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

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NSF ATM 0402474
NSF AGS 0908971
Relatively few long high-resolution terrestrial tropical proxies

Tropical marine proxies from corals, sediments terrestrial from speleothems and laminated lake sediments
A **327 chronology** tree-ring network from Vietnam, the Philippines, Pakistan, Kyrgyzstan, 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
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?

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
LATE VICTORIAN DROUGHTS (GREAT DROUGHT)

3 YEAR MEAN

1877 – 1879

PDSI

3 YEAR MEAN

Cook et al., Science, 2010
LATE VICTORIAN DROUGHTS

4 YEAR MEAN

1888 – 1891

PDSI

40°N
30°N
20°N
10°N
0°
10°S
75°E
95°E
115°E
135°E

-2 -1 0 1 2

4 YEAR MEAN
FALL OF THE MING DYNASTY

1638 – 1641

PDSI

4 YEAR MEAN

Cook et al., Science, 2010
The ‘Strange Parallels’ Drought, 1756-1768
"STRANGE PARALLELS" MEGADROUGHT

13 YEAR MEAN

PDSI

Cook et al., Science, 2010
‘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’

A: ANNUAL

B: DECADAL

Anchukaitis et al. in preparation
Meyers-Ummenhofer plots composite Australasian climate fields by ENSO/IOD years

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

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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

Reconstructed

Instrumental

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.
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

Model Analog PDSI

Convec’tive precipitation anomaly (mm/day)

SST anomaly (C)

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

Ammann et al. 2007 (n = 16)

Ammann and Naveau 2003 (n = 53)

Fischer et al. 2007 (n = 12)

MADA

CSM1.4

Anchukaitis et al. 2010
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