Possible Solar Forcing of Late Holocene Mega-Droughts in India

Ashish Sinha
California State University Dominguez Hills

Kevin G. Cannariato, Lowell D. Stott, & Hongchun Li
University of Southern California

Hai Cheng & Larry Edwards
University of Minnesota

Ramesh Rengaswamy & Madhusudan G. Yadava
Physical Research Laboratory, India

Indra-Bir Singh
Lucknow University, India
The Indian Monsoon is the Largest Global Hydrologic Anomaly on Inter-Annual Timescales

The East Asian Monsoon Regime

The Indian Monsoon Regime
Has the Instrumental record captured the full range of the Indian Monsoon Variability?

- How have the frequency and magnitude of droughts varied before the instrument record began?
- Is there a link between the Indian Monsoon rainfall and the Solar Variability on decadal to centennial timescales?
Most Marine and Lake sediment records (# 1-14) provide a history of long-term temporal changes (orbital to tectonic timescales).
Speleothems as Climate Proxy

Tropical and Monsoon Regions

lower rainfall ↔ positive ↔ $\delta^{18}$O$_{\text{rain}}$ ↔ negative ↔ higher rainfall

$\delta^{18}$O of dripwater

$\delta^{18}$O$_{\text{speleothem}}$ variations reflect mainly precipitation changes

Air Temp, Amount, Source, Evap, etc

Cave Temp, Kinetic, Water-Rock interactions

18O of dripwater

Cave Temp, Kinetic, Water-Rock interactions
Current Network of the Indian/Asian Monsoon Speleothem Records

- Our Sites
- Others

Sites:
- Hoti & Qunf (Oman)
- Dongge (Current Study)
- Timta
- Cherrapunji
- Hulu
The Study Area: Dandak Cave, Central-Eastern India

- Sub-Tropical Climate with dense Teak Forests
- Abundant Rainfall in Monsoon Months
- Stalagmite DAN-D collected at growth position
DAN CAVE
Bay of Bengal (BoB) Trajectory of the Indian Monsoon

Modern Climatological Characteristics of the Study Area

Mean Monthly Rainfall (mm) (1910-1990)

- MAR = 1530 mm
- MAT = 25.5°C
- $\delta^{18}O_{\text{non}} \sim 0$
- $\delta^{18}O_{\text{monsoon}} \sim -3.0 \pm 1.0$
Suitability of the Cave Site
Local or Regional Precipitation Signal?

- Although considerable spatial and temporal variability exist in the ISM rainfall patterns over India....
- Monsoon rainfall variability at Dandak seems to be reflective of the overall strength of ISM because of its location.
Th dating of Stalagmite DAN-D

Variable Growth Rate, ranging from 0.1 to 0.85 mm/year

Temporal resolutions range from <1 year to ~ 10 years
Dandak Cave Indian Monsoon Precipitation Record

Stalagmite $\delta^{18}O$

Year (AD)

Dry

Wet

Stalagmite $\delta^{18}O$ (% VPDB)
The theoretical and observational considerations suggest rainfall reduction of 15-30% compared to the present—amounting to ‘Mega-Droughts’. 

Source: The Demography of Famines: An Indian Historical Perspective. Arup Maharatna, Oxford University Press, 1996
Dandak Cave Indian Monsoon Precipitation Record

Stalagmite $\delta^{18}O$ (% VPDB)

Wet

-5.0

4.5

3.5

3.0

Dry

Little Ice Age

Medieval Warm Period

$\delta^{18}O$ Range of Modern Dandak Cave Calcite

< 1 yr. Resolution

Durga Devi 1396-1407 AD

~ 1 yr. Resolution

Year (AD)

1410 1400 1390 1380 1370

Year (AD)

640 630 620 610 600 590
Longer intervals of more reduced rainfall during LIA compared to MWP
Is there a Sun-Monsoon Connection?

Recent Speleothem $\delta^{18}O$ Records from Oman and China suggest the Sun-Monsoon Connection on multi-decadal timescales.
Indian Monsoon Precipitation and Solar Variability

- Stalagmite δ¹⁸O (% VPDB)
- Stalagmite δ¹⁸O ²³⁰Th Chronology
- Δ¹⁴C Solar Variability Proxy (IntCal98)

Year (AD)

2000 1500 1000

Stronger Sun

Weaker Sun

Δ¹⁴C (%)

Dry

Wet
Neff et al., 1999

Coherent changes in the Indian monsoon ($\delta^{18}O$) and solar variability ($\Delta^{14}C$) on decadal to centennial timescales
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Sun–Monsoon Connection?

Speleothem δ\(^{18}\)O record from Dongge Cave, southern China

Coherent changes in the East Asian monsoon (δ\(^{18}\)O) and solar variability (Δ\(^{14}\)C) on decadal to centennial timescales
Conclusions

- Our record suggests persistent failures in the Indian monsoon had occurred in the recent past.
- Compared to recent, some past episodes of monsoon failures were of longer durations and were significantly stronger (mega-droughts).
- If $\Delta^{14}C$ is indeed a proxy of solar variability, our record (albeit, inconclusively) hints of a possible Solar Forcing of Indian Monsoon on multi-decadal timescales.
Residual $\Delta^{14}C$ Versus $^{14}C$ Production Rate Record

Which one is a better proxy for the Solar Variability?