Southeast Asian Monsoon may have assisted the rise and fall of the Khmer Empire

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Introduction

The Southeast Asian summer monsoon is characterized by distinct wet and dry seasonal variability and has enormous impact on society, economy, agriculture and infrastructure

Photograph: Reuters

Photo: The Hindu Business Line

Changes in Asian summer monsoon intensity have been linked to the rise and fall of ancient civilizations (Weiss et al 2001; Buckley et al 2010).

Objectives of study

- To ascertain the drivers of summer monsoon intensity within the last two millennia
- To identify the mechanisms involved in monsoon variability in Southeast Asia.
- To further assess the effects of changes in summer monsoon intensity on Angkor civilization

Methods

We analyzed the hydrogen isotopic composition of terrestrial plant leaf waxes (δ Dwax) deposited in Lake Pa Kho, North-east Thailaind (Fig. 2). This approach is based on the premise that the hydrogen isotopic composition of the plant waxes reflects that of their source water, which in its turn is influenced by summer monsoon intensity. Strong monsoon rains carry an isotopically more depleted signal, and droughts result in more positive δDwax values.

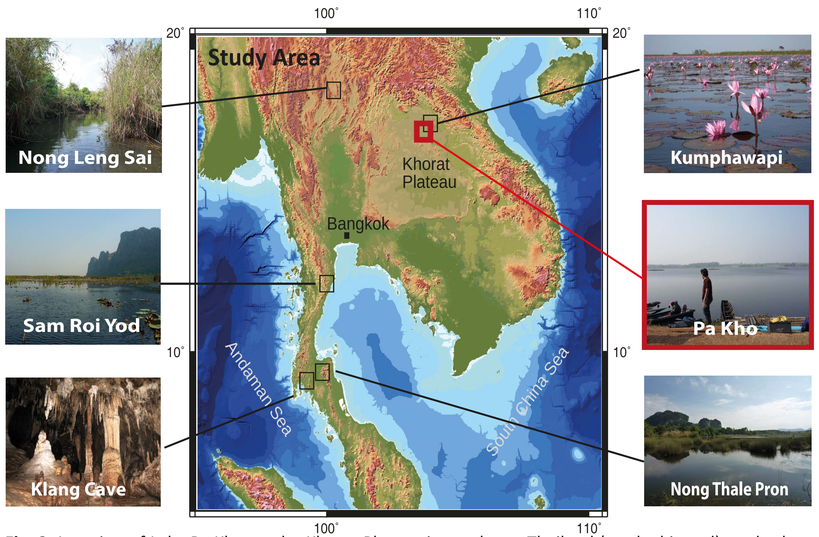

Fig. 2: Location of Lake Pa Kho on the Khorat Plateau in northeast Thailand (marked in red), and other sites within the "Thailand Monsoon Project". Map produced by Sakonvan Chawchai. See also posters **Z254, Z200, Z227**

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Fig. 1: Angkor Ta Kheo Temple. Photo: Bandarin, UNESCO

The Khmer Empire (AD 802-1431) also known as Angkor civilization, had an agrarian economic system model (Hall, 1985) and thus affected by the monsoon variability.
The achievements of the Khmer Empire included advances in agriculture and complex hydrologic systems.
The demise of Angkor has been partly attributed to severe droughts (Buckley et al. 2010)

Results, climatic comparisons and interpretation

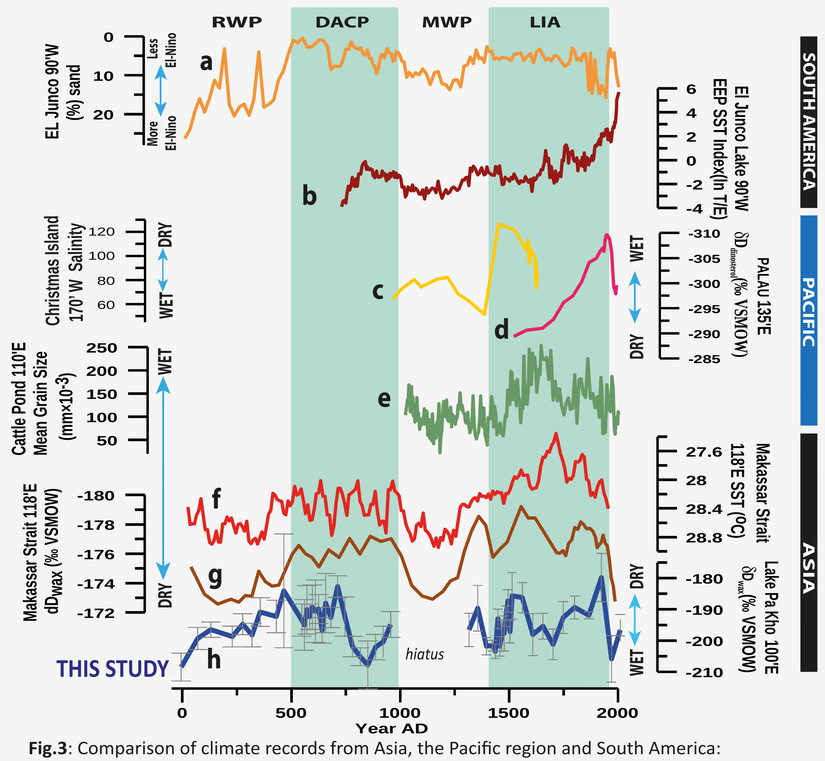

Fig.3: Comparison of climate records from Asia, the Pacific region and South America:
(a), El Junco T/E index (Conroy et al, 2008)
(b), El Junco sand record, an indicator of El Niño events (Conroy et al, 2008)
(c), Inferred lake salinity from Washington Island lake (Sachse et al, 2008)
(d), Dinosterol δD from Spooky Lake, Palau (Sachs et al. 2009)
(e), Mean grain size (mm×10-3), Cattle Pond, Dongdao Island, (Yan et al, 2011)
(f), SST reconstruction, Makassar Strait, central Indonesia (Oppo et al. 2009)
(g), δDwax Makassar Strait, central Indonesia (Tierney et al., 2010)
(h), δDwax from lake Pakho in Northeastern Thailand.
RWP, Roman Warm Period; **DACP**, Dark Ages Cold Period; **MWP**, Medieval Warm Period; and **LIA**, Little Ice Age

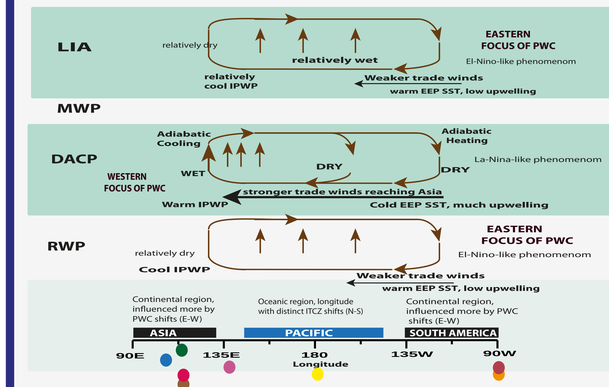

Fig. 4: Eastward and Westward focus shifts of the Pacific Walker Circulation (PWC) within the last two millennia

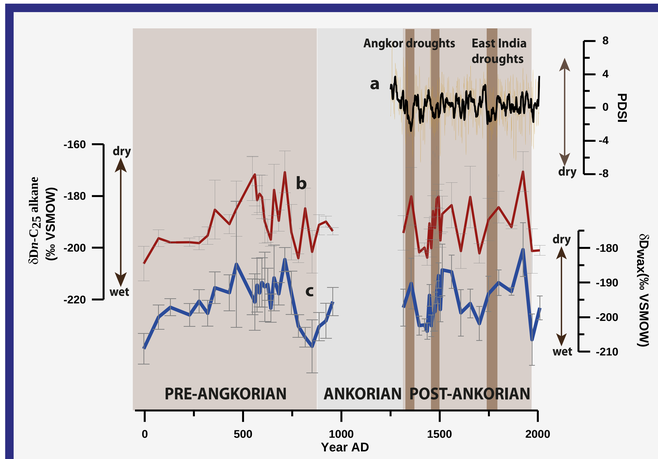

Fig. 5: Comparison of **(a),** the Palmer Drought Severity Index (PDSI), reconstructed from the Vietnam tree ring record (Buckley et al, 2010) with **(b),** only δD of the C25 alkanes and **(c),** the composite δ Dwax, for the Pre-Angkorian (AD 0-802), Ankorian (802-1431) and Post-Angkorian (1431-2000).

Summary

- Summer monsoon intensity in Thailand within the last 2000 years is mainly driven by sea surface temperature (SST) variation in the Indo Pacific Warm Pool (IPWP). An increase/decraese in SSTs leads to a corresponding increase/decrease in precipitation.
- Apart from the north and south movement of the mean position of the Inter-tropical Convergence Zone, the eastward and westward shift of the Pacific Walker Circulation (PWC) also influences summer monsoon intensity on centennial to millennial time scales.
- An eastward shift of the PWC, punctuated by extreme dryness and wetness brought a prolonged weakening of the monsoon during the Little Ice Age (LIA).
- The Monsoon failure during the LIA may have had a direct impact on agricultural decline that may have set in motion a ripple effect thus leading to the demise of Angkor.

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