Role of Seasonal Transitions and Westerly Jets in East Asian Paleoclimate*

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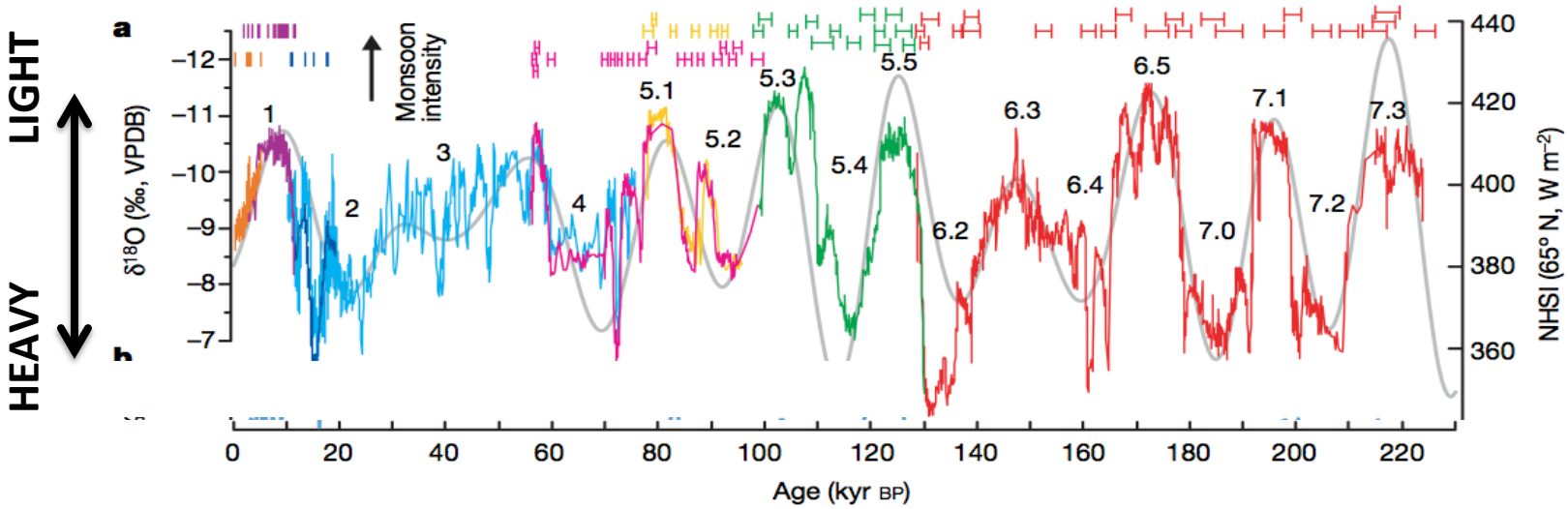
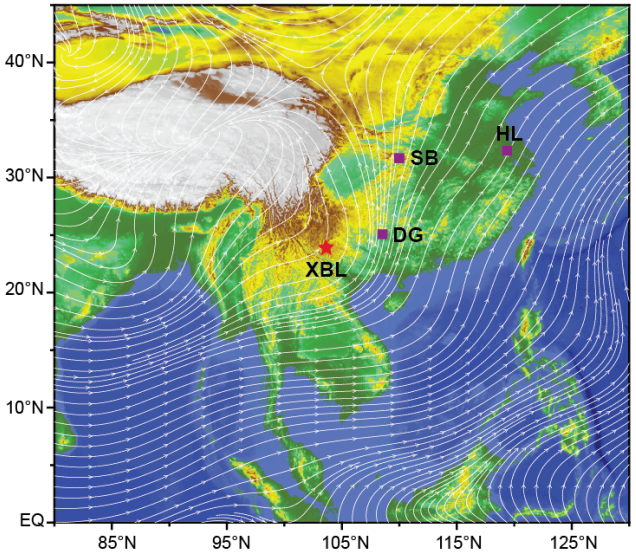
Acknowledgements to: NSF, Academia Sinica

**Quaternary Science Reviews (2015)*

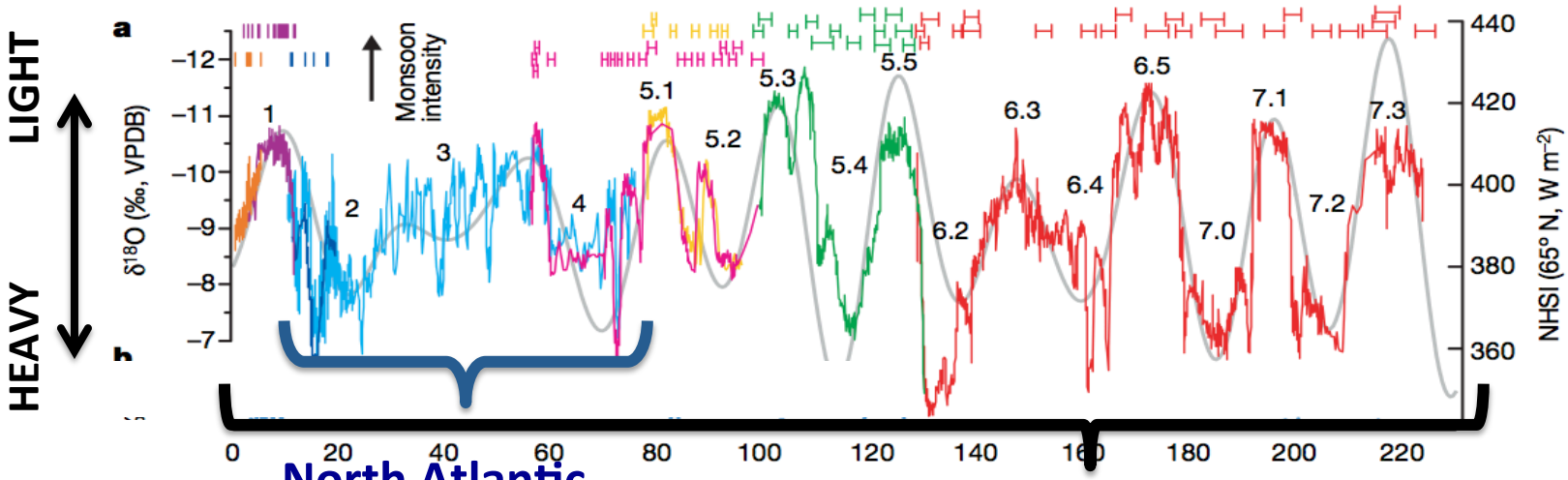
Wang et al. 2008





Blue: Hulu cave (HL)
Others: Sanbao cave (SB)

Wang et al. 2008

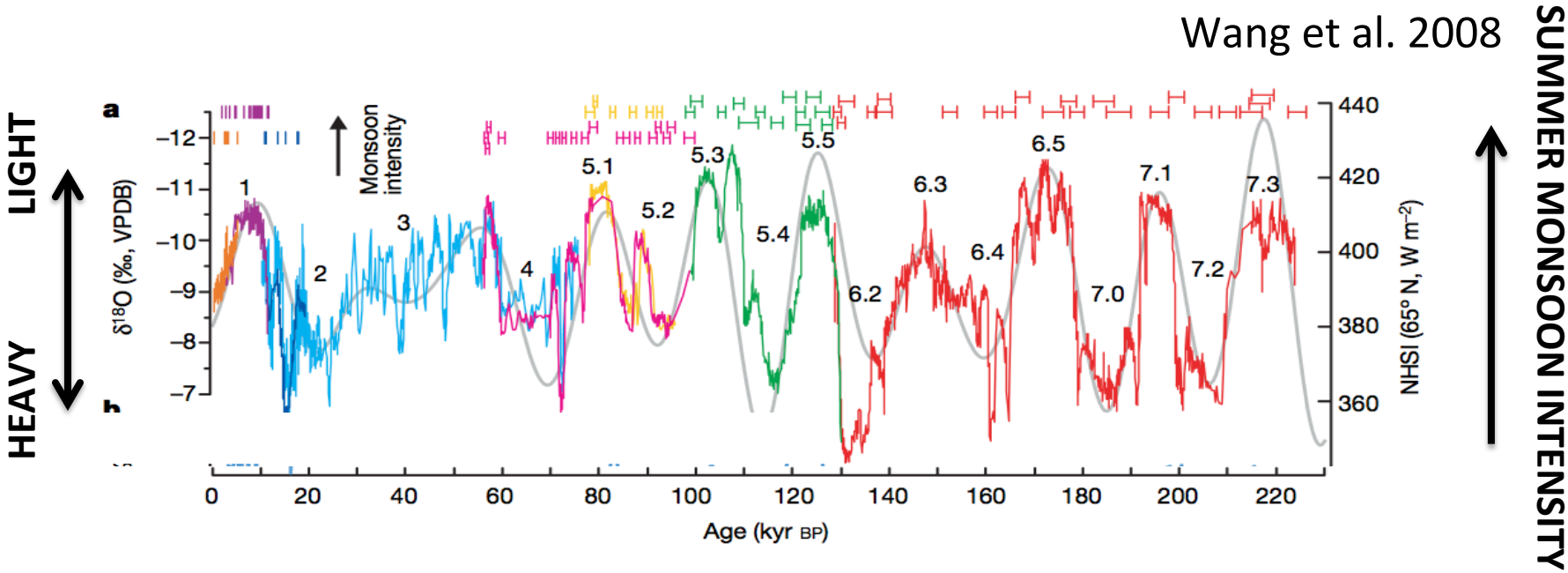


North Atlantic cooling/warming

Precessional cycles

(grey line is insolation change)

Wang et al. 2008

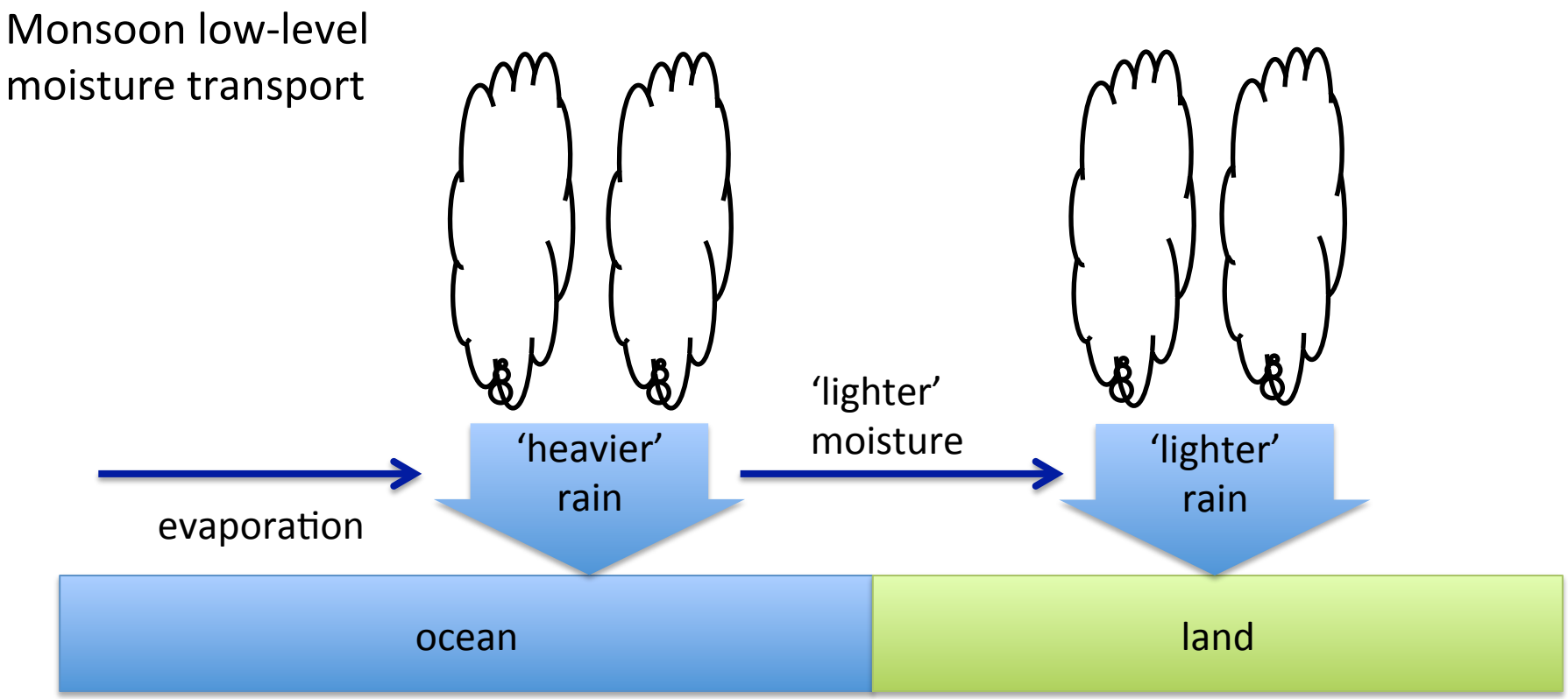


Differing Interpretations

1. Summer Monsoon Intensity ("amount effect")
2. Seasonality (ratio of summer to winter monsoon)
3. Upstream effect

Upstream effect

(*Pausata et al. 2012; Lee et al. 2012*)



Idea

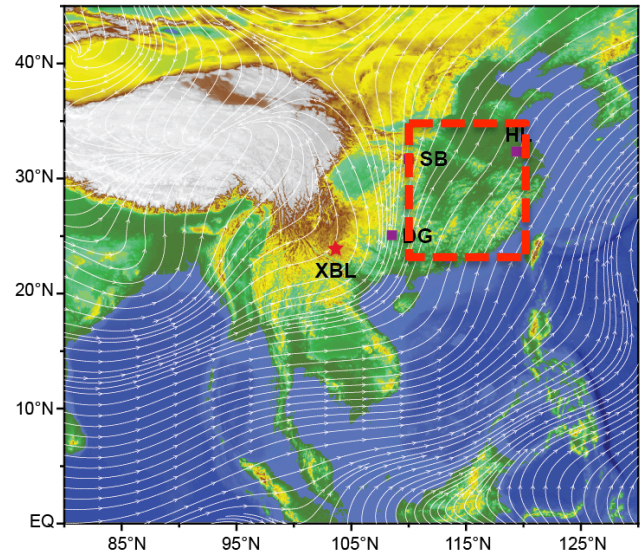
We pursue a **rainfall seasonality argument**

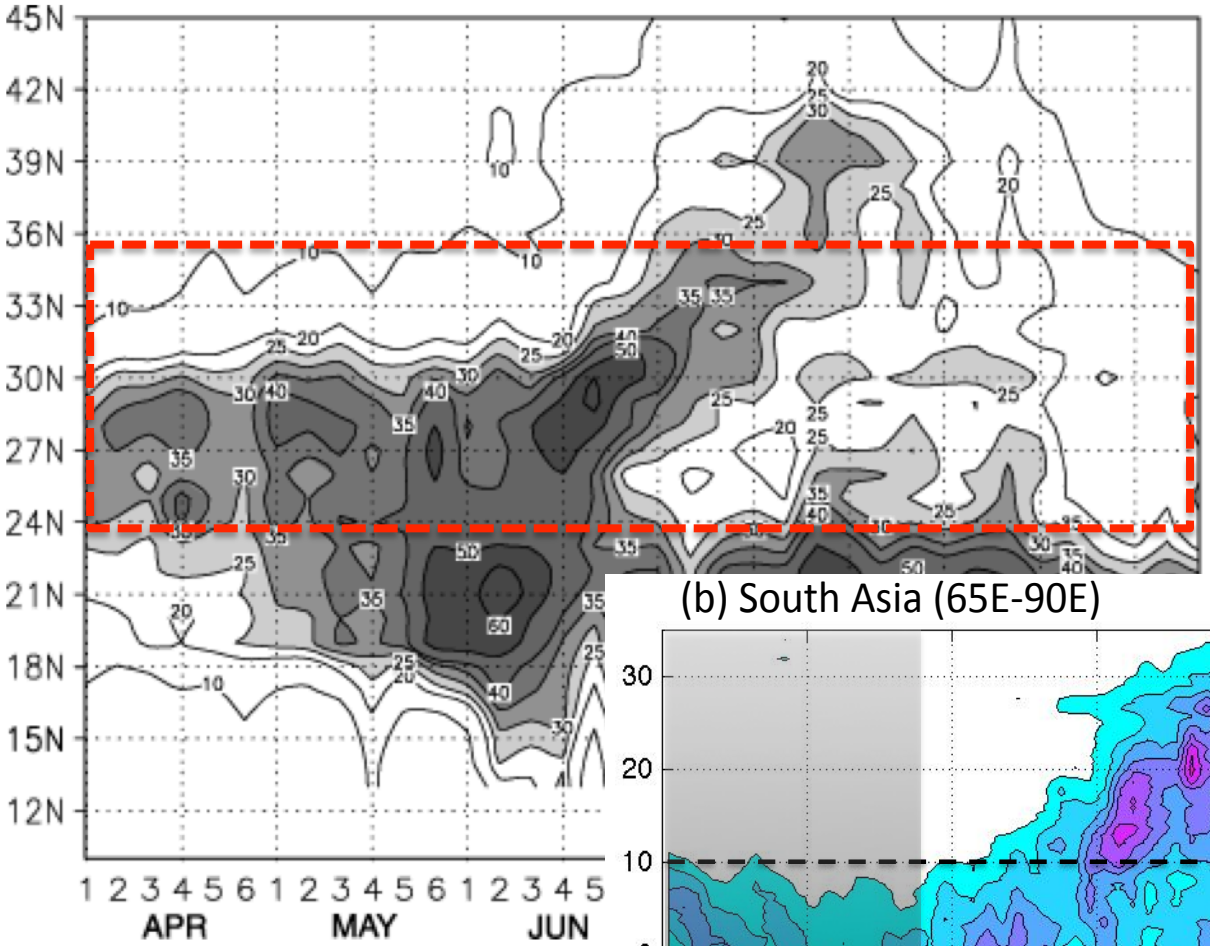
recognizing that the seasonality of the East Asian rainfall climate undergoes abrupt transitions

Ding and Chan 2005:

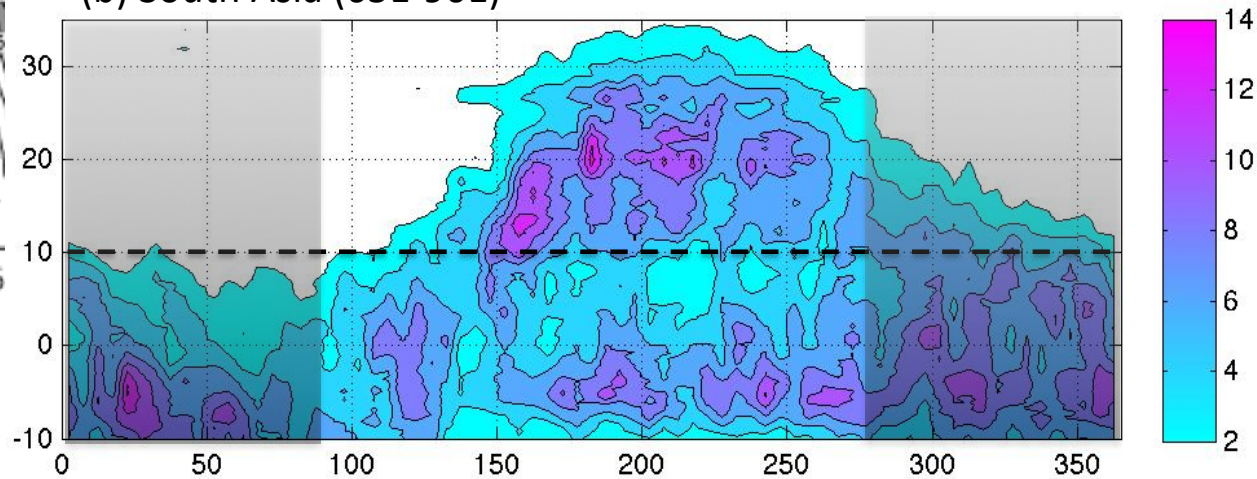
"The seasonal march of the East Asian summer monsoon displays a distinct stepwise northward and northeastward advance, with two abrupt northward jumps and three stationary periods"

Rainfall over East Asia

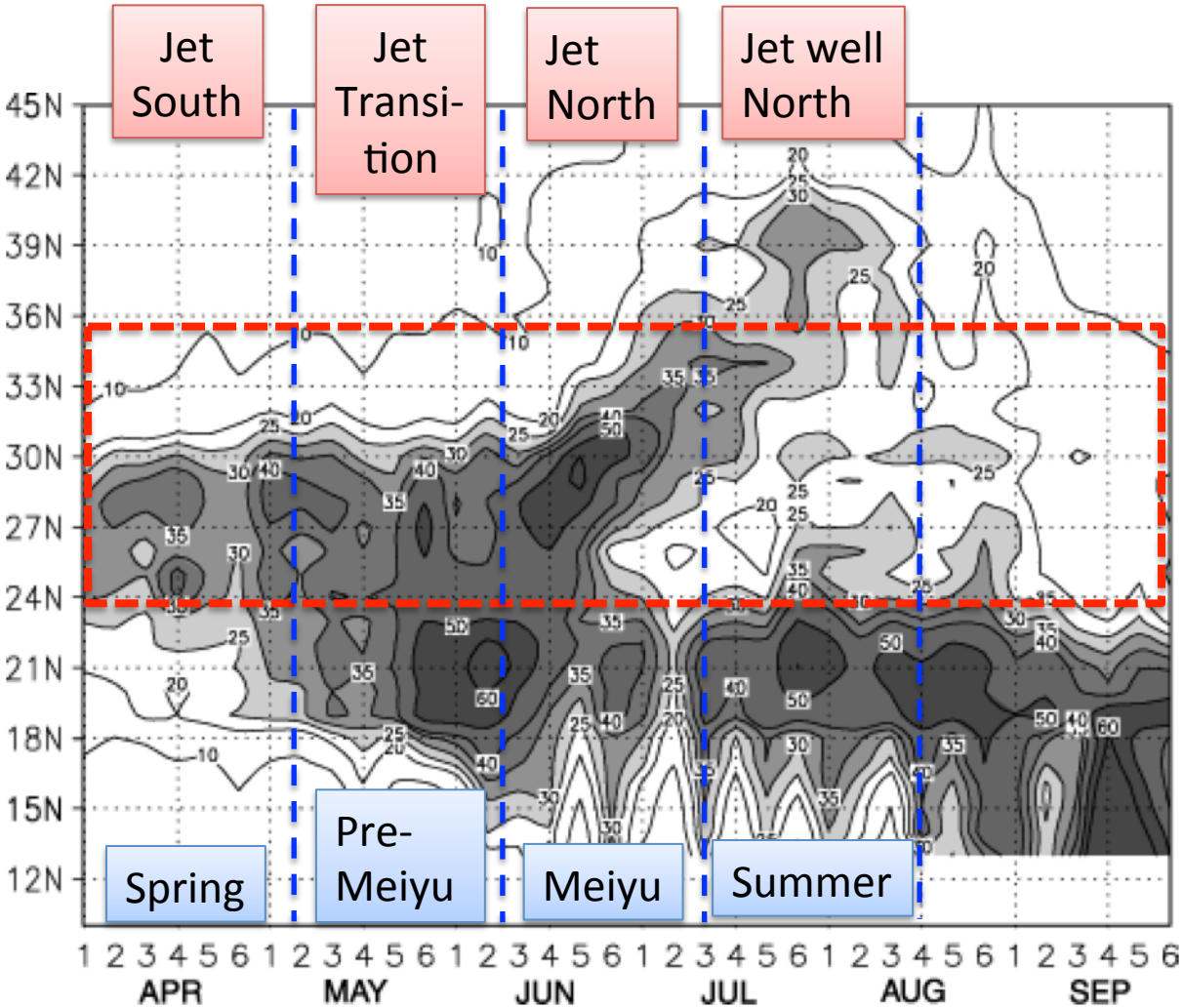


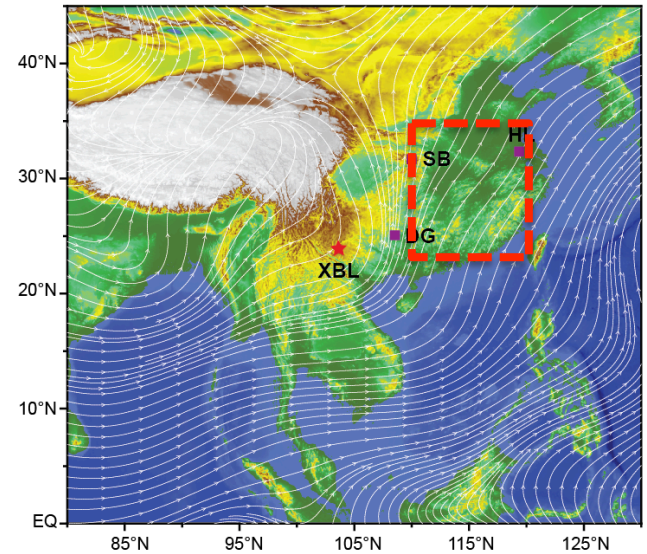


(b) South Asia (65E-90E)



Rainfall over East Asia

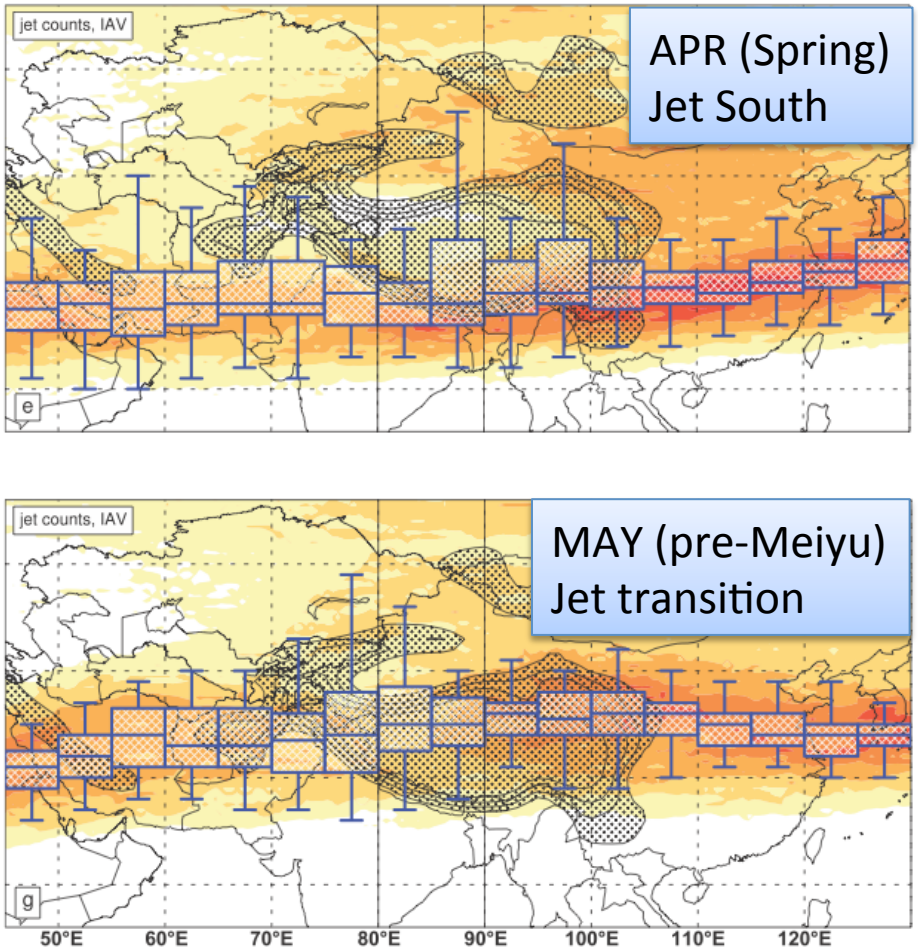


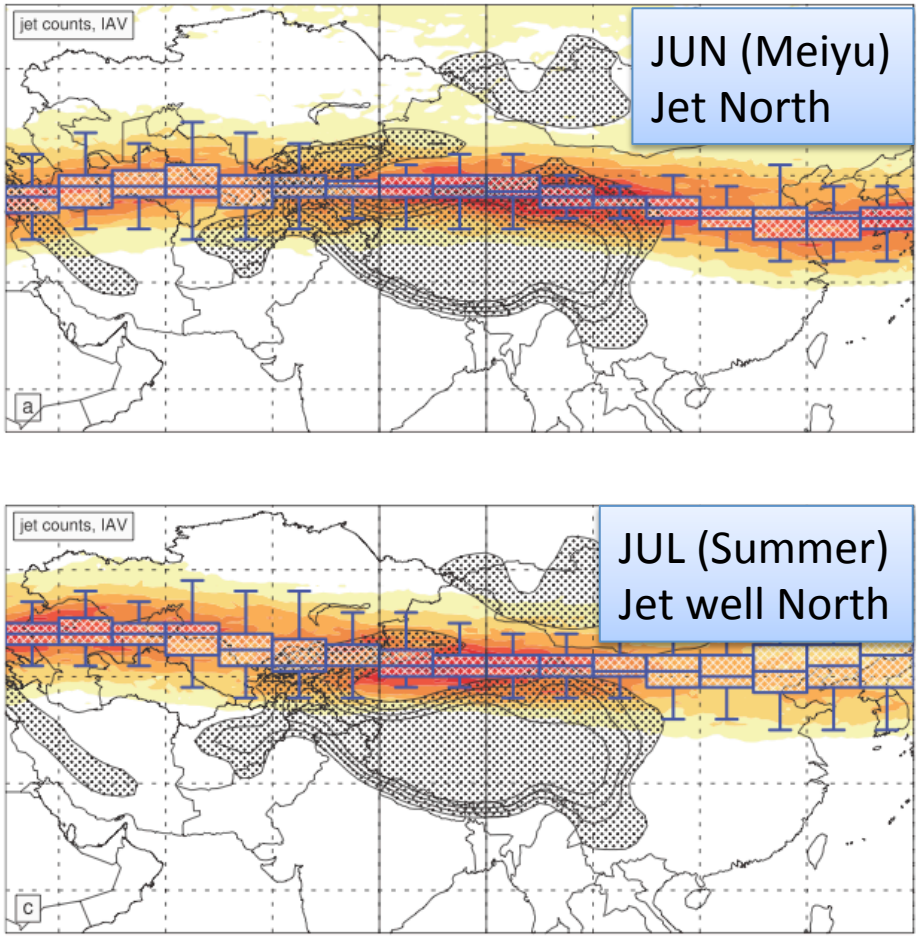


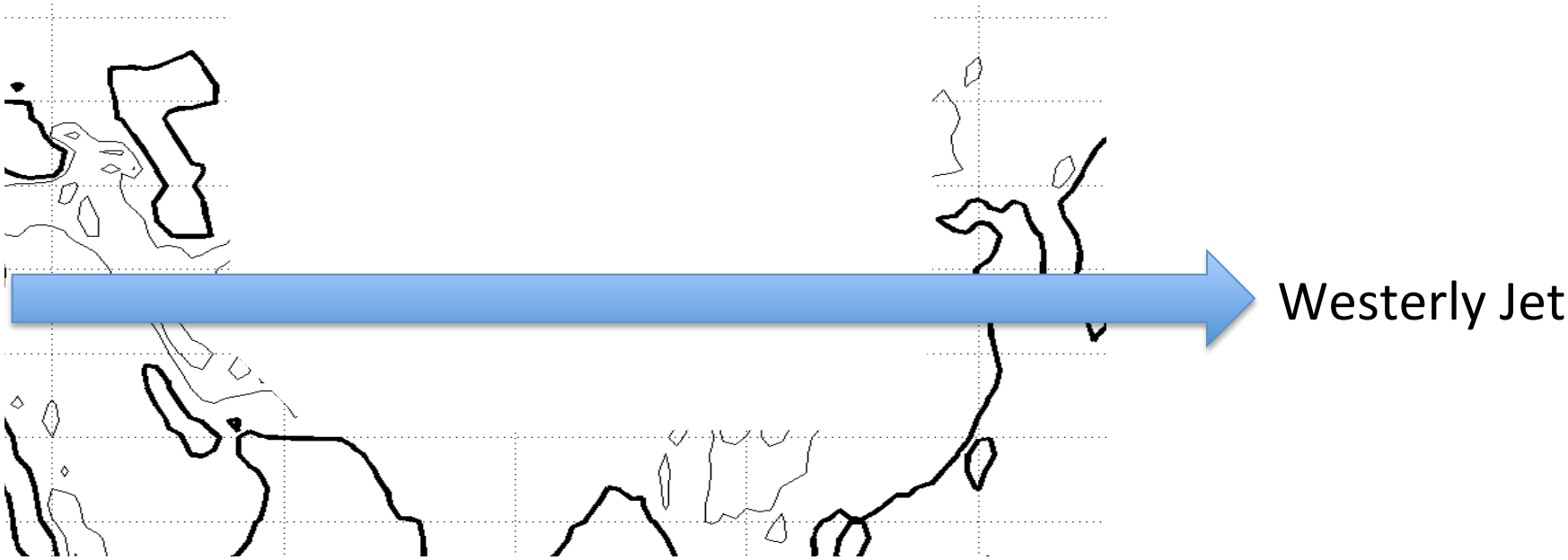
Ding and Chan 2005

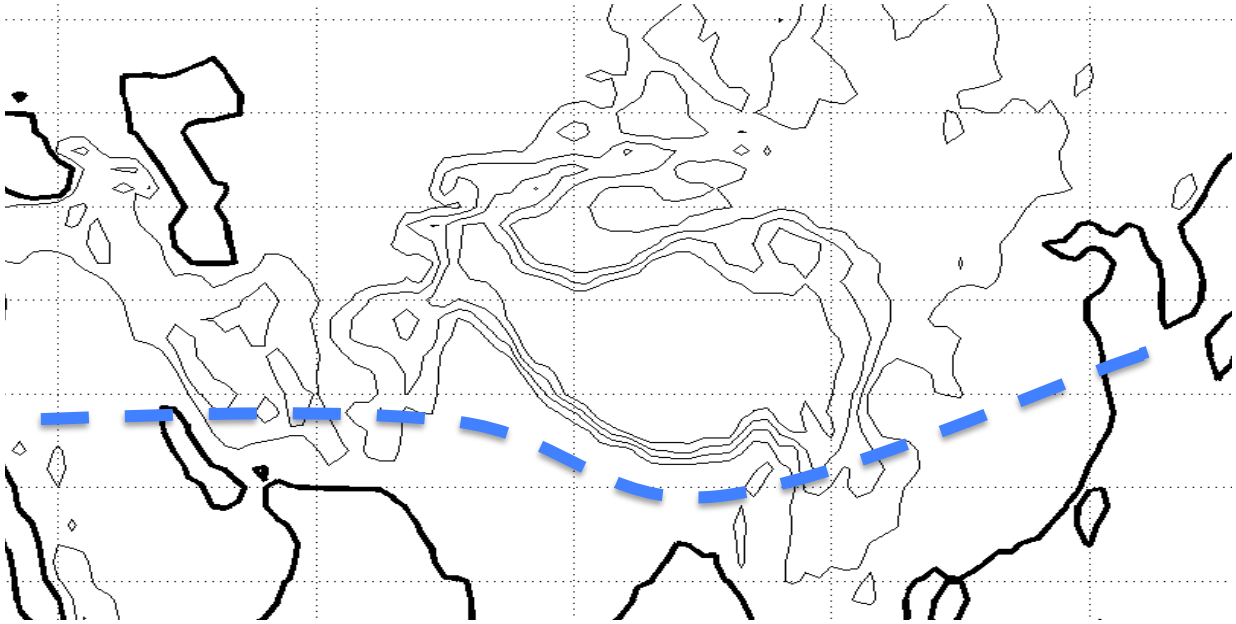
Westerly Jet Climatology

(Schiemann et al. 2009)

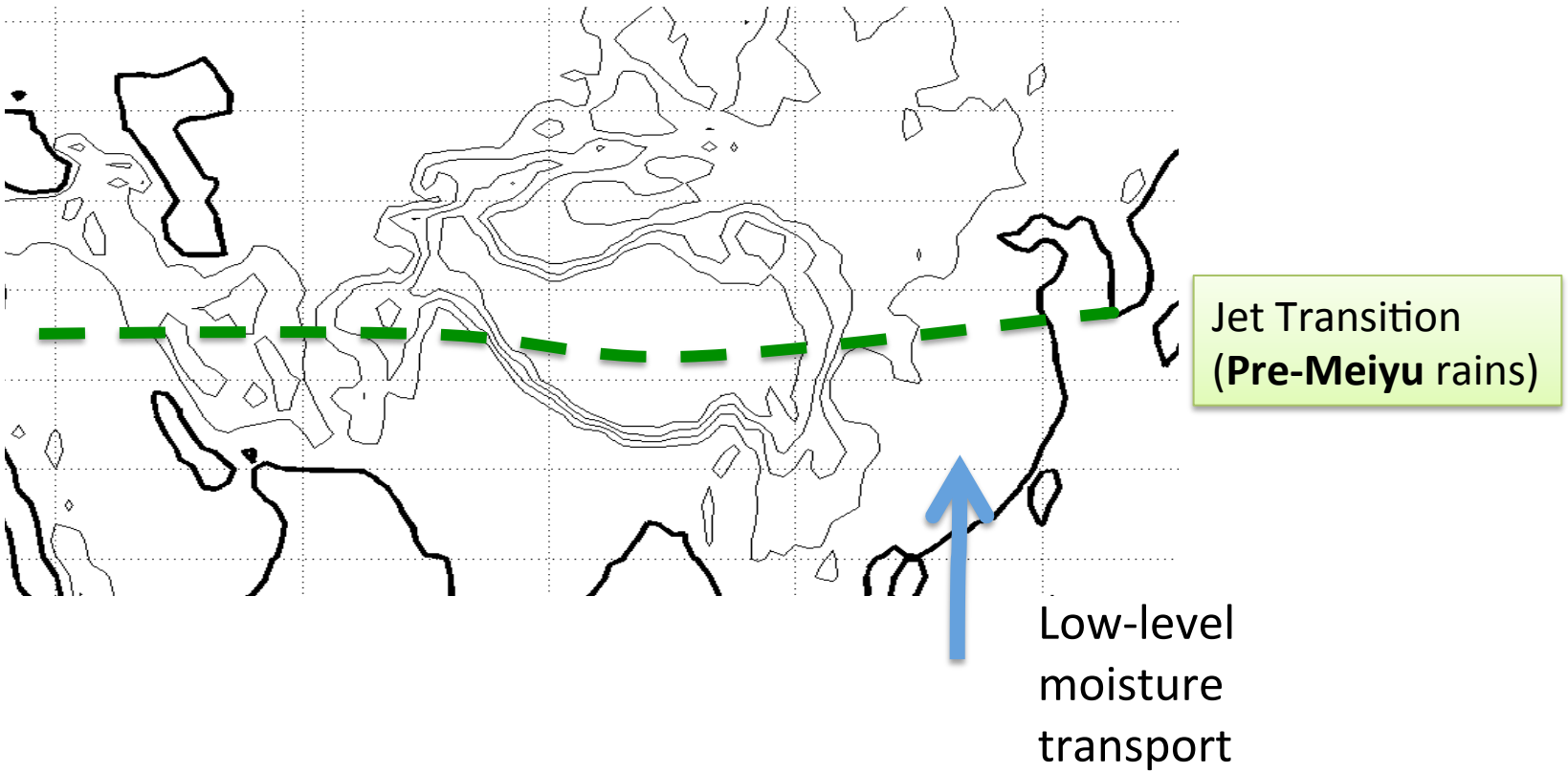


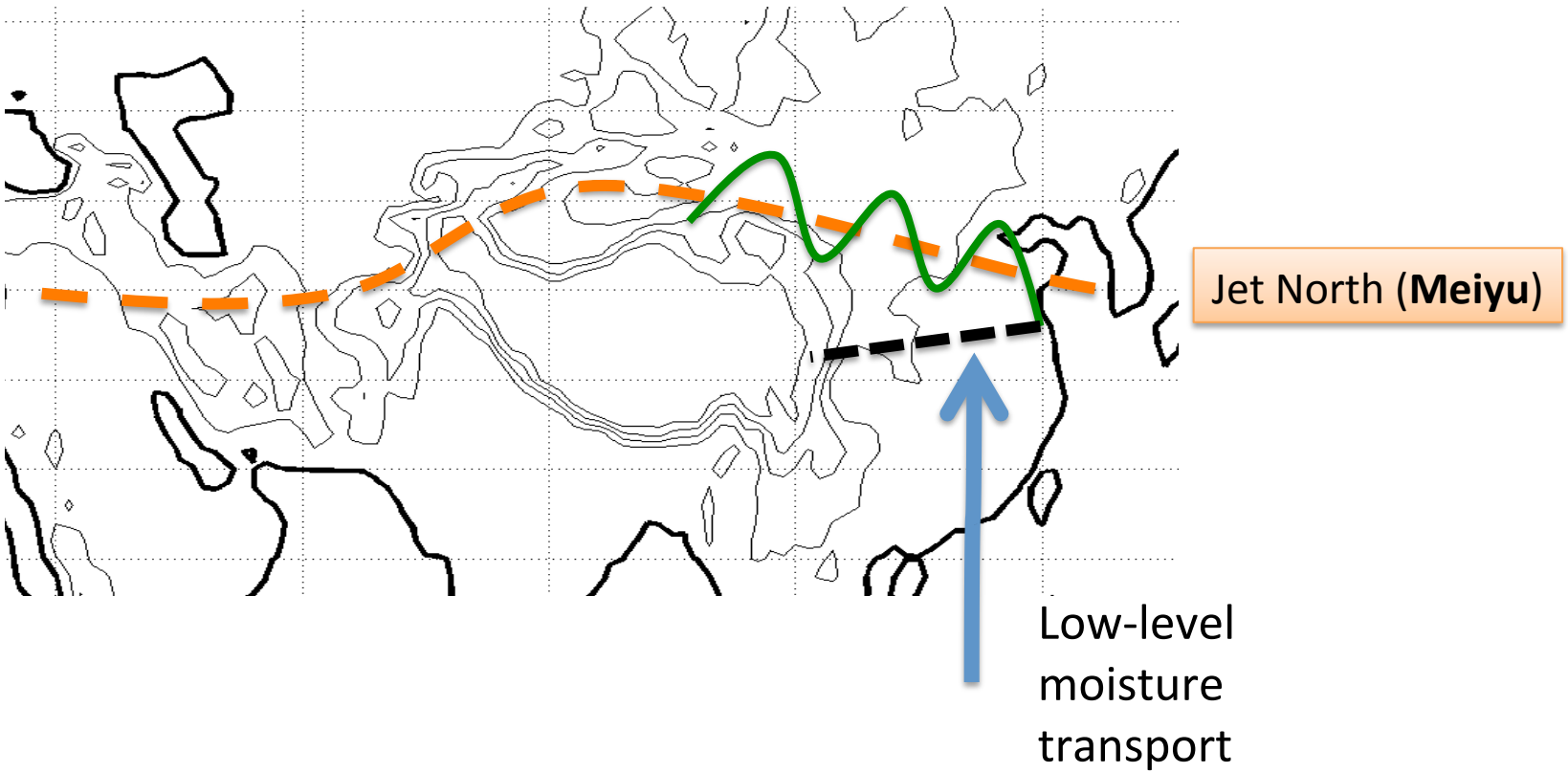


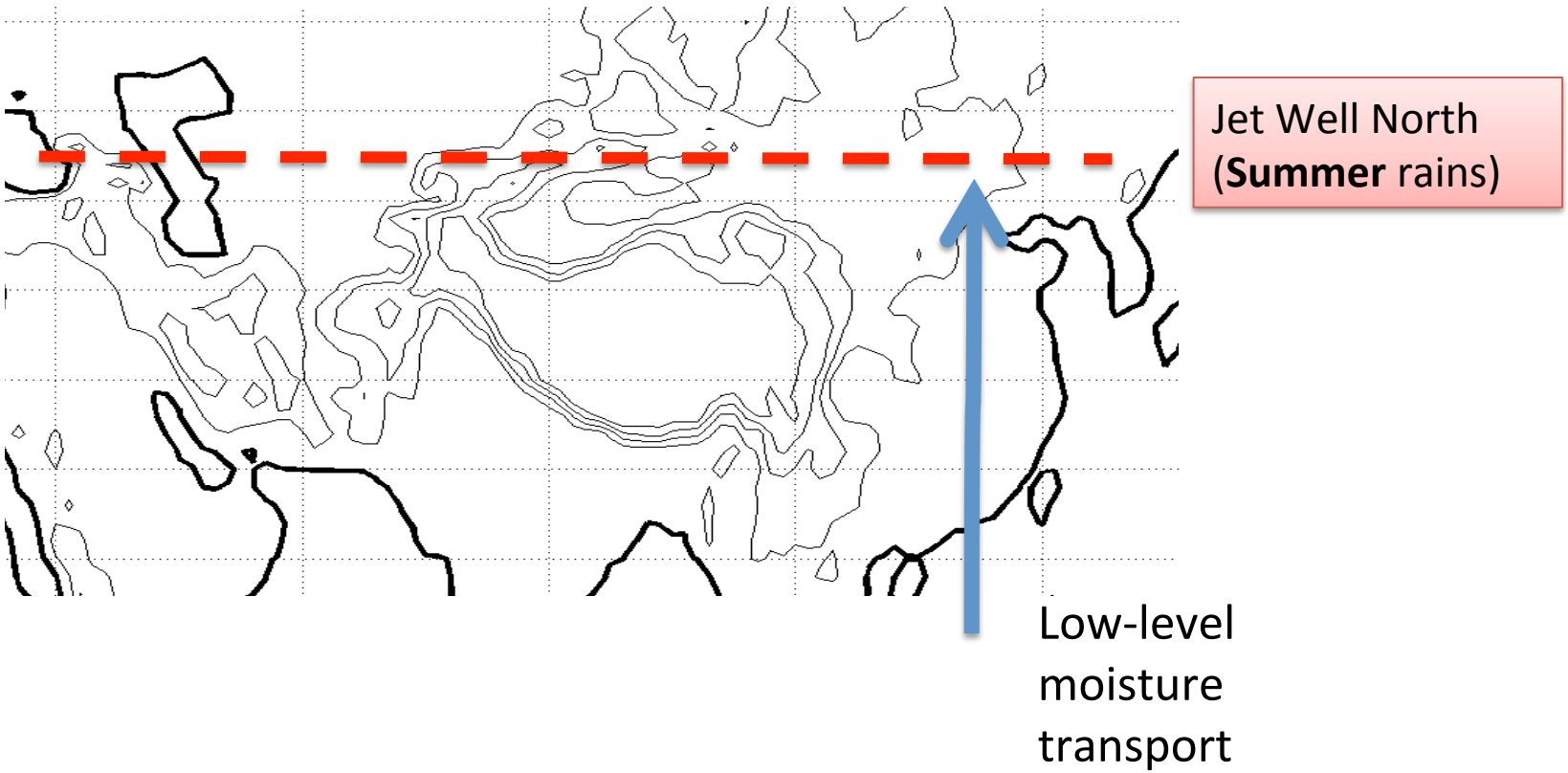

Westerly Jet



Jet South (**Spring** rains)


Jet Transition
(**Pre-Meiyu** rains)
Low-level
moisture
transport


Jet North (**Meiyu**)
Low-level
moisture
transport

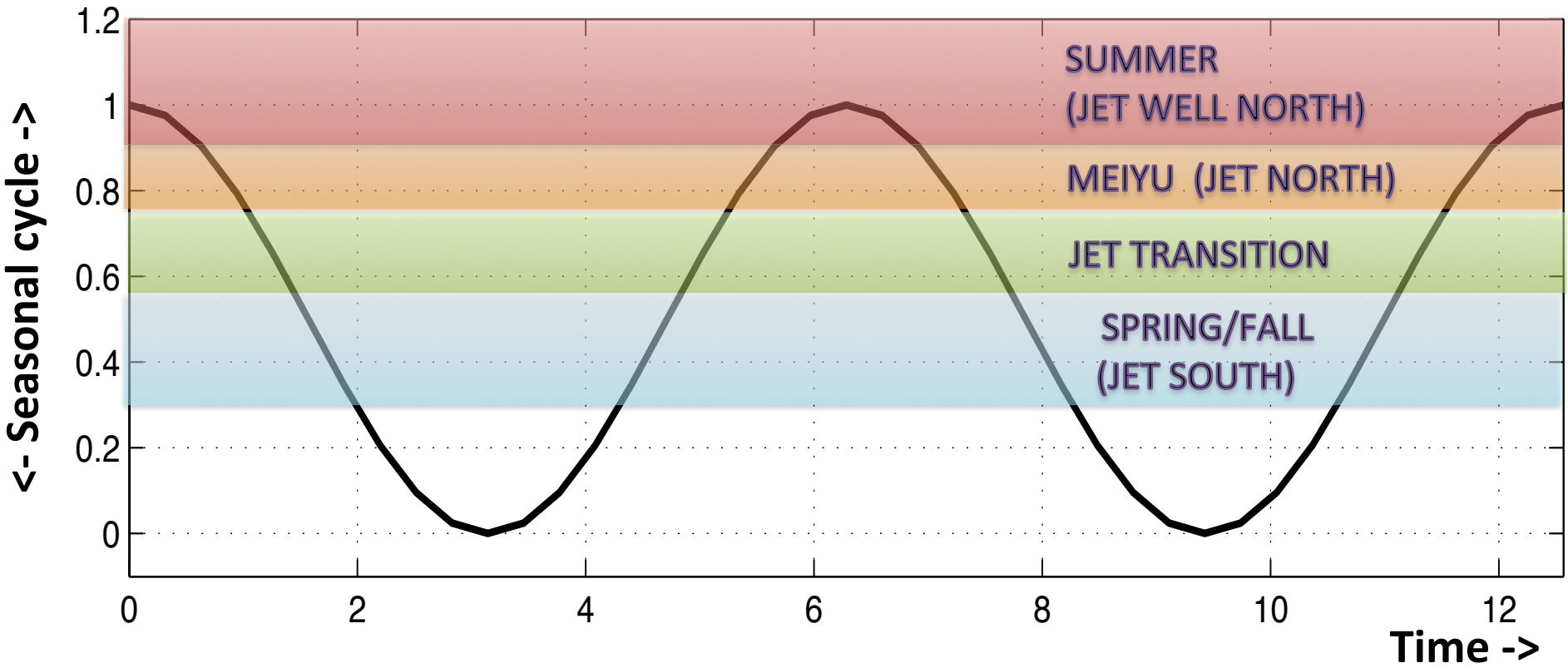

Jet Well North
(**Summer** rains)
Low-level
moisture
transport

Jet Transition Hypothesis*

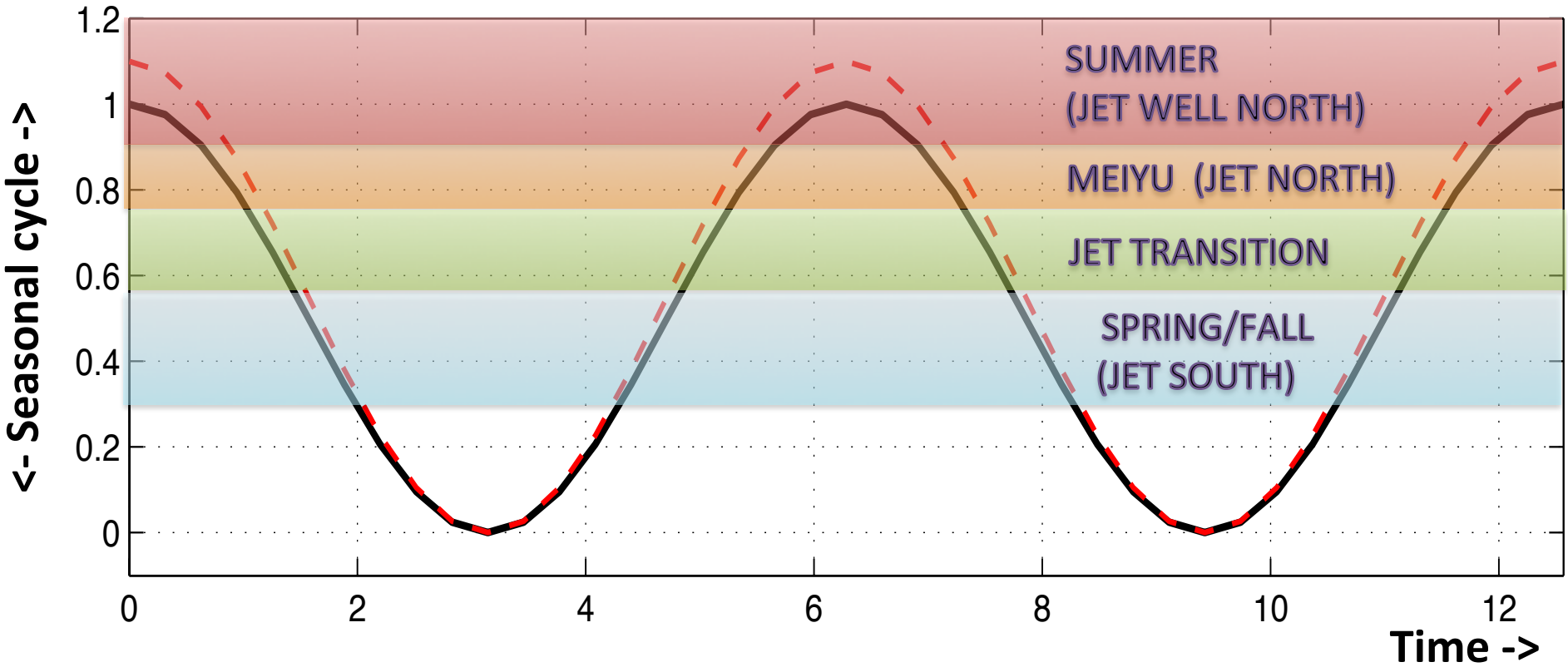
Changes to the seasonal meridional position of the westerlies relative to the Tibetan Plateau drives rainfall climate changes over East Asia on paleoclimate timescales

* First proposed by Kana Nagashima et al. (2007, 2011)

Conceptual Idea



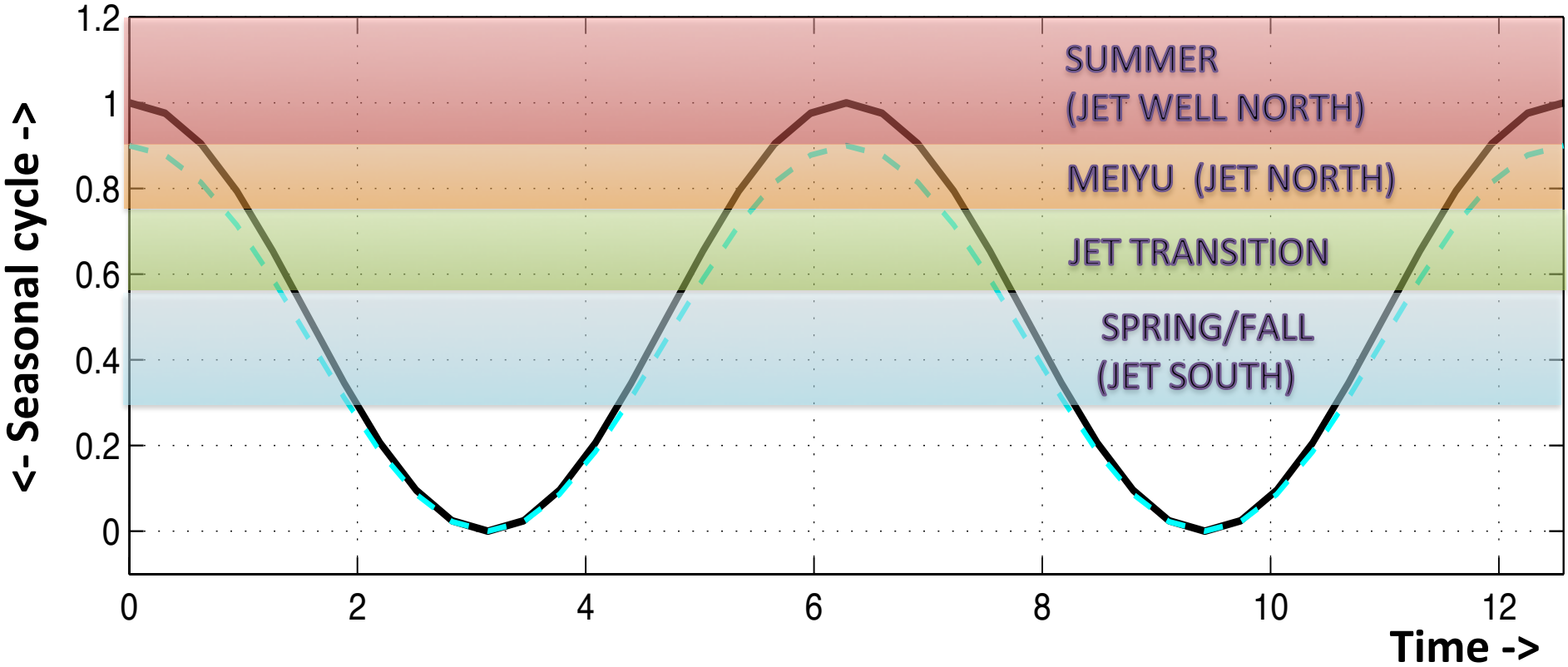
Earlier Jet Transition



Predictions

- Earlier Meiyu onset
- Longer Summer rains

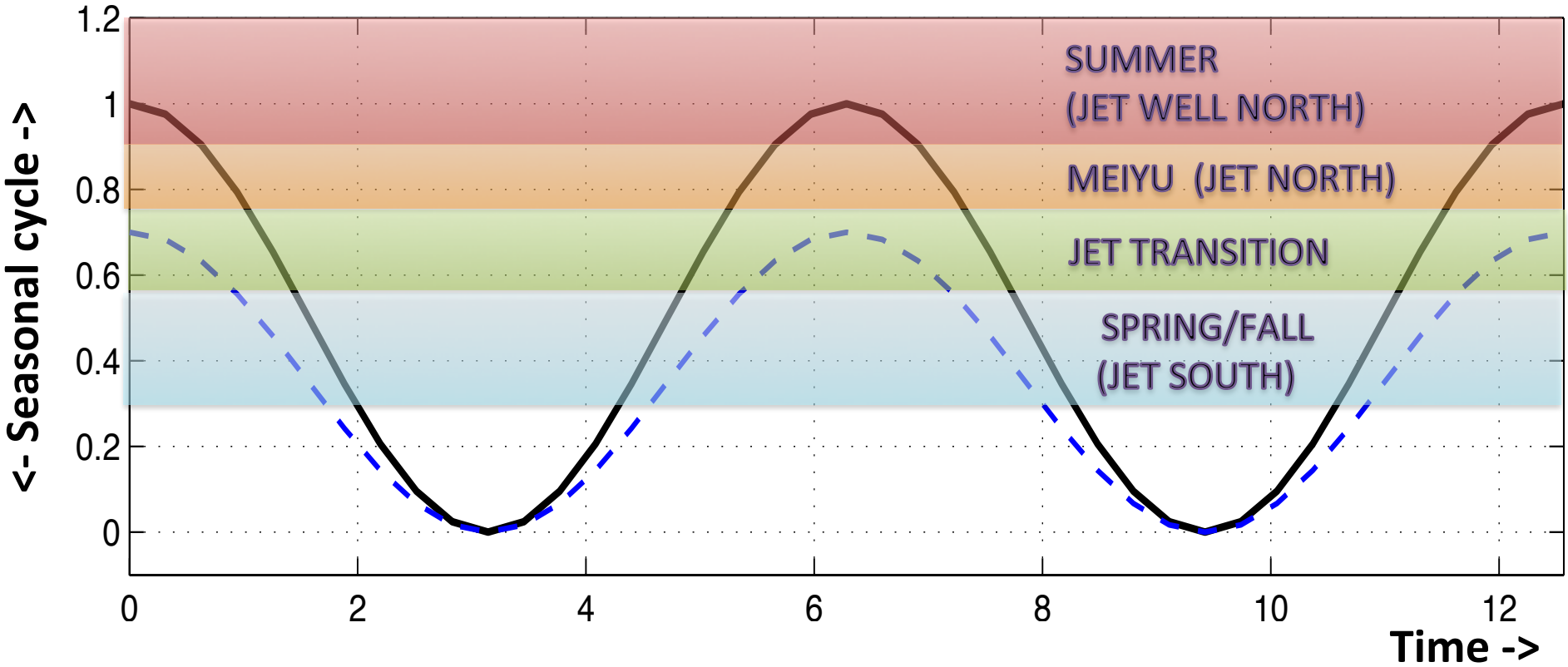
Delayed Jet Transition



Predictions

- Later Meiyu onset
- Longer Meiyu
- Less or no Summer rains

No Jet Transition



Predictions

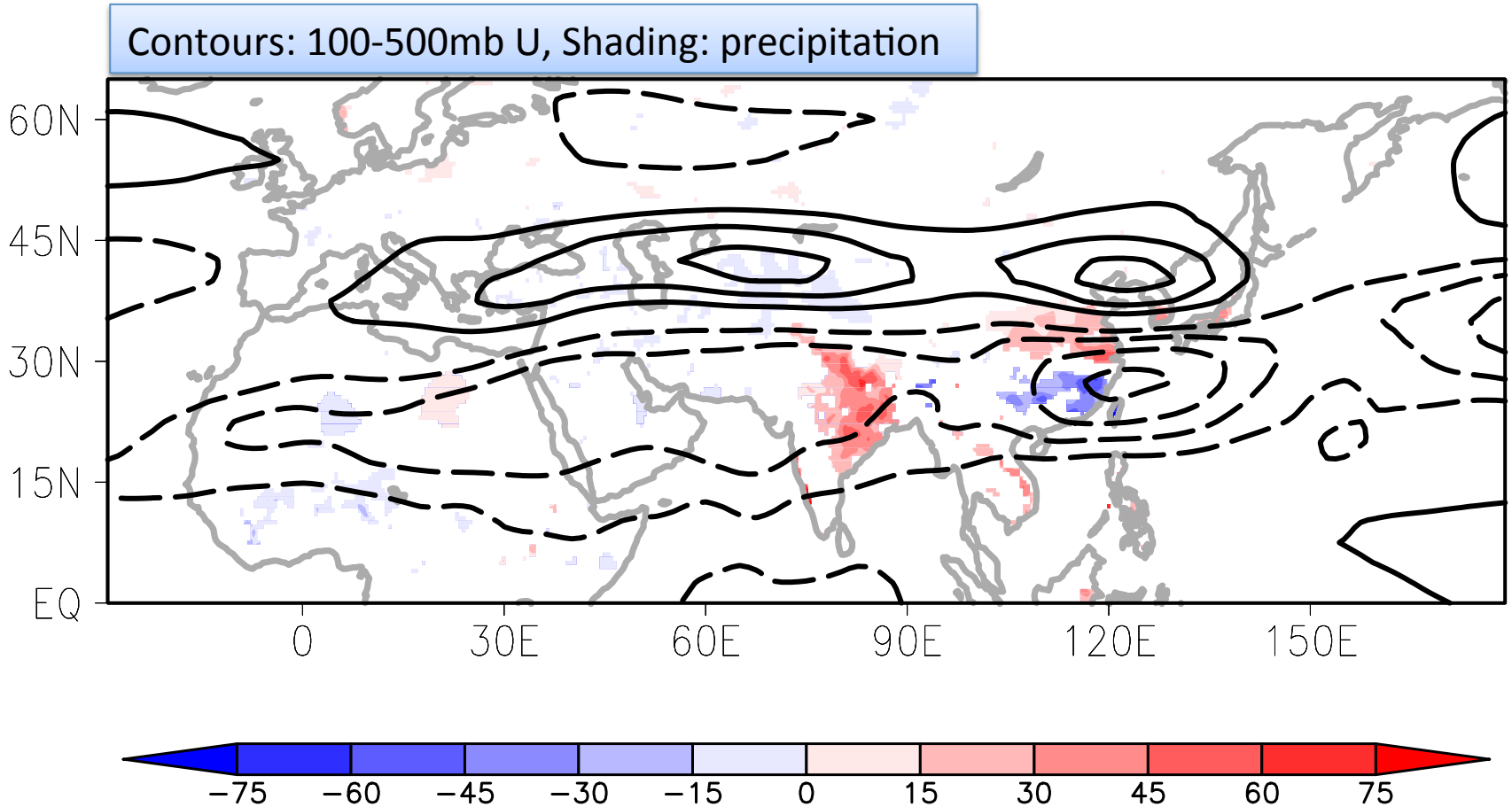
- Longer Spring rains
- No Meiyu or Summer rains

Testing the Hypothesis

- Modern Analogs (interannual variability)
- Model simulations of past climate (11kbp)
- Explaining speleothem $\delta^{18}O$ variations

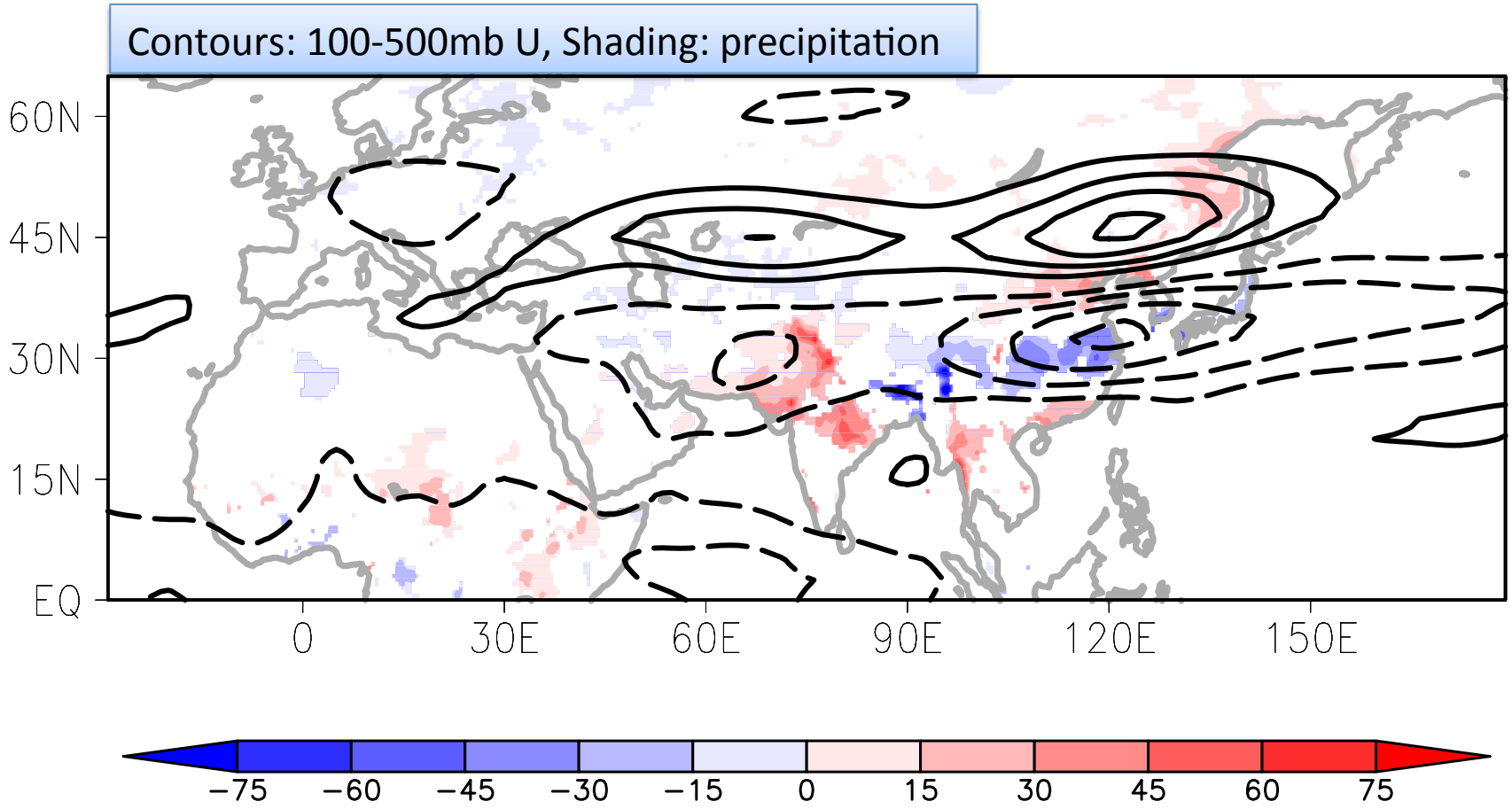
June MCA mode 1 – regional patterns

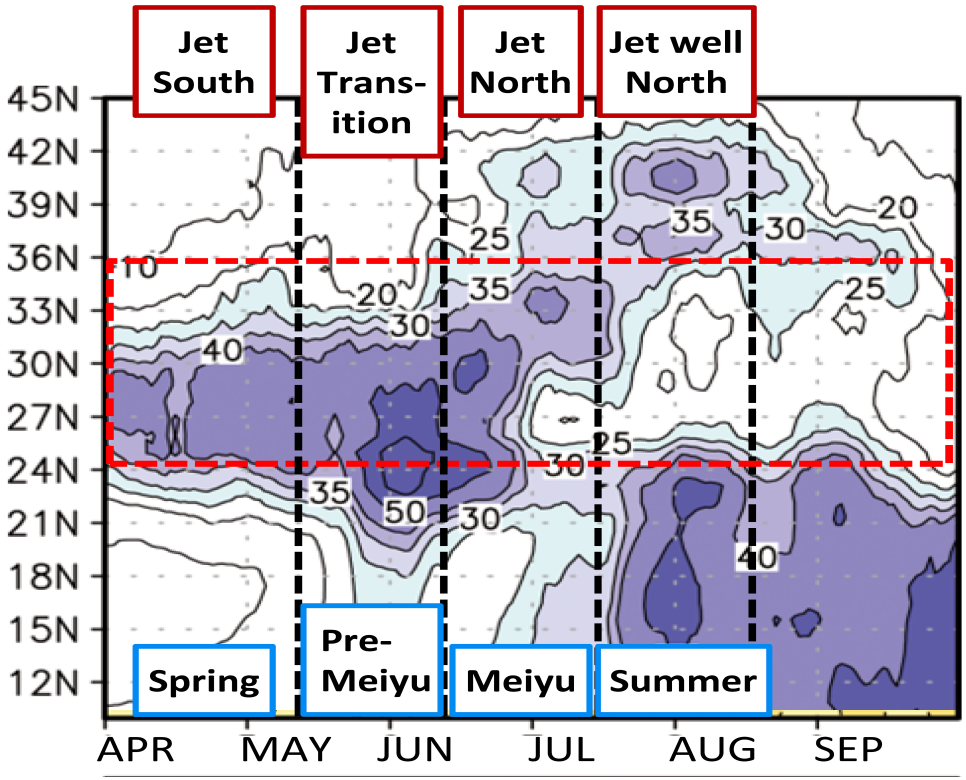
(regression onto U expansion coefficients)



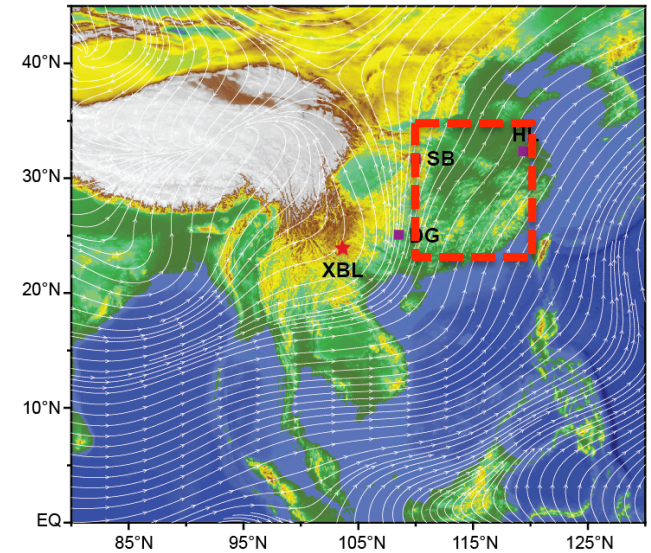
July-Aug MCA mode 1 – regional patterns

(regression onto U expansion coefficients)





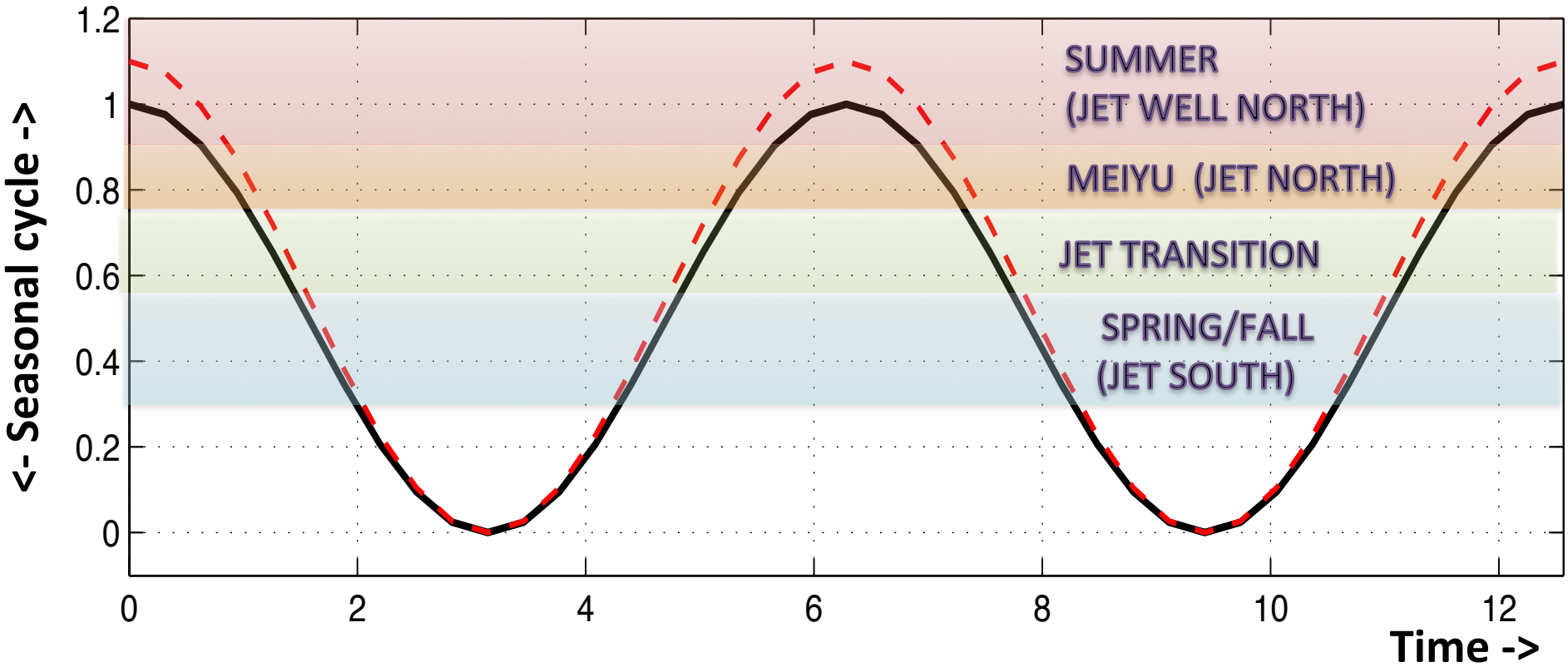
CAM5 (w/ slab ocean)
1 degree simulation



Question:

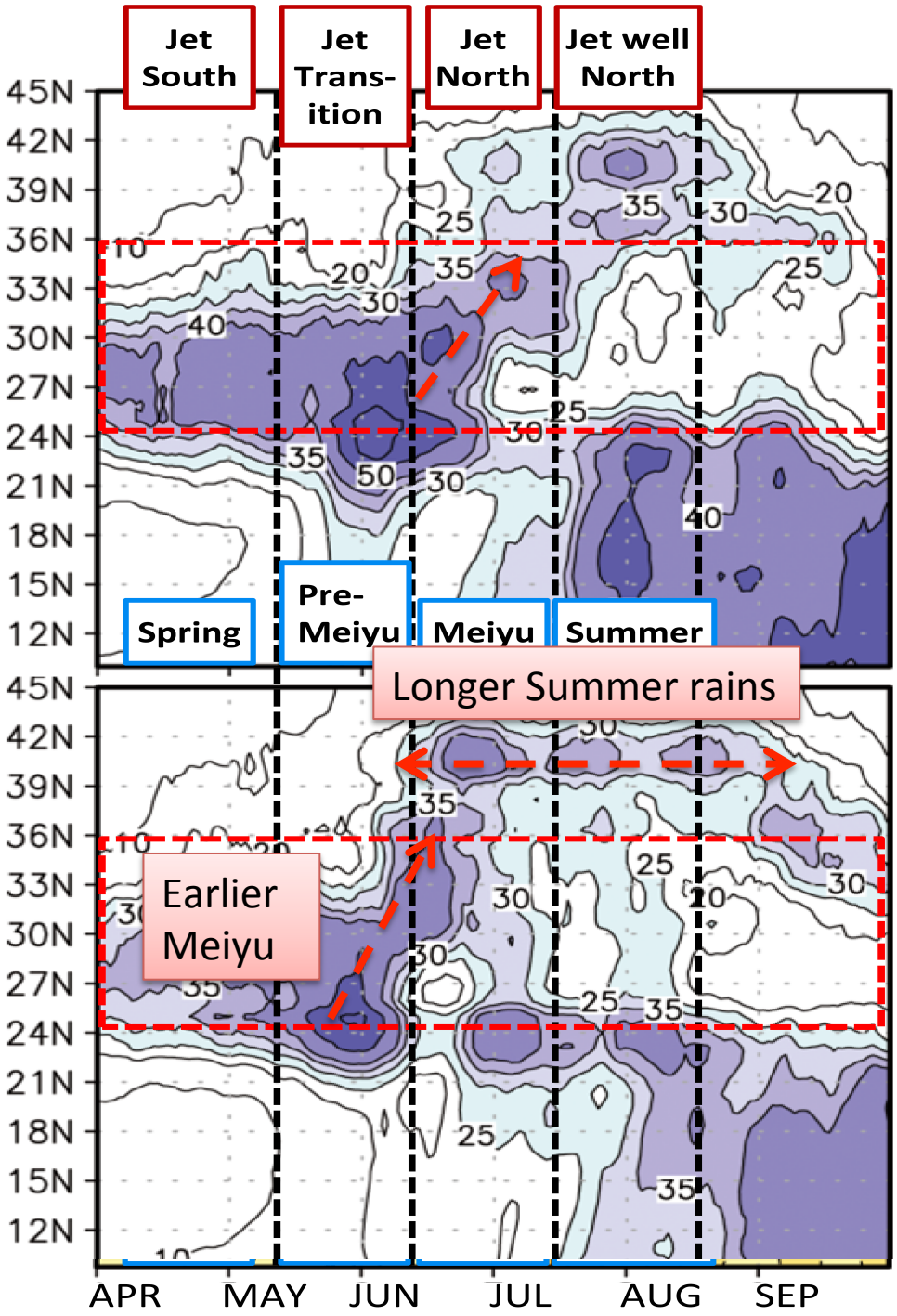
How would you expect the rainfall to behave if I set orbital conditions to 11,000 years before present? (keeping all else same)

Earlier Jet Transition



Predictions

- Earlier Meiyu onset
- Longer Summer rains



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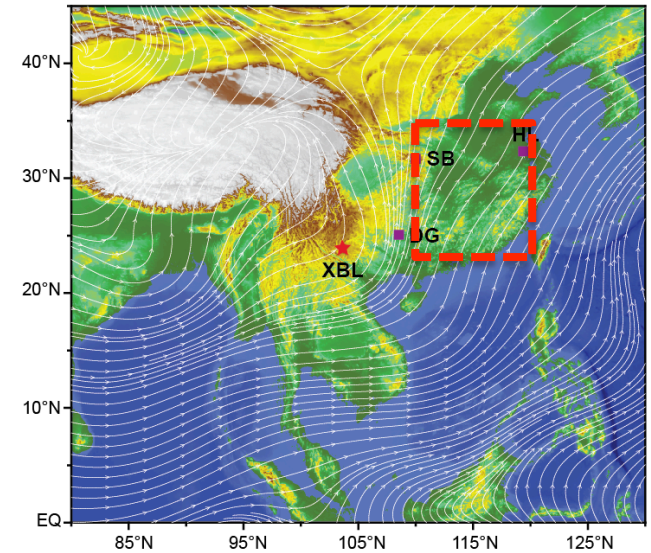
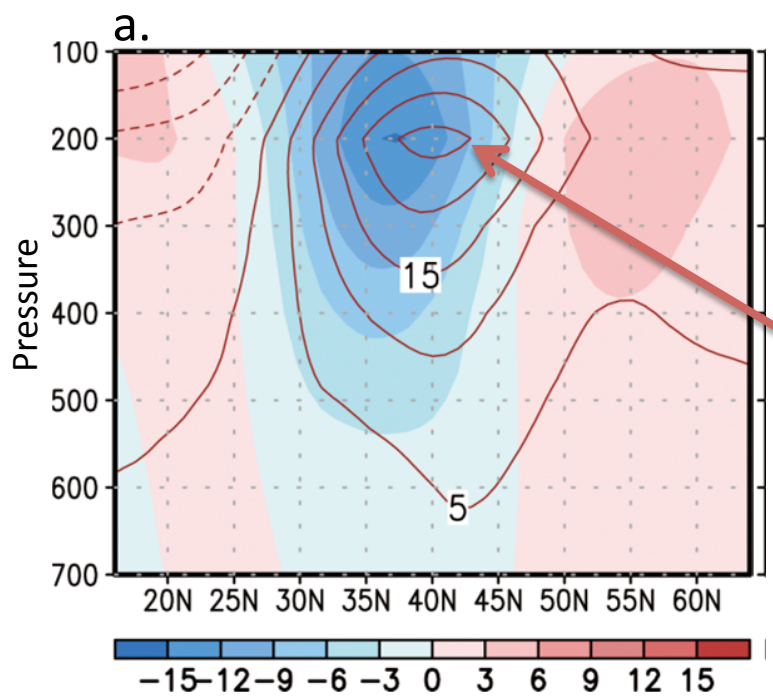


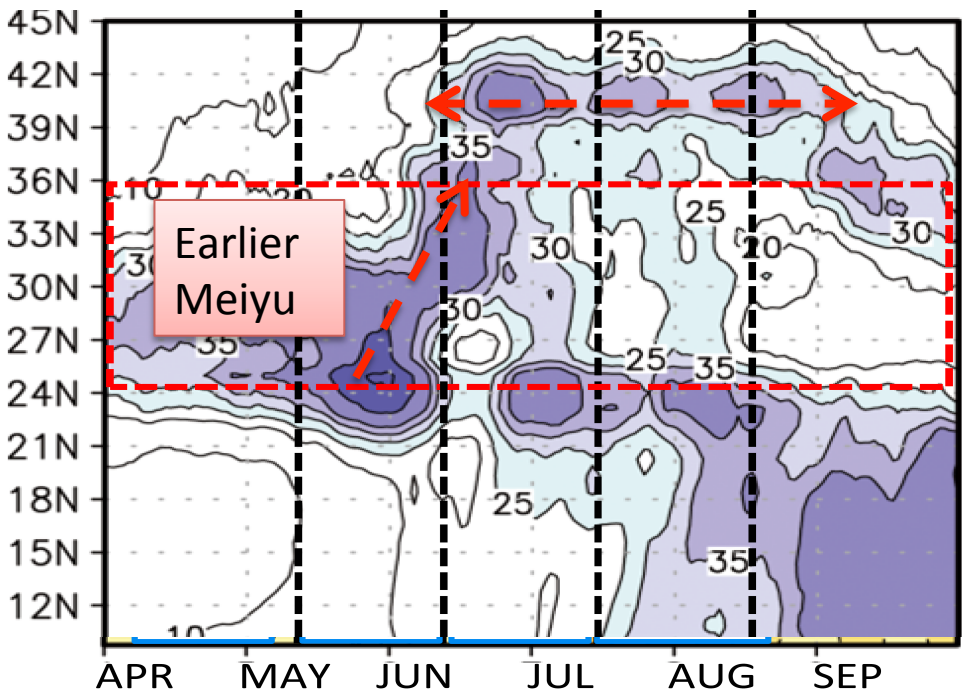
11,000 ybp simulation

- Meiyu occurs earlier in season
- Longer Summer rains



June-August zonal wind change averaged over East Asia 100°E-125°E

Mean max jet location

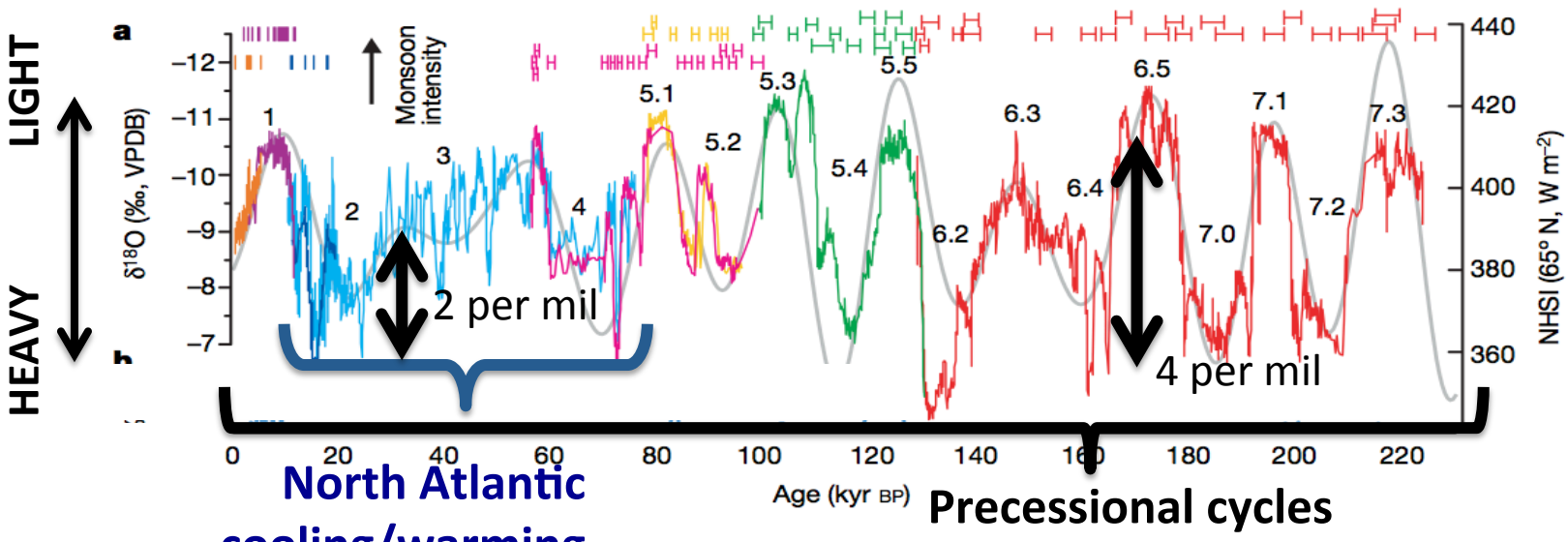


11,000 ybp simulation

- Meiyu occurs earlier in season
- Longer Summer rains

What does the Jet Transition Hypothesis say about speleothem $\delta^{18}O$ variations?

Wang et al. 2008



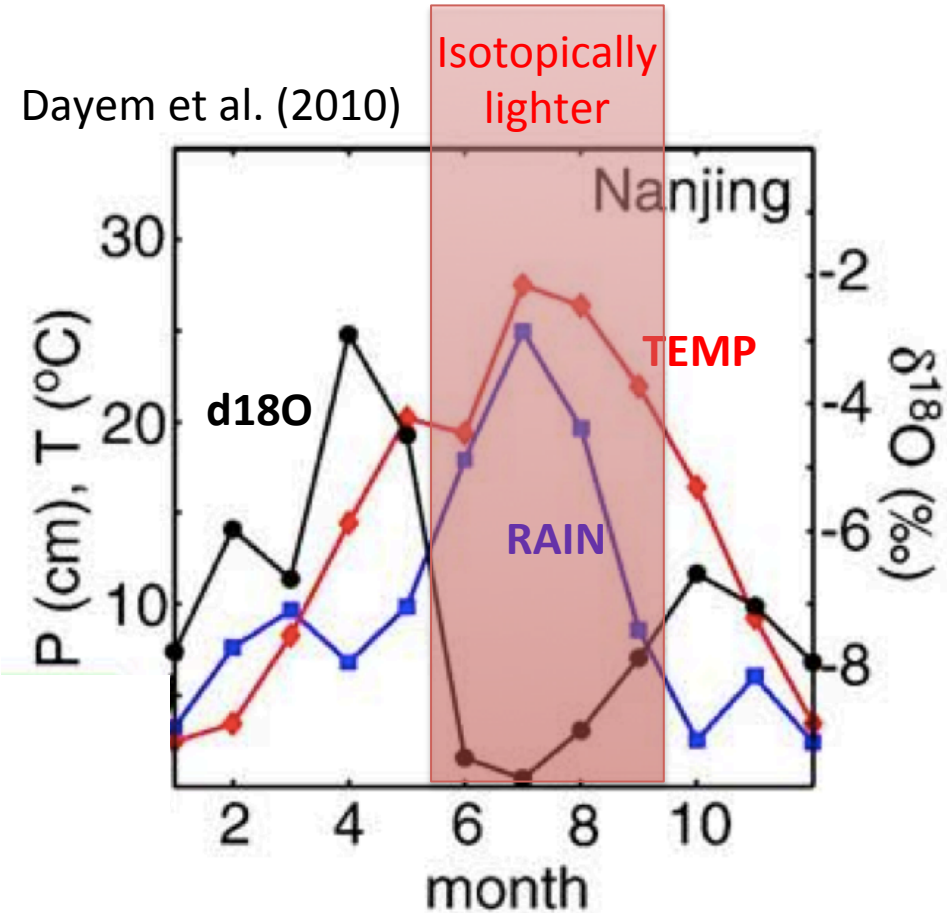
North Atlantic cooling/warming

Precessional cycles

(grey line is insolation change)

Seasonal cycle of $\delta^{18}O$, Nanjing

Dayem et al. (2010)

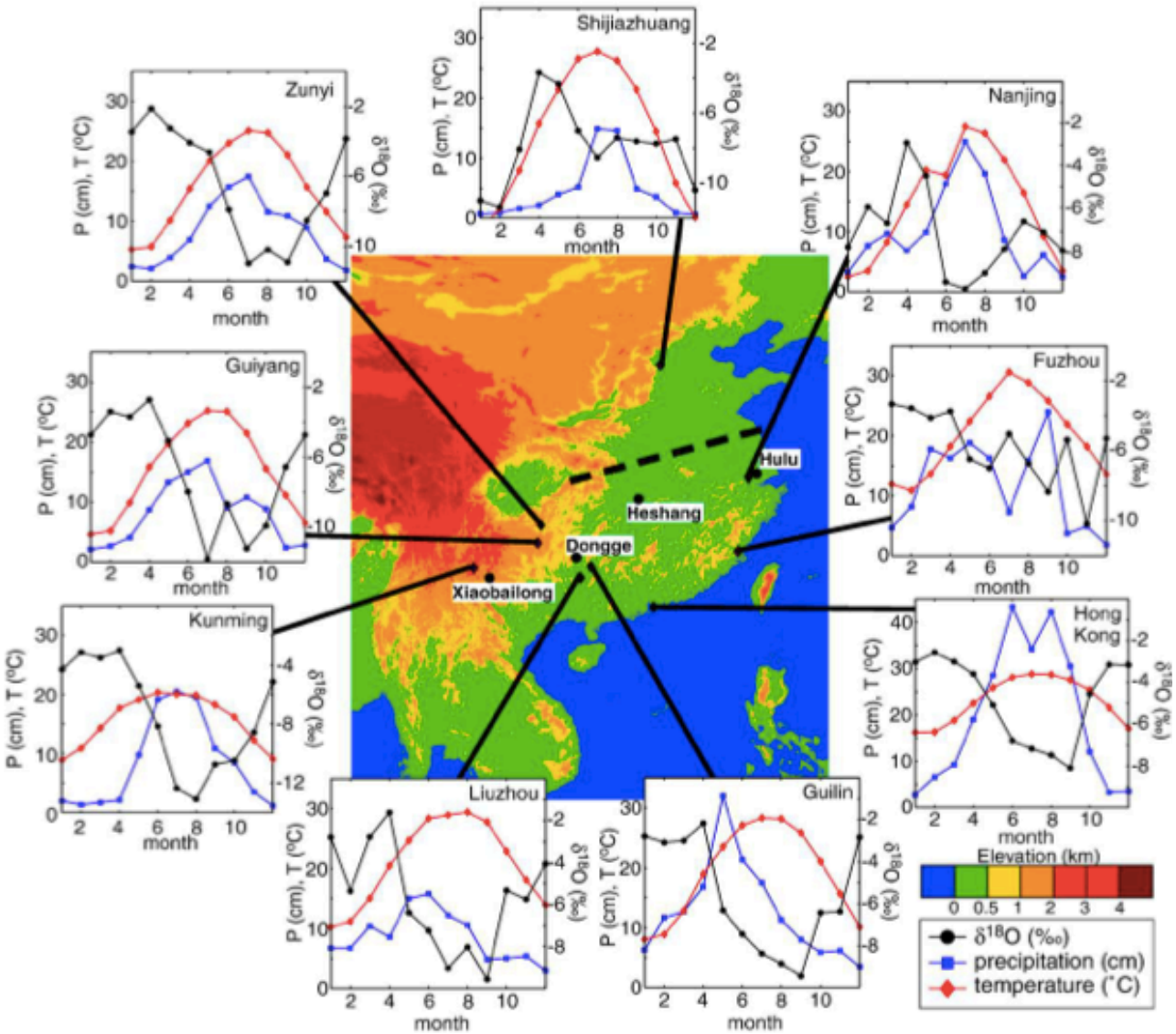


Question: what if the East Asian monsoon was kept to Spring conditions throughout the summer months?

(i.e. Westerlies failed to transition to the North of the Plateau during its seasonal evolution)

Nagashima et al. (2007): prolonged Spring conditions during cold D/O phases consistent with East Asian dust records

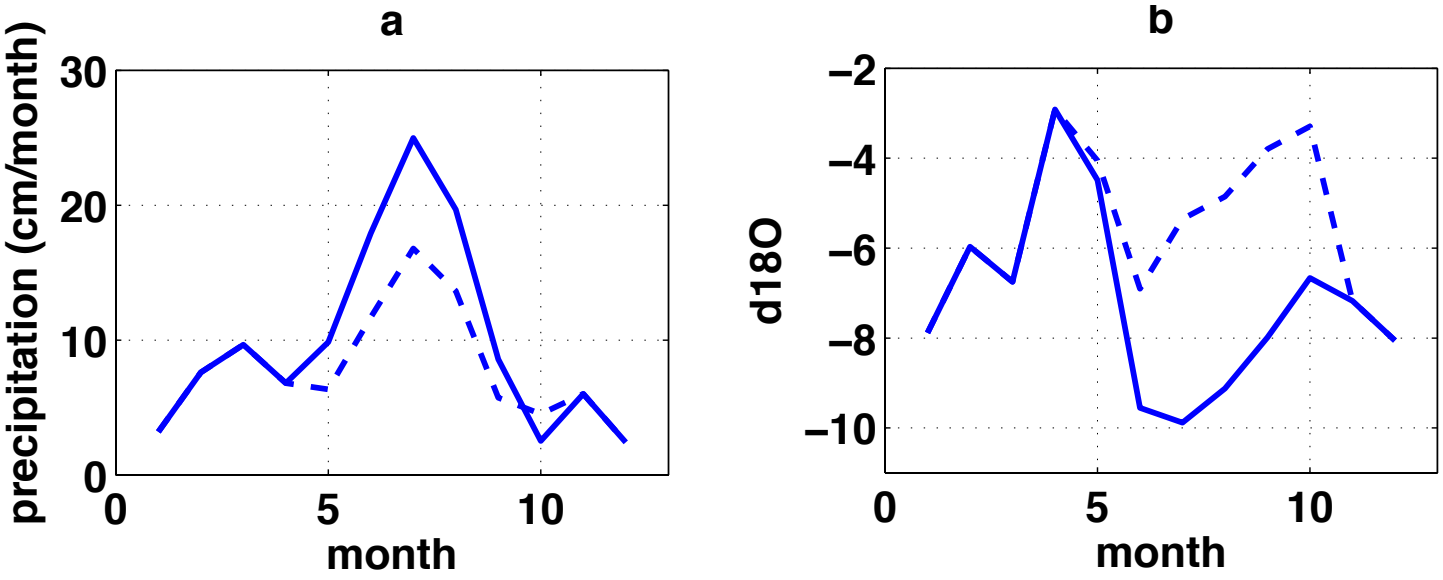
Seasonal cycle of d^{18}O in precipitation



1. Apply a combined EOF to monthly climatological rainfall and d18O
2. Modify the principal components of EOF 1 and 2 (seasonal cycle) to fix summer months to May conditions
3. "Reconstruct" rainfall and d18O

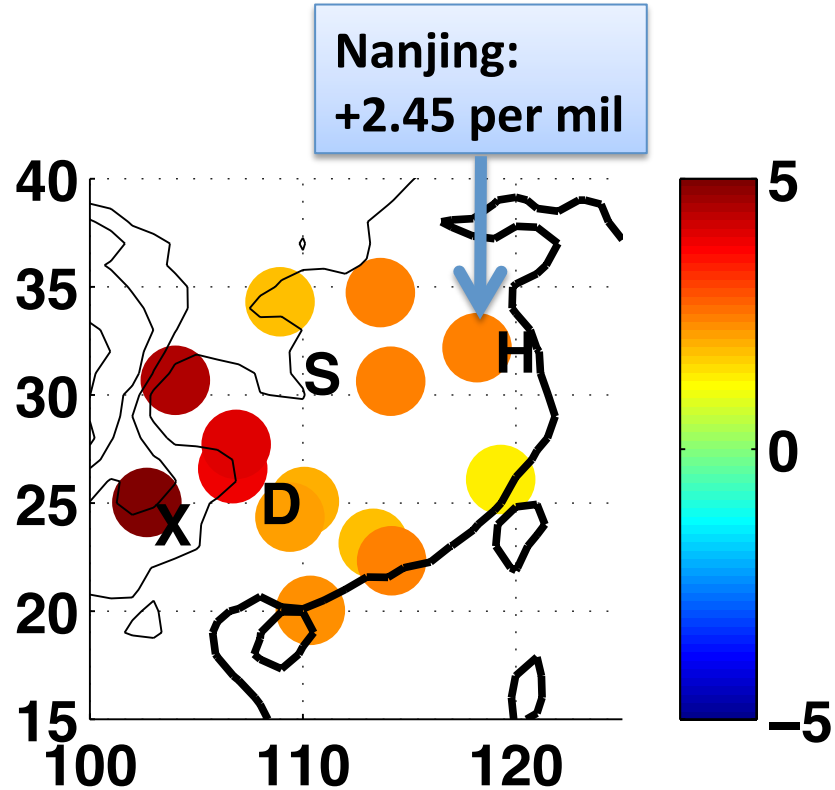
Dayem et al. 2010

Nanjing



Annual mean $\delta^{18}O_p$ change (precipitation-weighted)

ALL increased over Central and South China



“Jet Transition Hypothesis” conjecture for speleothem $d^{18}O$ variations

- Low level monsoonal inflow of moisture is isotopically light
- The meridional position of the westerlies (relative to the Plateau) limits how far northward the monsoonal moisture penetrates

Summary

- East Asian rainfall change in the distant past may have resulted from a *modulation of its seasonal transitions*
- This modulation is dynamically tied to *the latitude of the westerlies relative to the Tibetan Plateau*
- There is an *modern-day analog* that links interannual variability in the timing of seasonal transitions to westerly jet changes
- *Modeling of paleoclimate scenarios* (11,000ybp and North Atlantic cooling) support this hypothesis
- The hypothesis *may be able to explain the behavior of disparate paleoclimate records*, in particular East Asian speleothem $d^{18}O$ and dust records