Review: Bassinot et. al., Holocene evolution of summer winds and marine productivity in the tropical Indian Ocean in response to insolation forcing: data-model comparison.

This is an excellent paper, appropriate to publication in Climates of the Past. It is among the best data-model comparison papers I've read. The authors clearly make the case for entirely out-of-phase responses among two proxy records of summer-monsoon-induced upwelling and offer clear and well-reasoned explanations for the underlying mechanisms, derived from coupled AOGCM-ecological model simulations. I recommend publication with minor modification at the discretion of the authors.

Below I offer a number of comments and suggestions that authors may wish to consider in revisions. The more extensive comments center on two issues: (1) the choice of an insolation forcing curve and (2) the consequent implication of that choice on assessing the timing of the Holocene (orbital-scale) monsoon maximum relative to insolation forcing. I try to make the case that there is a measurable 3 to 5 kyr lag in the Holocene response to insolation forcing and that this implies mechanisms beyond a direct and sole response of the summer monsoon to northern hemisphere summer insolation forcing. This line of discussion in no way disputes the overall thrust/findings of the work but does reflect an ongoing debate in the community regarding the timing of the summer monsoon response at the orbital time scale (including the Holocene and extending into the late Pleistocene).

With Regard,
Steve Clemens

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Line by Line comments:

P487, 11. The circulation at the tip of India also is affected by…. (why 'also'?). 'Also' implies the East African current is fresh as well.

P488, 19-21. Seems unlikely that such a local factor as salinity at the southern tip of India would drive the onset of the large-scale summer monsoon. One might make the case that salinity is more of a response to hydrological processes, rather than a driver.

P 490, 26-27. …the growth of height foraminifer species… unclear, text error?

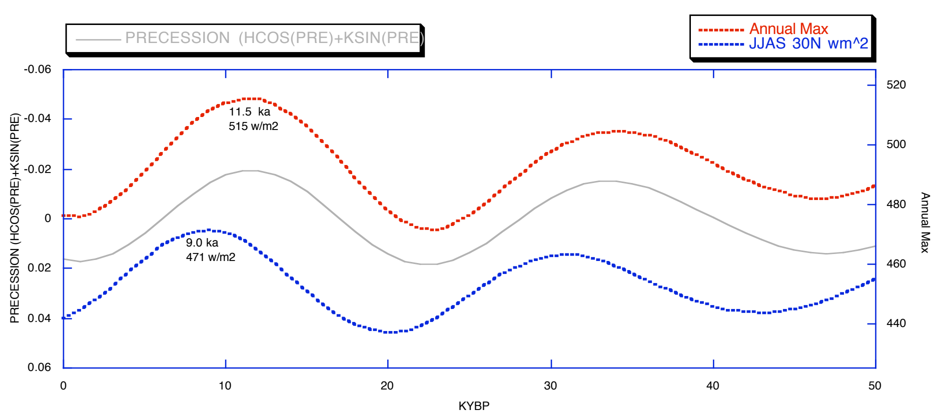
P492, 5-7. On orbital time scales, productivity records do not indicate that the strongest summer winds occurred during times when perihelion was aligned with summer solstice. A recent synthesis of 18 orbital-scale records (~300 kyrs in length) indicate that the strongest winds occurred ~50° after ice minima at the precession band (~125° after precession minima) [*Clemens et al.*, 2010] and are inconsistent with a direct/sole northern hemisphere summer insolation forcing mechanism. This 125° phase is inconsistent with the current interpretation of cave speleothem d18O as being forced only by the strength of summer monsoon precipitation, a strongly contested interpretation [*Clemens et al.*, 2010; *Dayem et al.*, 2010; *LeGrande and Schmidt*, 2009; *Maher*, 2008; *Hu et al.*, 2008]. The orbital-scale timing issue has been addressed in a number of past and recent publications [*Clemens et al.*, 2010; *Clemens et al.*, 1991; *Clemens and Prell*, 2003; 2007; *Liu et al.*, 2006; *Ruddiman*, 2006; *Wang et al.*, 2008; *Weber and Tuenter*, 2011; *Ziegler et al.*, 2010].

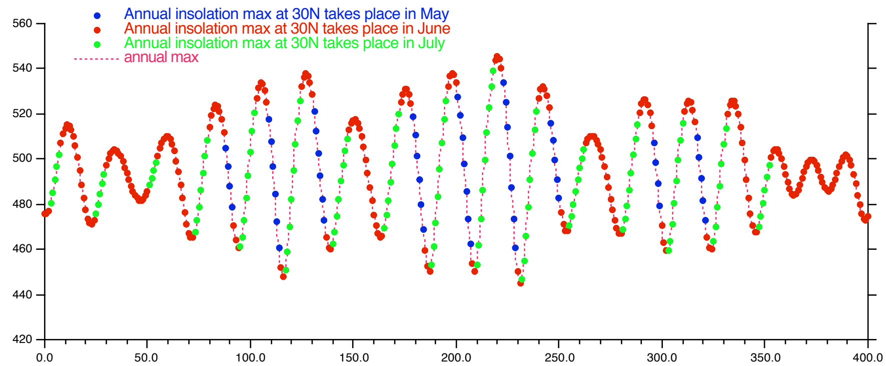
P496, 9-12. These rates are consistent with those measured by Honjo et al [1996] and Clemens [1998] in Arabian Sea sediment traps.

P498, 11-13 (global comment). It is unclear as to why JJAS 30°N is chosen as the forcing against which to compare records of G. bulloides upwelling strength and timing at the orbital time scale. The JJAS 30°N curve is the same as that calculated for August 14 (omega at 143° from the vernal point). This JJAS (August 14) radiation curve is never the strongest radiative forcing at 30°N as is seen from the figure below spanning the past 50 ka. In this figure, the dashed red curve shows the absolute annual maximum radiation at 30°N; it is not restricted to any particular omega value (timing of the date of perihelion). The maximum annual radiation forcing at 30°N always occurs either in May, June, or July as indicated in the figure below spanning the past 400 ka (after Clemens et al., [2010]). All of the 30°N insolation maxima (and minima) at the precessional-scale are associated with insolation at times of June perihelion (never august perihelion).

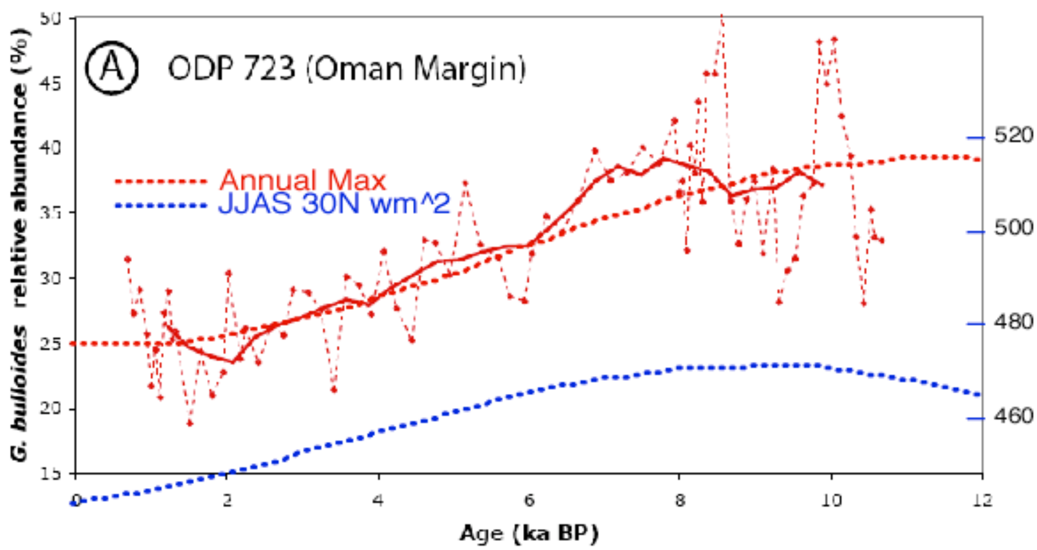
To the extent that modern Arabian Sea winds are already southwesterly in May, it is evident that times of high insolation during May perihelion are equally as important as times of high insolation during July perihelion with regard to the strength and duration of summer monsoons. Beyond this, the JJAS curve is always 30 to 50 w/m2 weaker than the annual max curve. An intuitive way to look at this issue is to pose the following question, comparing the monsoon response to insolation at 9 ka and 11.5 ka as follows. Should the summer monsoon be stronger at 9 ka (based on a radiation forcing of 471 w/m2 as on the blue dashed JJAS curve) or at 11.5 Ka (based on a radiation forcing of 515 w/m2 as on the red dashed Annual Max curve)?

In summary, the JJAS curve is not a particularly useful forcing curve with regard to the strength or timing of strong summer monsoons relative to external insolation forcing; it never captures the strongest forcing. The authors might consider using the absolute maximum curve in this regard. Note that the timing of the precession-scale highs and lows of the absolute max insolation curve is the same as that of the precession curve (grey solid curve). Orbital (precession) extremes do reflect the max and minimum radiation forcings.

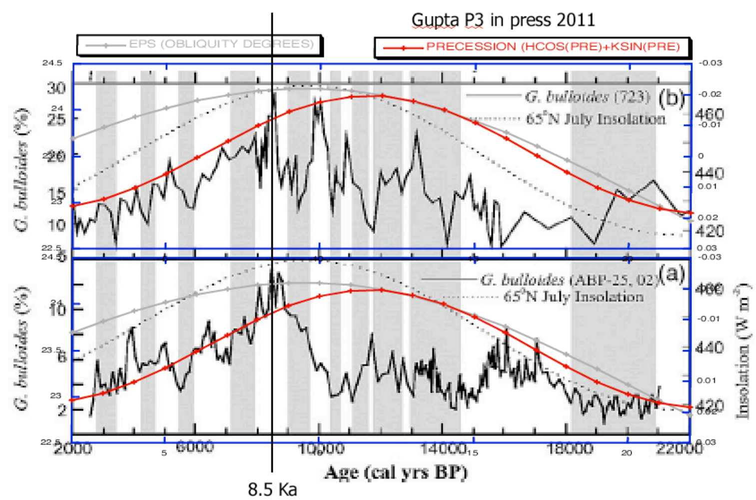




P498, 19-21. On the basis of the Annual Max forcing curve shown below with the manuscript data, the increase in productivity since ~1.5 ka does not require any ad-hoc explanation as to why it diverges (with the JJAS 30°N insolation curve). Both the G. bulloides and the forcing curve flatten at the same time. I take this is evidence that the annual max curve is more appropriate.

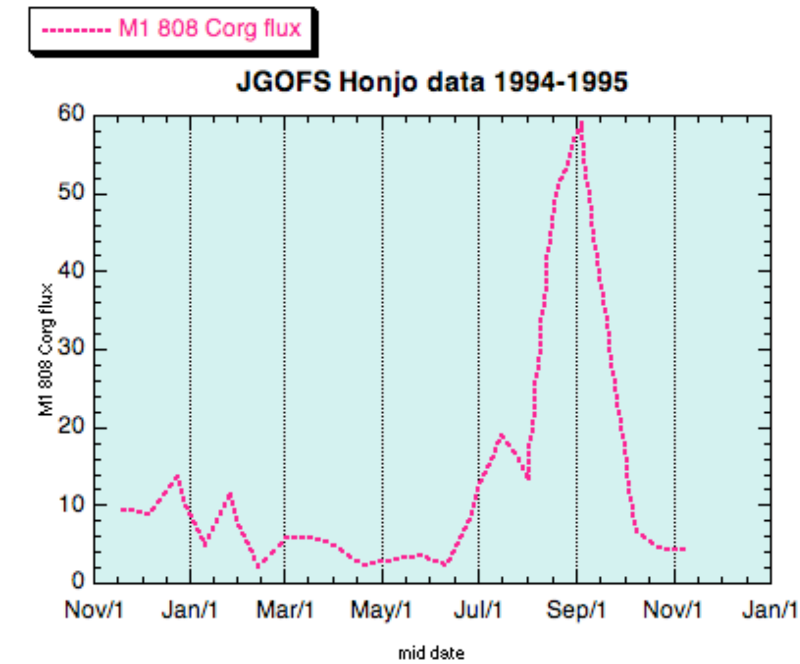


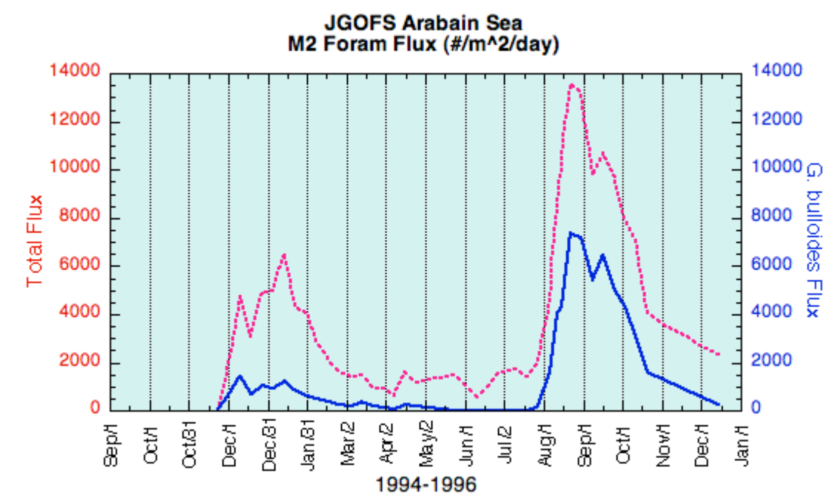
P499, 1-4. On the basis figure 5A, the summer monsoon maximum is at either 7.5 Ka (smoothed) or 8.5 Ka (max unsmoothed). Including other very well-dated G. bulloides records from the Northern Arabian Sea (Gupta 2011 in press, P3 – figure below) one might set the date at 8.5 Ka, 3,000 years after the maximum radiation forcing at 11.5 Ka. However, an 8.5 Ka max falls 4,500 years after the timing the Indo-Asian monsoon precipitation maximum indicated by the 280,000 year time-dependent modeling using insolation only forcing [*Kutzbach et al.*, 2007]. Δd18O records from speleothems [*Hu et al.*, 2008] point to an even later maximum response at 6 Ka (a lag of 5.5 ka after the 11.5 ka absolute max). My effort here is to convince the authors that a real lag of 3-5 kyrs exists in the Holocene data and, on this basis, to refrain from stating that the summer monsoon is a direct response to northern hemisphere summer insolation forcing, a point made in Clemens et al [2010] relative to interpretation of cave d18O. Proxies that are not in phase with orbital extremes (maxima or minima) to within a few degrees likely have more than one process influencing their timing. This may seem like a relatively minor point when considering the large difference the authors are really trying to address (timing differences between the northern Arabian Sea and southern tip of India) but it is important and both data and models have identified other processes, in addition to direct insolation forcing, as important [*Liu et al.*, 2006].



P499 15-22. Not clear that possibilities (1) and (2) are really distinct from one another. Please clarify.

P501, 1-5 and figure 7A. Why is export production shown in Figure 7 if the model includes the relative % of G. bulloides? Why not show flux of G. bulloides? In either case, Northern Arabian Sea trap data exists for comparison as shown below [*Honjo et al.*, 1999; *Lee et al.*, 1998]. I do not recall if/where the G. bulloides data are published but they can be made available to the authors. The strongly bimodal northern Arabian Sea response in the PICES model (fig 7b) where the March peak is larger than the Aug-Sept peak is not supported by trap data which shows the vast majority of Corg (808 mbsl trap depth) and bulloides (3141 mbsl trap depth) export in Aug.





P502, 9: Why 'Somalian' margin – do you mean 'Oman' margin?

P503, 8-10. In the broadest sense, yes, in reality there is a significant lag implicating more than one (insolation) forcing mechanism.

P503, 13-15 and 23-26. Uncomfortable with the 'direct response to insolation forcing' phrasing. The system is more complex than that at orbital time scales, especially in the late Pleistocene.

Figures. Please plot core locations directly on Figures 1, 2, and 6 (making figure 3 unnecessary).

This is an excellent paper, a pleasure to read.
Steve Clemens

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