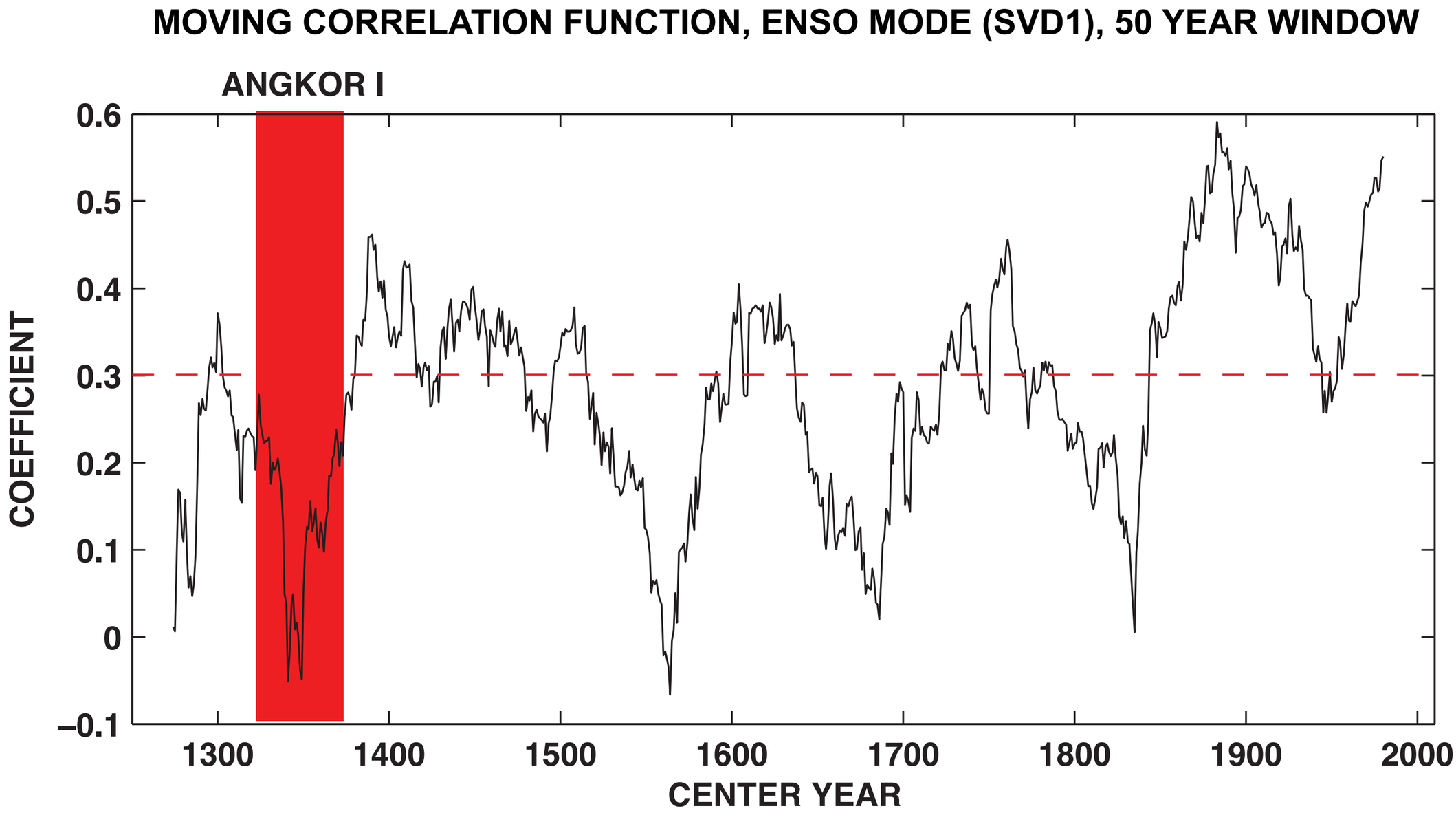
Anchukaitis et al. in preparation



Second coupled MADA-NADA mode has same sign central USA and southeast Asia

Bidecadal and multidecadal (60-70 yr) power

SVD/CCA: Bretherton et al. 1992

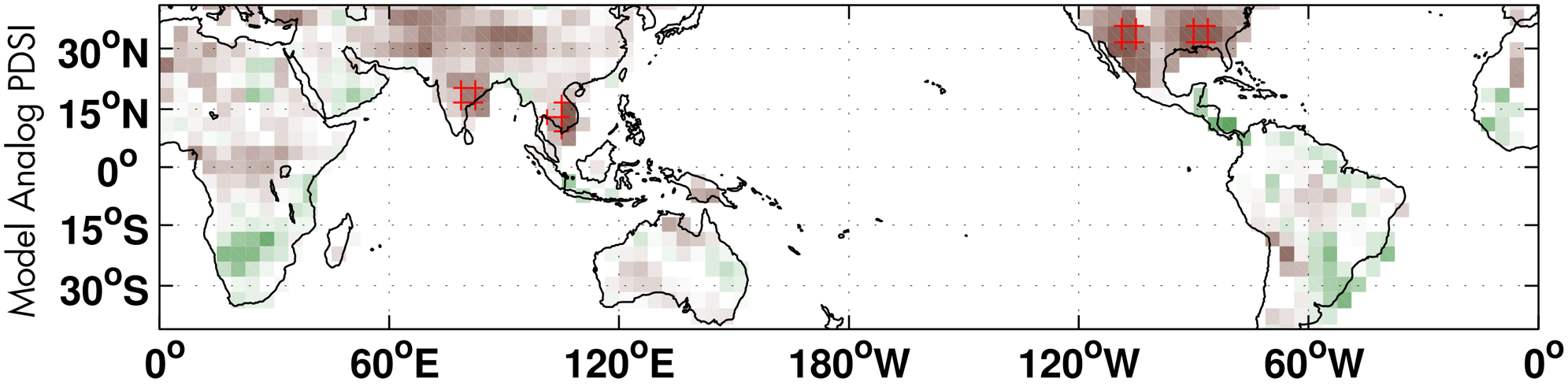


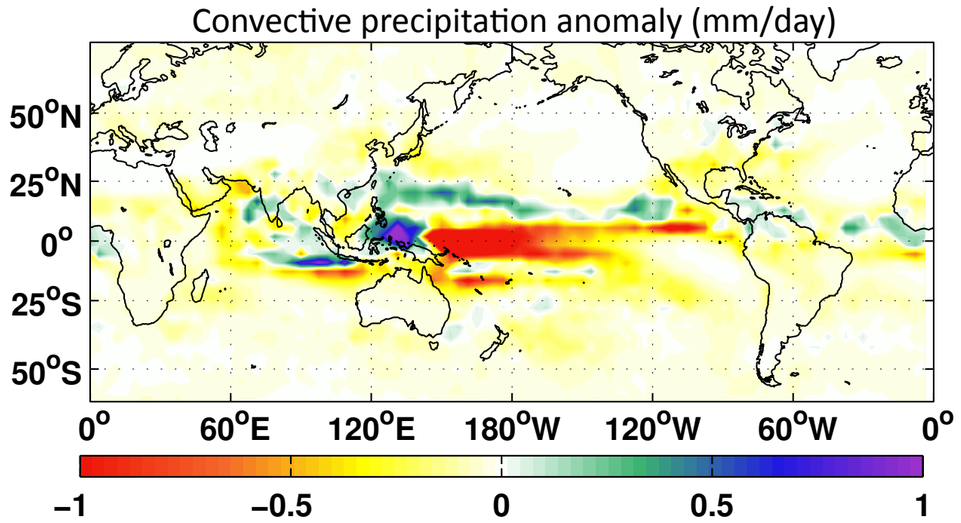
Several epochs where MADA-NADA ENSO coupling is weak, including Angkor I

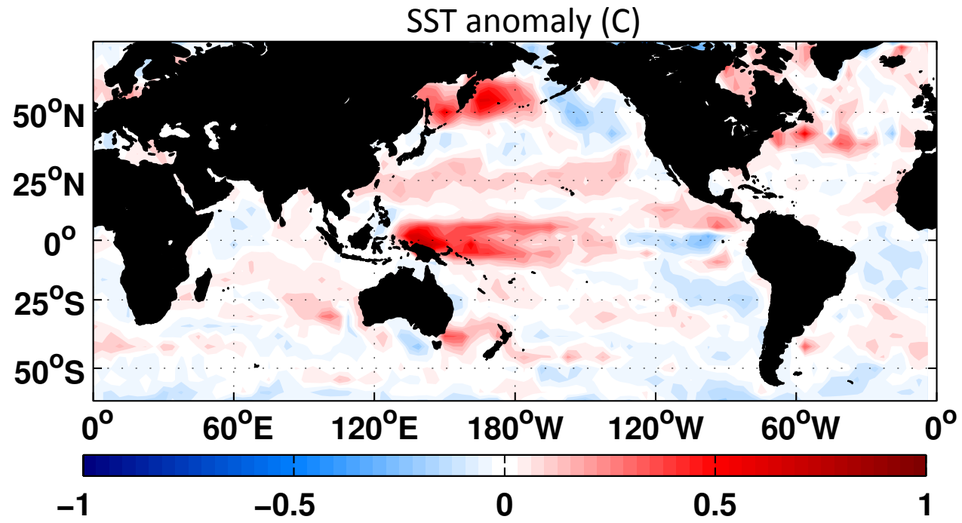
COSMOS MPI PROXY-MODEL ANGKOR I ANALOGS

COSMOS MPI MILLENNIUM: Jungclaus et al. 2010

167 minimum threshold analogs out of 6000 model years





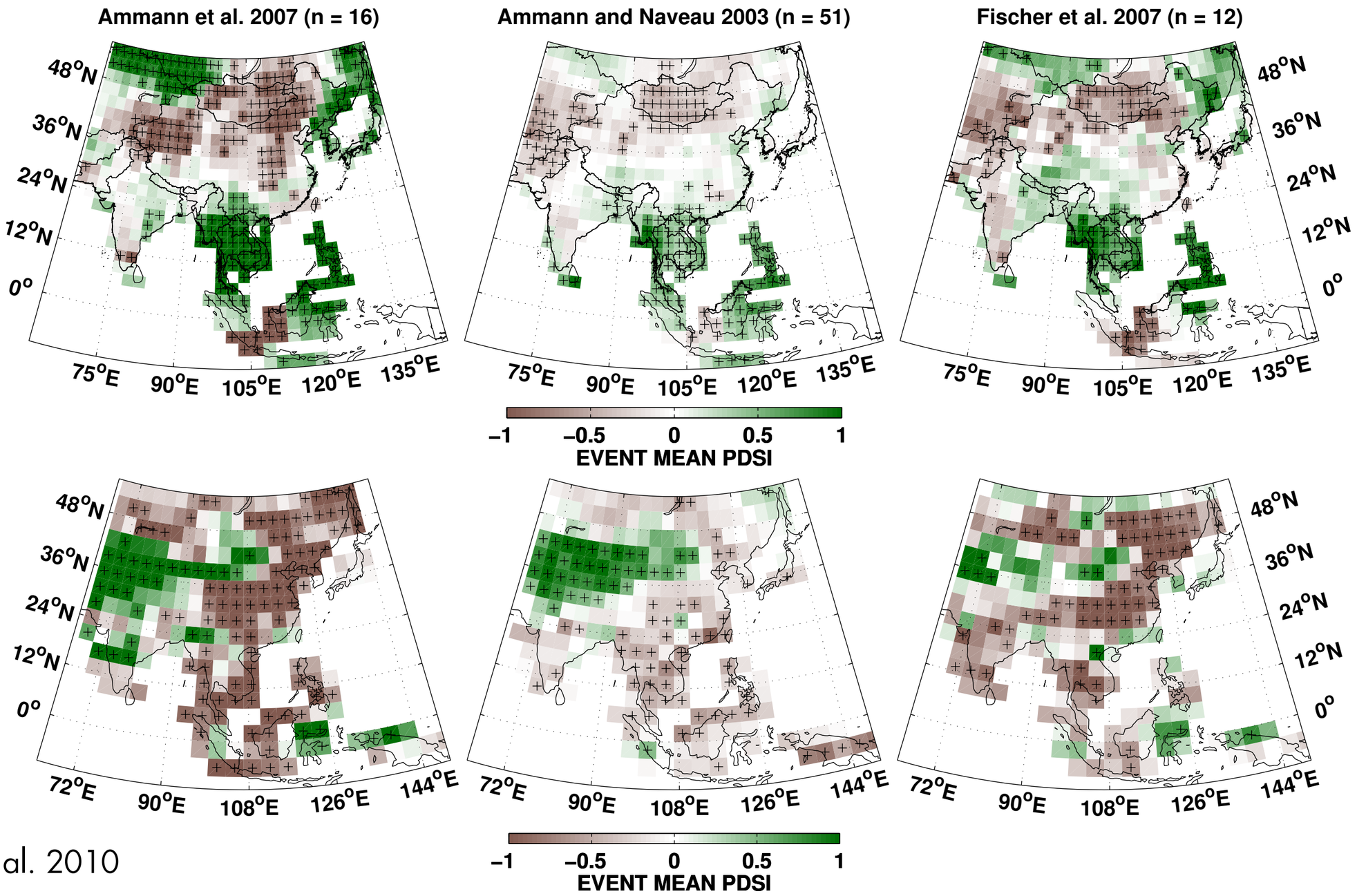


Anchukaitis et al. in preparation

'PSR': Graham et al. 2007

The influence of volcanic eruptions on the climate of the Asian monsoon region

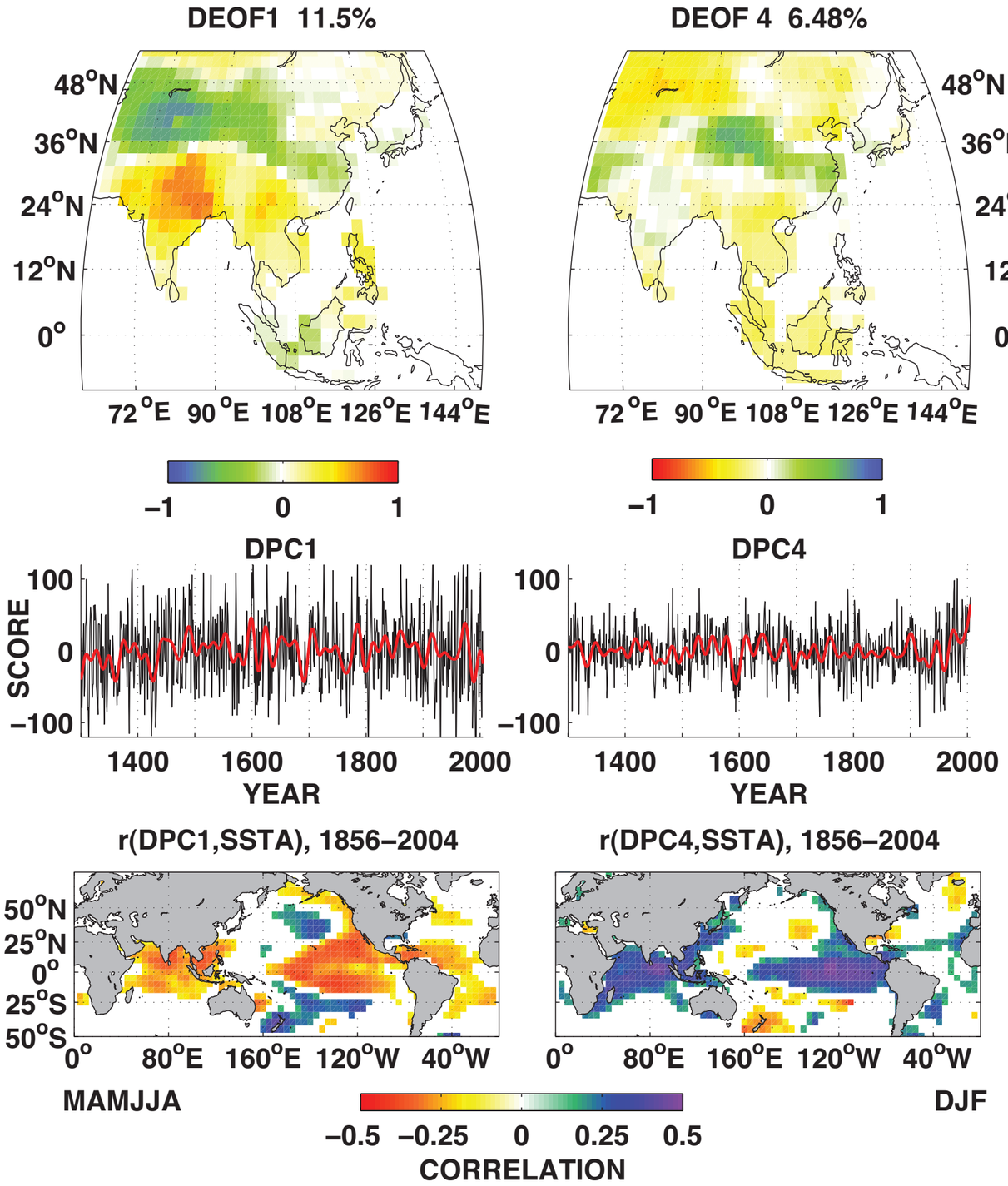
Proxy Model Comparisons



Anchukaitis et al. 2010

extra slides

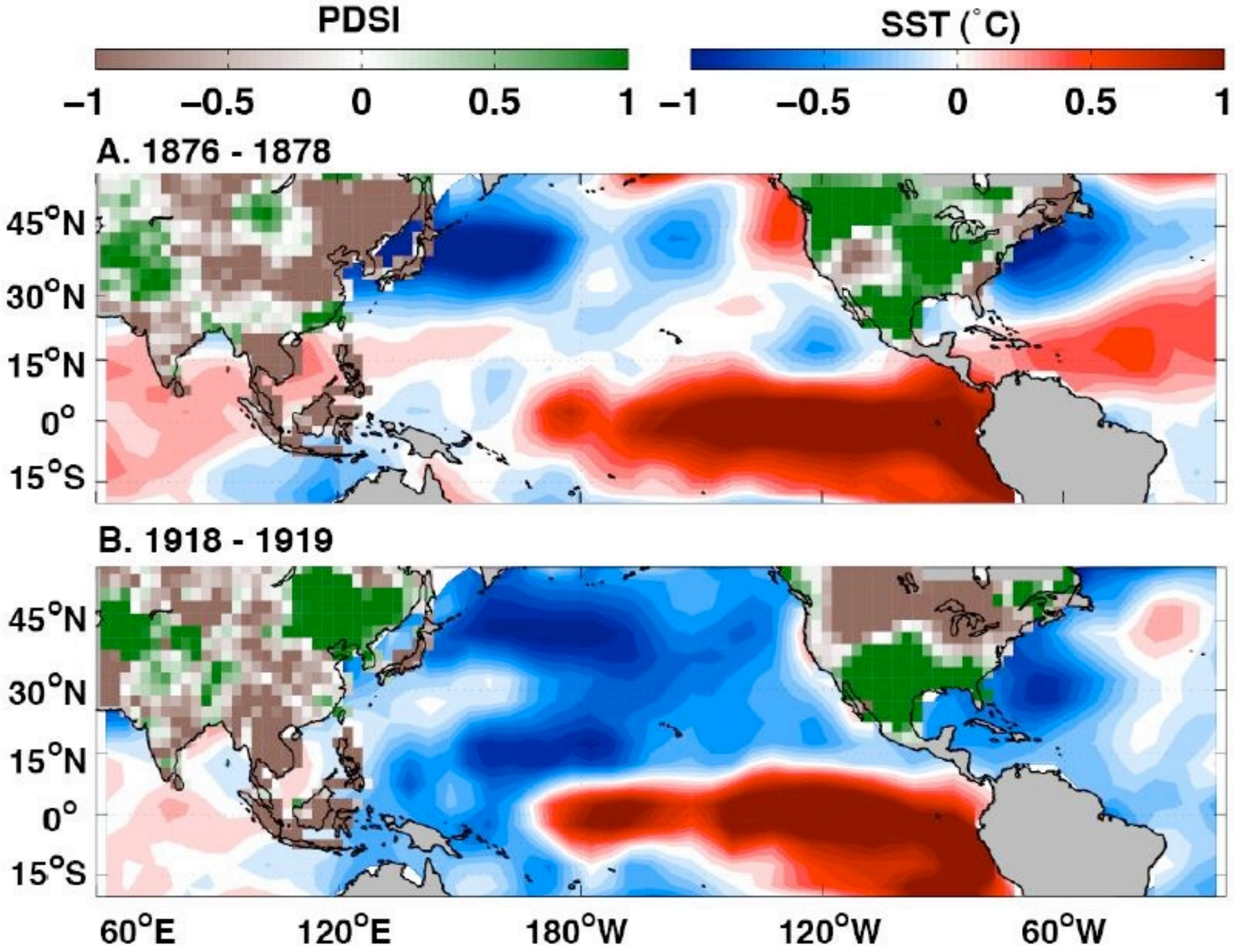
Distinct Drought Modes since 1300 CE



Distinct Empirical Orthogonal Decomposition [**DEOFs**] finds spatiotemporal patterns different that expected from a pure isotropic process

DEOF1 is pan-tropical linked to Pan-Pacific ENSO-like variability and shows drying over decent decades

DEOF4 has positive loadings over the eastern Tibetan Plateau & time is positively correlated with eastern equatorial SST anomalies and trends strongly toward more positive PDSI values during the 20th century



NADA: *Cook et al.. 2004;* **MADA**: *Cook et al. 2010*