Correlation and Anti-correlation of East Asian Summer and Winter Monsoons during the Last 21,000 Years

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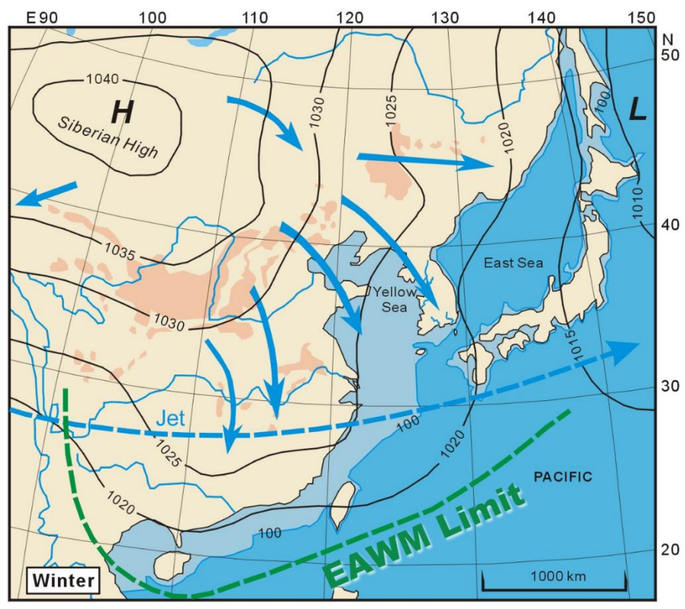
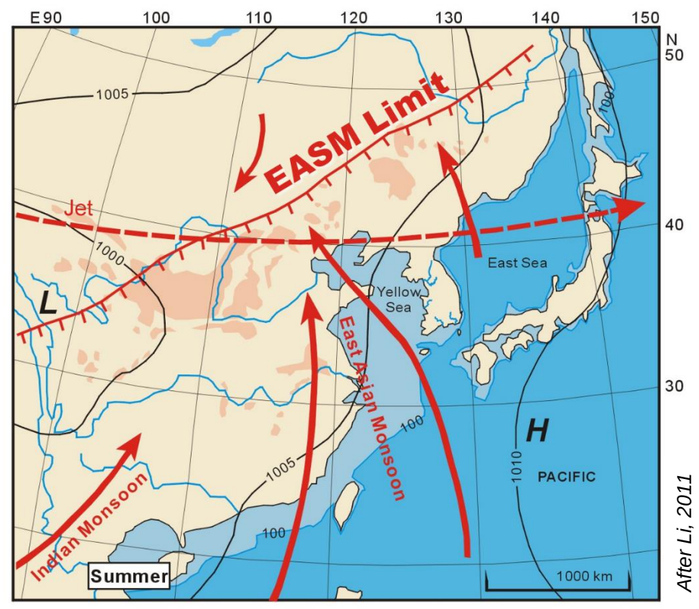
Introduction

Understanding the past significant changes of the East Asia Summer Monsoon (EASM) and Winter Monsoon (EAWM) is critical for improving the projections of future climate over the East Asia. One key issue that has remained outstanding from the paleo-climatic records is if the evolution of the EASM and EAWM are anti-correlated. Here we show that the EASM and EAWM are positively correlated on the orbital timescale in response to the precessional forcing, but are anti-correlated on millennial timescales in response to North Atlantic melting water forcing by using a set of long-term transient simulations of the climate evolution of the last 21,000 years. The relation between EASM and EAWM can differ dramatically for different time scales because of the different response mechanisms, highlighting the complex dynamics of the East Asian monsoon system and the challenges for future projection.



EAWM (EA Winter monsoon)



EASM (EA Summer monsoon)

Model & Numerical Experiments

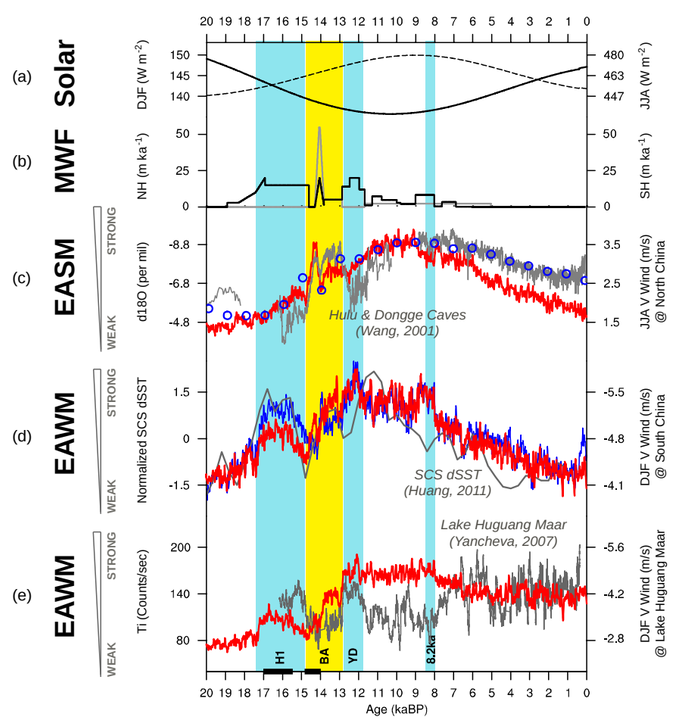
Model: NCAR CCSM3 and isotope-enabled version of CAM3 (called "isoCAM3", After *Noone, 2010*)
Simulation Length: 22,000 years (22ka to present) for Experiment 1 and 2; 50 years for each snapshot in Experiment 3

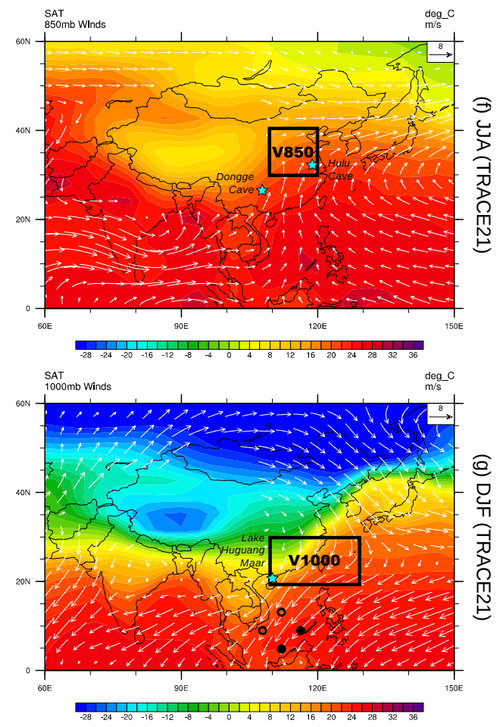
Experiment 1: All-forcing transient run (TRACE21) with forcing of ORB + CO2 + MWF + ICE
Experiment 2: 4 transient runs with single-forcing of ORB / CO2 / MWF / ICE separately
Experiment 3: 23 snapshot (slice) runs using isoCAM3 with prescribed SST/SICE derived from TRACE21

Forcing Details:

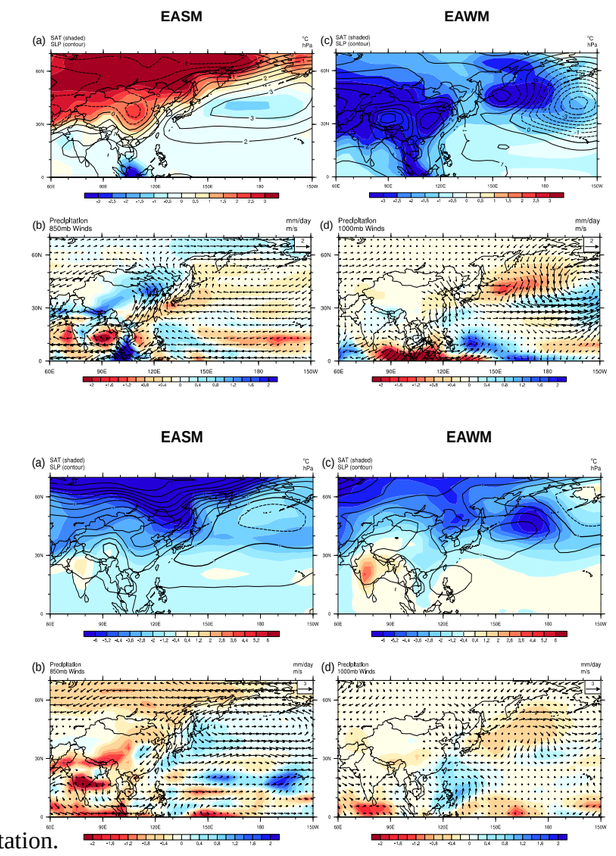
ORB:	Solar insolation with 22ka-through-present realistic orbital parameters	**See Fig 1a**
CO2:	Greenhouse gases (CO2, CH4, and N2O) concentrations from ice cores	**See Fig 5a**
MWF:	North Atlantic and Antarctica surrounding melting water flux	**See Fig 1b**
ICE:	Land ice sheets from ICE-5G dataset	
Others:	Modifications of coastlines due to sea level changes	**See Fig 5b**

Results from All-forcing Run: Two Key Modes





Monsoon Climatology and Indices
Observation vs. Model



Orbital Mode
Early – Late Holocene

N. A. Melting Water Mode
H1 – BA

Fig 1. Monsoon climatology (right) and related indices (left) in proxy and model. The key subplots (c) and (d) show EASM and EAWM time series.
Fig 2. Orbital mode (10-8ka minus 2-0ka) shows positively correlated spatial patterns for SAT, SLP, winds, and precipitation.
Fig 3. North Atlantic melting water mode (17-15.5ka minus 14.8-14ka) shows negatively correlated spatial patterns for SAT, SLP, winds, and precipitation.

Results from Single-forcing Runs

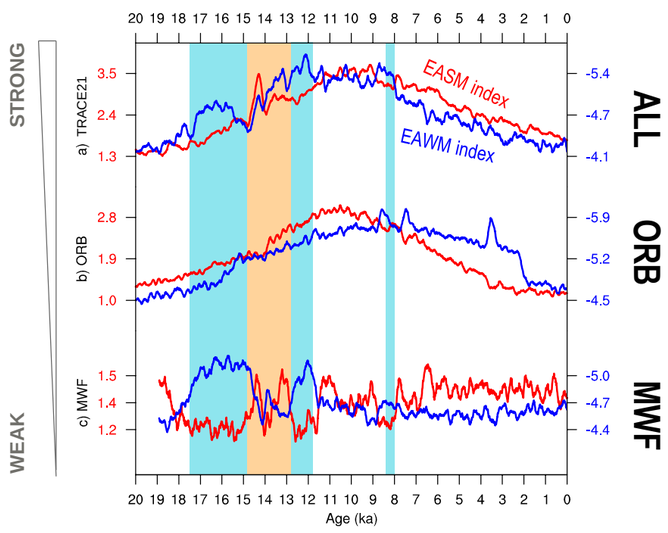


Fig 4. EASM (red line) and EAWM (blue line) indices in all-forcing (a), as well as single-forcing ORB (b) and MWF (c) runs. The linear combination of ORB (b) and MWF (c) can explain most of features in all-forcing run (a).

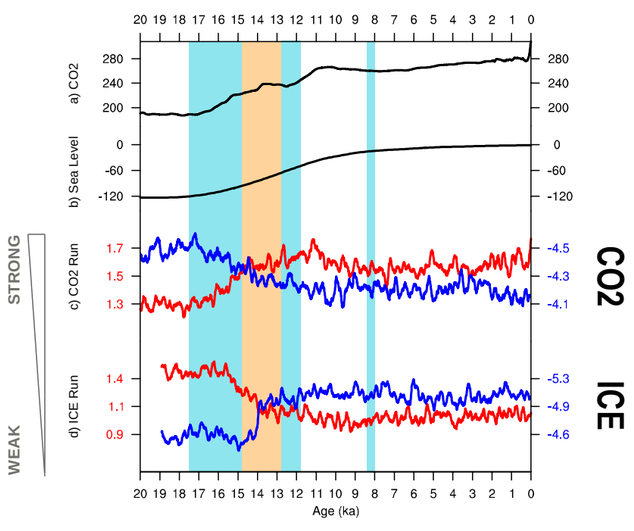
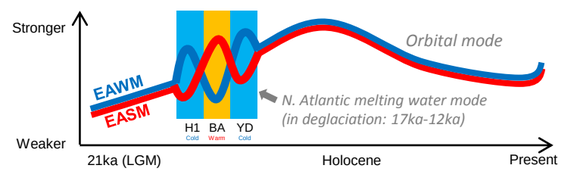


Fig 5. EASM (red line) and EAWM (blue line) indices in single-forcing CO2 (c) and ICE (d) runs. The two responses might be opposite so that there is little residual signal left after the deglaciation. Their coupled effects over monsoon variability need more investigations on the longer glacial-interglacial timescale..

Conclusions

The evolution of EASM and EAWM is correlated at the orbital scale in response to the precessional forcing, but anti-correlated at millennial time scale in response to the meltwater forcing and the resulting AMOC change. The monsoon correlation is also slightly affected by the rising GHGs and retreating ice sheets.

The new understanding from a modeling framework reconciled the conflicting interpretations on the co-variability between EASM and EAWM in proxy records, and demonstrated that their relationship is influenced by multiple physical processes on diverse timescales. This work presents great challenge and potential to understand the response of the East Asian monsoon system to global climate changes in the past and future.



Schematic demonstration of the impacts from orbital forcing and N. Atlantic melting water flux on East Asian summer/winter monsoons

Reference: **Wen, X.**, Z. Liu, S. Wang, J. Cheng, and J. Zhu: Correlation and anti-correlation of the East Asian summer and winter monsoons during the last 21,000 years. *Nature Communications*, 2016, 7, 11999, doi: 10.1038/ncomms11999
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