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Climate of the Past
Discussions

Interactive comment on "The Global Monsoon across Time Scales: is there coherent variability of regional monsoons?" *by* P. X. Wang et al.

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I. Overview and Recommendation:

The task of conducting syntheses and writing overview papers such as this grows ever more difficult with the rapid increase in the number of scientific papers published across interrelated fields, in this case, modern meteorology, paleoclimate modeling and paleoclimate reconstruction based on geological archives. This PAGES Working Group synthesis paper seeks to bring together evidence from all three in support of the Global Monsoon (GM) concept.

Within the strict GM paradigm, all northern hemisphere (NH) monsoonal regions (e.g. Indian, Asian, N. African, N. American) should have the same response to changing

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NH insolation patterns and all southern hemisphere (SH) monsoonal regions (e.g. Australian, South African, South American) should have the same response to changing SH insolation patters. A corollary of the GM paradigm is that the NH and SH monsoon systems should be out of phase with one another at the precession band, given the out of phase nature of NH/SH precession-driven radiation at the orbital time scale.

If the paradigm described above were true in all regards, the title of the paper would likely be phrased as a statement, as opposed to a question (The Global Monsoon across Time Scales: coherent variability of regional monsoons). The phrasing of the title in terms of a question reflects the fact that there are significant exceptions to the strict GM paradigm, a finding that the authors appear to have some of difficulty coming to terms with. This difficulty is reflected in the way the overall manuscript is written; clear statements in support of the GM paradigm are often followed by significant qualifications or hedge statements. Examples are found in the abstract and conclusions. The abstract reads: "On the basis of observation and proxy data, the WG found that the regional monsoons can vary coherently, although not perfectly, at various time scales, ranging from interannual, interdecadal, centennial and millennial, up to orbital and tectonics time scales, conforming the global monsoon concept across time scales". This is then hedged with the following statement: "Within the global monsoon system each subsystem has its own features depending on its geographic and topographic conditions. Discrimination of global and regional components in the monsoon system is a key to reveal the driving factors of monsoon variations, hence the global monsoon concept helps to enhance our understanding and to improve future projection of the regional monsoons". Conclusion #2 reads: "Within the GM system, each subsystem has its own features depending on its geographic and topographic conditions, and recognition of the GM system does not negate the value of regional monsoon studies. On the contrary, the GM concept helps to enhance our understanding and to improve future projection of the regional monsoons, while discriminating between the global and regional components of their variability".

The hedged statements above and throughout the text reflect the fact that real and significant regional differences exist within the regional monsoon subsystems. At the same time, there is no doubt as to the general anti-phased monsoon response across the northern and southern hemispheres, or to its main driver (insolation). Thus, it is truly difficult to decide on whether a qualified 'no' or a qualified 'yes' is more appropriate in answer to the question posed in the title. Ultimately it comes down to whether there is scientific utility in using the concept of a GM as a scientific paradigm for promoting further advances in our understanding of monsoon dynamics. In my opinion the authors successfully make the case that the GM is a useful framework to consider in this regard.

Using selected data sets, the authors present a summary of the extent to which the various regional systems can or cannot be described as a single global response. They successfully argue that the GM paradigm is a useful construct within which to identify and understand differences among the regional responses. The manuscript is appropriate to publication in Climates of the Past.

Below I make the case that the manuscript is slightly biased toward the GM paradigm at the expense of the regional differences, at least at the orbital scale. I offer comments and suggestions along these lines in the section below, which the authors may consider at their discretion in revision.

II. Specific Comments and Suggestions:

(2178) "Even very high resolution records (4–5 years) have been made available from the Cariaco Basin for the North American monsoon (Haug et al., 2001) and elsewhere".

". . .South American Monsoon. . .?

(2179) "The two diverging views on monsoon variations differ in orbital-scale periodicity and phasing: with the former assuming a direct response to boreal summer insolation, while the latter infers an 8-ka delay in responding to precession, due to latent heat transfer from the Southern Hemisphere (Ruddiman, 2006)".

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A common misinterpretation of the 8-Ka delay relative to Precession minima is that it requires the monsoon system to have a long response time similar to, for example, the delayed response of ice sheet melting to summer insolation forcing. The 8-ka 'delay' relative to precession mimima is interpreted as a response to multiple forcing mechanisms, only one of which is latent hear export from the SH. The other two are glacial boundary conditions and NH summer insolation.

Appropriate reference to these two diverging views should include both views, Ruddiman 2006 as well as Clemens and Prell, 2007 (Quaternary Science Reviews, 26, 2007, 275–278, Viewpoint: The timing of orbital-scale Indian monsoon changes).

(Table 1) Speleothem d18O, to my knowledge, has not been put forth as a proxy for Precipitation Rate (e.g. mm/d). I don't think that any proxy has been so boldly interpreted.

(2181) "Hence the summer monsoon factor for the northern Arabian Sea was proposed on the basis of factor analyses of five proxies: lithogenic grain size, Ba accumulation rate, d15N, abundance of G. bulloides and opal mass accumulation rate (Clemens and Prell, 2003). Since all of the five proxies are indicative of primary productivity, even the use of multi-proxy approach is challenged".

Lithgenic grain size does not depend on primary productivity yet yields the same answer. Stating that the multi-proxy approach has been 'challenged' calls for a reference at this location.

(2181) 'In the geological records, the enhanced productivity can be induced by processes other than the summer monsoon, "such as the strength of winter monsoon winds blowing offshore, or changes related to ice-volume cycles, including changes in ocean nutrients and in offshore transport of particulate and nutrient material from the continental shelf " (Ruddiman, 2006)'.

See comment directly above concerning lithogenic grain size.

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If Ruddiman 2006 is referenced here then Clemens and Prell 2007 should also be included at this location (Quaternary Science Reviews, 26, (2007), 275–278, Viewpoint: The timing of orbital-scale Indian monsoon changes).

(2182) "Among the most remarkable progress since 2000 are the exciting paleomonsoon records of the late Quaternary yielded by speleotheme analyses from East Asia and South America (e.g., Y. Wang et al., 2001; Cheng et al., 2009a), although, at mentioned above, the extent to which speleotheme d18O acts as a strongly constrained indicator of summer monsoon intensity remains unclear".

In the spirit of parallel treatment of marine and terrestrial proxies (see 2181 above) one might modify this statement to read something along the lines of . . .'In the geological records, the surface precipitation isotope signal recorded in speleothem calcite can be induced by processes other than local summer monsoon rainfall, including Spring- Winter- and Fall-season rainfall, changes in the isotopic composition of the vapor source, changes in evaporation and precipitation along the transport path, changes in the local temperature of atmospheric condensation, residence time and exchange with extant groundwaters, and evaporation in the epikarst and/or within the cave itself (Fairchild 2006, Earth-Science Reviews 75, 105– 153; Baker 2010, Global and Planetary Change 71, 201–206; Dayem, 2010, Earth and Planetary Science Letters 295, 219–230; McDermott 2004, Quaternary Science Reviews 23, 901–918)'.

(2183) "The local summer rainfall in the monsoon region dominates the annual total rainfall amount, hence the annual total rainfall, to a large degree, can be used as an approximate indication of overall monsoon strength".

This manuscript defines monsoon regions on the basis of having local summer precipitation exceed 55% of the annual total. It's not clear that this meets the threshold of being deemed 'dominant'; it is more co-equal in the context of understanding the impact of seasonality on water isotope proxies. For example, in the cave region of SE China, 45% to 50% of the total annual precipitation falls outside the summer monsoon season, with very distinct isotopic compositions. Hence, in this region, cave d18O cannot be interpreted as a summer-season monsoon proxy. This general point is supported by the author's interpretation of CH4 as 'compromised' (as a GM proxy) due to the fact that approximately 40% of it comes from boreal sources.

(2187) "Nevertheless, the above discussion narrows the choice of GM proxies to two ideal candidates: the Dole effect at the precession frequency band represented by the d18Oatm record in ice-cores with ice-volume signals removed, and the marine inorganic d13C at the long- eccentricity band. The two parameters are mutually connected by the monsoon-driven low-latitude hydrological cycle. Although the Dole effect and marine d13C are proposed as GM proxies, there is a long way to go before confidence in them is high, and a number of important questions have yet to be answered before the physical meaning of these and related parameters can be revealed".

In the context of all the GM proxies considered in section 3.2, it is not clear why the Dole effect and inorganic d13c rise to the top of potential GM proxy candidates. Both are described as having remaining obstacles that seem no less to overcome than the difficulties of the other proxies discussed.

(2202-2212; Section 6, Global Monsoons at Orbital Time Scales, including Figures 14, 15 and 16)

This section is oddly constructed. Given the large number of long orbital-scale records, it's not clear why the authors choose to discuss orbital-scale variability largely on the basis of figure 13; Holocene records with total lengths less than $\frac{1}{2}$ that of the shortest orbital cycle. The response to one half of one precession cycle is insufficient to understand the GM response to orbital forcing at any frequency band, regardless of the global distribution of available records. Discussion of Holocene records should be limited to Section 5.

Figures 14, 15 and 16 (and associated text) discuss records that span only 120 to 200 kyrs, the first 60 kyrs of which is largely dominated by millennial-scale variability. It's

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difficult to assess orbital-scale variability on the basis of these short records. For the purposes of considering orbital-scale variability in this type of paper, records out to 500 kyrs might be more appropriate.

The Arabian Sea record of Caley et al., 2011 (Earth and Planetary Science Letters 308, 2011, 433–444) should be included in figures 14 and 15 and discussed. It is an Arabian Sea (NH monsoon) record that is clearly out of phase with the NH monsoon records (and clearly in phase with the SH monsoon records) currently presented in these two figures; in particular, it matches very well with the Brazil stalagmite record shown in figure 15. This Arabian Sea record is not an anomaly, it is in phase with other Arabian Sea records such as published in Ziegler et al., 2010 and Clemens et al., 2003. The Arabian Sea records do not fit the GM paradigm (NH monsoons following NH insolation and SH monsoons following SH insolation, with the two hemispheres being out of phase at the precession band). The distinct differences between these records and those currently shown in fig. 14 are important in the context of a paper such as this; they are representative of why the title ends in a question mark. The differences possibly indicate a decoupling of the monsoon wind and precipitation regimes (e.g. Liu et al. 2006, Hemispheric insolation forcing of the Indian Ocean and Asian Monsoon: Local versus remote impacts, Journal of Climate, 19, 6195-6208). Alternatively, they may reflect the fact that the Indian monsoon system is directly linked to the SH via the Findlater Jet (cross-equatorial moisture flow from the SH).

The GM publication of Caley and others (2011) should also be referenced and discussed (Caley et al., Orbital timing of the Indian, East Asian and African boreal monsoons and the concept of a 'global monsoon' Quaternary Science Reviews 30, 2011, 3705-3715.) as it presents an opposing view that a GM may not be an appropriate paradigm for making future progress.

(2207) "By controlling the weathering rate and other processes, these low frequency monsoon cycles also lead to periodic changes in the oceanic carbon reservoir. Since the residence time of carbon in the ocean is much longer than 100 ka (Kump, 1991;

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Katz et al., 2005), the 400 ka period of the monsoon is most evident in the inorganic d13C and carbonate reservoirs, representing a key mode of monsoon variability at orbital time scales, as supported by recent modeling experiments (Russon et al., 2010; Ma et al., 2011)".

Russon 2010 may not be an appropriate reference here as it makes no mention of monsoons in the explanation of the global ocean d13C cyclicity. Rather, it focuses on changes in global-scale carbonate and silica production.

(2209) "The inter-hemispheric factor is most significant in equatorial regions where cross-equatorial exchanges are strong. A prime example of such a region is North Africa, where lacustrine deposit sequences south of the Equator nonetheless are coherent with insolation variations in the NH".

The other prime example is the Arabian Sea summer-monsoon wind regime (see discussion in previous comment).

(2179) "This divergence in opinion has evoked a hot debate as to which proxies are representative of the Asian monsoon: the marine records from the Arabian Sea or the speleothem records from the Asian land (e.g., Clemens and Prell, 2007; Clemens et al., 2010; Ziegler et al., 2010; Weber and Tuenter, 2011) which will be discussed in in our follow on work".

In this context the correct Ziegler et al., 2010 reference is (Ziegler et al., 2010 Precession phasing offset between Indian summer monsoon and Arabian Sea productivity linked to changes in Atlantic overturning circulation. PALEOCEANOGRAPHY, VOL. 25, PA3213, doi:10.1029/2009PA001884, 2010), instead of the reference to the 2010 Mediterranean work.

(2179) "Here our goal is to note that the divergence of opinion is, at least partly, related to the different nature of the proxies used: with upwelling records based on wind being physically distinct from the speleothem records based on rain. Looking back at the

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evolution of paleo-monsoon research, it was initiated with both wind- and rain-based proxies, and the two kinds of sequences correlated fairly well at that stage".

Appropriate references to the clear distinction between which parts of the monsoon system various proxies monitor (e.g. wind, rainfall...) would be Clemens et al., Paleoceanography, V. 25, PA4207, doi:10.1029/2010PA001926, 2010. In terms of the links between winds, moisture transport, and rainfall, an appropriate reference would be Liu et al. 2006, Hemispheric insolation forcing of the Indian Ocean and Asian Monsoon: Local versus remote impacts, Journal of Climate, 19, 6195-6208.

Best Regards, Steve Clemens 6.4.14

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