Biogeosciences
Discussions

Interactive comment on "Stable isotope and modelling evidence that CO_2 drives vegetation changes in the tropics" *by* F. J. Bragg et al.

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Bragg et al. present simulations from a biogeography model which show that vegetation at the LGM shifts equatorwards only when both climate and CO2 are set at LGM levels. They argue that the equatorward shift of the vegetation belts at the LGM shown in Collins et al. (2011) should be re-interpreted as a direct consequence of reduced atmospheric CO2 concentration, rather than as an equatorward shift of precipitation. Their re-interpretation goes on to propose that the vegetation data could even be explained by a southward shift of the African rainbelt at the LGM. This implies that any effect of this southward shift on vegetation distribution must have been completely overprinted by the effect of CO2, because there is no indication of a southward shift of the vegetation belts in Collins et al. (2011). However, the assertion of

complete dominance of CO2 on vegetation distribution ignores a large body of work which indicates that vegetation distribution has changed independently of CO2 in the past. For example, vegetation evolution has been shown to track climate evolution rather than CO2 evolution in a number of independent studies (e.g. Huang et al., 2001; Vidic and Montañez, 2004; Agrawal et al., 2012). Although these studies do not completely rule out some control of CO2 on vegetation distribution, they certainly indicate it was the smaller of the two controls. Similarly, in Collins et al. (2011), we found that marked vegetation changes occurred between the mid-Holocene and late Holocene (modern). This could not be explained by CO2 changes and thus also indicates that climate must be capable of exerting a major control on vegetation distribution. Bragg et al. do not acknowledge these data and their implications, even though they are from the same dataset as the Collins et al. (2011) LGM data. Furthermore, the authors quote the study of Sinninghe Damsté et al. (2011) in support of their argument that CO2 dominates vegetation change. However, even in this study, vegetation changes are shown to have taken place independently of CO2 changes. For example, during the Y-D, both vegetation and precipitation (as indicated by the BIT index) changed but CO2 did not. Overall, there is a great deal of evidence that climate is capable of driving vegetation change independently of CO2. Consequently, there have been a number of publications interpreting C3-C4 vegetation change as a precipitation indicator (e.g. Castañeda et al., 2007; Castañeda et al., 2009; Huang et al., 2007; Schefuß et al., 2003). Therefore, a re-interpretation of Collins et al. (2011) is not necessary.

The argument that CO2 alone controls C3-C4 vegetation type is, in fact, not explicitly evident from the Bragg et al. data. The simulation in which vegetation change takes place (i.e. at the LGM, 189ppm) is forced by both climate and CO2. The vegetation contraction could easily be a response to a combination of the effects of both climate and CO2, rather than just to CO2. The relative magnitude of the effects of precipitation, CO2 and temperature on vegetation distribution is not discussed in the manuscript.

Bragg et al. evaluate the performance of their model using: 1) continental pollen re-

constructions and 2) leaf-wax n-alkane δ13C. At the mid-Holocene, the model shows little vegetation change relative to the PI (Figs 2a, 3a) in northern and southern Central Africa. The presented pollen data for the mid-Holocene are stated by the authors to 'support the model predictions of little change between MH and today' (P15709, L7-8). However, this is not really the case. For example, in southern Africa there are no data between 5°S and 20°S for the mid-Holocene. This therefore completely omits the area in southern Central Africa (at 12°S) where other pollen studies (Dupont et al., 2008) and n-alkane δ13C data (Collins et al., 2011) indicate that major vegetation changes took place between the mid-Holocene and late Holocene (modern). Additionally, in northern Central Africa, the closure of the Dahomey Gap (Salzmann and Hoelzmann, 2005) and the northward shift or thickening of the rainforest (Maley and Brenac, 1998; Lezine and Vergnaud-Grazzini, 1993; Salzmann et al., 2002) at the mid-Holocene (relative to late Holocene) are not reproduced by the model (Fig. 3a). As such, it seems that the model underestimates vegetation change when climate was the major forcing factor. Conversely, when the model is forced with reduced CO_2 (189ppm), the vegetation change is stronger than that in the pollen data. For example, the two sites indicated by the pollen as tropical forest at the LGM (Fig. 3b) are actually simulated as grassland in the model. As such, it seems that the changes may be overestimated when the model is forced with CO_2. Could it be that the model is too 'sensitive' to changes in CO_2?

Finally, the authors also evaluate their PI model simulation against the dataset of Rommerskirchen et al. (2006). This dataset includes samples as old as 6.8 ka, integrating both the late and mid-Holocene. As such, this dataset does not resolve the vegetation change between the two periods. Unsurprisingly, this dataset therefore fits well with the model, which also simulates no change between mid-Holocene and PI. Perhaps the PI simulation would be better evaluated against the (more extensive) dataset of Vogts et al. (2012) which includes only recent surface sediments?

References:

Agrawal, S., Sanyal, P., Sarkar, A., Jaiswal, M. K., Dutta, K., 2012. Variability of Indian monsoonal rainfall over the past 100 ka and its implication for C3-C4 vegetational change. Quaternary Research: 77, 159-170.

Castañeda, I. S., Werne, J. P., Johnson, T. C., 2007. Wet and arid phases in the southeast African tropics since the Last Glacial Maximum. Geology:35, 823-826.

Castañeda, I. S., Werne, J. P., Johnson, T. C., Filley, T. R., 2009. Late Quaternary vegetation history of southeast Africa: The molecular isotopic record from Lake Malawi. Palaeogeography, Palaeoclimatology, Palaeoecology: 275, 100-112.

Collins, J. A., Schefuß, E., Heslop, D., Mulitza, S., Prange, M., Zabel, M., Tjallingii, R., Dokken, T. M., Huang, E., Mackensen, A., Schulz, M., Tian, J., Zarriess, M., Wefer, G., 2011. Interhemispheric symmetry of the African rainbelt over the past 23,000 years. Nature Geoscience: 4, 42-45.

Dupont, L. M., Behling, H., Kim, J-H., 2008. Thirty thousand years of vegetation development and climate change in Angola (Ocean Drilling Program Site 1078). Climate of the Past: 4, 107-124.

Huang, Y., Street-Perrott, F. A., Metcalfe, S. E., Brenner, M., Moreland, M., Freeman, K. H., 2001. Climate Change as the Dominant Control on Glacial-Interglacial Variations in C3 and C4 Plant Abundance. Science: 293, 1647-1651.

Huang, Y., Clemens, S. C., Liu, W., Wang, . Y., Prell, W, L., 2007. Large-scale hydrological change drove the late Miocene C4 plant expansion in the Himalayan foreland and Arabian Peninsula. Geology: 35, 531-534.

Lezine, A. M., and Vergnaud-Grazzini, C., 1993. Evidence of forest extension in West Africa since 22,000 BP: A pollen record from the eastern tropical Atlantic. Quaternary Science Reviews: 12, 203-210.

Maley, J. and Brenac, P., 1998. Vegetation dynamics, palaeoenvironments and climatic changes in the forests of western Cameroon during the last 28,000 years B.P. Review

of Palaeobotany and Palynology: 99, 157-187.

Rommerskirchen, F., Eglinton, G., Dupont, L., Rullkötter, J., 2006. Glacial/interglacial changes in southern Africa: Compound specific δ13C land plant biomarker and pollen records from southeast Atlantic continental margin sediments. Geochemistry, Geophysics, Geosystems: 7, Q08010.

Salzmann, U., Hoelmann, P., Morczinek, I., 2002. Late Quaternary Climate and Vegetation of the Sudanian Zone of Northeast Nigeria. Quaternary Research: 58, 73-83.

Salzmann, U and Hoelzmann, P., 2005. The Dahomey Gap: an abrupt climatically induced rain forest fragmentation in West Africa during the late Holocene. The Holocene: 15, 190-199.

Schefuß, E., Schouten, S., Jansen, J. H. F., Sinninghe Damsté, J. S., 2003. African vegetation controlled by tropical sea surface temperatures in the mid-Pleistocene period. Nature: 422, 418-421.

Sinninghe Damsté, J. S., Verschuren, D., Ossebaar, J., Blokker, J., van Houten, R., van der Meer, M. T. J., Plessen, B., Schouten, S., 2011. Earth and Planetary Science Letters: 302, 236-246.

Vidic, N. J. and Montañez, I. P., 2004. Climatically driven glacial-interglacial variations in C3 and C4 plant proportions on the Chinese Loess plateau. Geology: 32, 337-340.

Vogts, A., Schefuß, E., Badewein, T., Rullkötter, J., 2012. n-Alkane parameters from a deep sea sediment transect off southwest Africa reflect continental vegetation and climate conditions. Organic Geochemistry: 47, 109-119.