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Interactive comment on "Stable isotope paleoclimatology of the earliest Eocene using kimberlite-hosted mummified wood from the Canadian Subarctic" *by* B. A. Hook et al.

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Response to: Interactive comment on "Stable isotope paleoclimatology of the earliest Eocene using kimberlite-hosted mummified wood from the Canadian Subarctic" by B. A. Hook et al. Anonymous Referee #1 Received and published: 14 June 2015

Response by Benjamin A. Hook (corresponding author) on 16 July 2015

I would like to thank Referee #1 for their comments. I believe that they have led to improvements in this manuscript, especially in the carbon isotope section. Here, I respond to each comment, explaining the changes that have been made to the text.

1) What was the paleolatitude during the early Eocene with respect to modern latitude, and what are the paleoclimatic implications of a geographical transition?

This is a detail that had I meant to include, and mistakenly left it out, so I am glad that Referee brought it to my attention. The paleolatitude of the North American Arctic region has been estimated to be 62 $\pm$ 5 °N (McKenna 1980, Irving and Wynne 1991). Although considerable tectonic movement has altered its longitude, the paleolatitude is not much different than modern latitude (64° 42âĂš 49âĂšâĂš N, 110° 37âĂš 10âĂšâĂš W). Therefore, latitudinal influences on climate were not significantly different between the early Eocene and today. This point has been added to the introduction (page 16721, line 18) and in the site description in the methods section (page 16276, line 3).

2) What is the role of high pCO2 on carbon isotope composition of the atmosphere and cellulose. Variables in isotopic discrimination models (ci/ca and εpc) were calculated in modern pCO2, but how would higher pCO2 influence these? Can free air carbon enrichment (FACE) studies give any insights into this issue?

This point addresses an important issue. One of the major difficulties of paleoclimatology in my opinion is the fact that when you have to analyze climates that are outside of the modern calibration range, extrapolation is necessary, which can sometimes lead to significant errors, if, for example relationships between variables are nonlinear. I looked more deeply into studies of plants growing in experimentally higher pCO2 levels, including FACE studies (Battipaglia et al. 2013), the CLIMEX program (Beerling 1997), and controlled laboratory experiments using growth chambers (Lomax et al. 2012, Schubert and Jahren, 2012). One of the most intriguing studies regarding the relationship between pCO2 and carbon isotope discrimination (Δ) is that of Schubert and Jahren (2012) who had unprecedentedly tight controls on hydrologic factors in the chambers, which allowed them to investigate this relationship. Whereas previous researchers had estimated linear relationships between Δ and pCO2, but could not agree on the slope, Schubert and Jahren grew plants at a wide variety of pCO2 levels, showing that the

relationship is actually hyperbolic, such that it does not increase infinitely with higher pCO2, but "levels off" or "flattens out" as it approaches a limit (28.26 ‰ in their study). These experiments were designed to elucidate the Δ vs. pCO2 relationship, keeping the stomatal density (SD) constant. However, it is also known that during the geological past, SD has varied with pCO2 level. This is the basis for the SD-pCO2 proxy (Woodward 1986, 1987, Beerling 1997, Royer 2003, 2006, Beerling et al. 2009). Therefore, it seems likely that trees alter their SD (lower) during past greenhouse periods (high pCO2). Particularly, the results of Beerling (1997) and recent experiments genetically altering SD and investigating isotopic fractionation variables (ci/ca, Δ) have been very enlightening (Doheny-Adams et al. 2012, Dow et al. 2014). Reducing SD in mutant Arabidopsis plants leads to reductions in ci/ca (Franks et al. 2015) but at higher pCO2, ci/ca remains constant despite reduced SD (Beerling 1997). This mechanism shows how plants alter their SD to optimize water use efficiency in high pCO2 environments. Additionally, Referee 1 commented that the εpc value, or the difference between δ13C of bulk plant matter and cellulose, was measured in modern pCO2 (εpc = 2 – 5 ‰ $Barbour et al. 2002). Previously, we used the average \varepsilon$pc of modern wood ($\varepsilon$pc = 3.5 ‰. However, Hook et al. (2015) recently measured εpc for mummified wood and cellulose (εpc = 3 ‰. Therefore, I have recalculated the affected data analysis accordingly using the value from Hook et al. (2015). I have added a few paragraphs explaining this issue in detail, in the methods section 2.3 Carbon Isotope Analysis (page 16279, line 8), wherein I add an additional δ13Ccellulose-δ13Catm transfer function by Lomax et al. (2012), take the arithmetic mean of transfer functions by Arens et al. (2000) and Lomax et al. (2012), as well as the commonly-used intrinsic water use efficiency (iWUE) equation (Farquhar et al. 1982, 1989). Additionally, I have added a few paragraphs to the results and discussion (page 16284, line 7), the conclusions (page 16289, line 2), the abstract (page 16270, line 17), table 3, and the highlights section, regarding this matter. I believe that my understanding of this issue has been improved, and that the manuscript is now better in this section as a result.

3) Explain the large difference in δ18O isotopes during the subannually-sampled tree

ring 42, in light of the fact that modern annual range is $\sim$4‰

Most modern studies of subannual δ18O from tree rings find a smaller range around $\sim$4 ‰.However, one of the tree rings analyzed here has a larger range of δ18O ($\sim$5.5 ‰. This may be explained by a few different factors which are peculiar to the polar early Eocene climate. 1) increased amount effect from high rainfall potential (Dansgaard, 1964), 2) source water effect from freshwater Arctic Ocean (Brinkhuis et al., 2006), or 3) increased transpiration from polar forests with respect to today, recycling isotopically depleted water back into precipitation (Jasechko et al. 2013). An explanation of these factors has been added to the results and discussion section (page 16282, line 3).

4) Adjustments to font size and clarification of diagrams in figures 1 and 2.

These adjustments have been made to clarify the figures.

Additionally, I have made minor adjustments to the text for clarification, (page 16273, line 18 – "scenarios" to "situations" to reduce potential confusion with "scenarios" discussed later in carbon isotope discussion, the 3 scenarios discussed by Saurer et al. 2004 regarding ci/ca ratio in differing pCO2. Also, I changed Hook et al., in review, to Hook et al., (2015) throughout, and updated the reference section with all of the new literature added. Best, Benjamin A. Hook

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C9397/2015/bgd-11-C9397-2015-supplement.pdf

Interactive comment on Biogeosciences Discuss., 11, 16269, 2014.

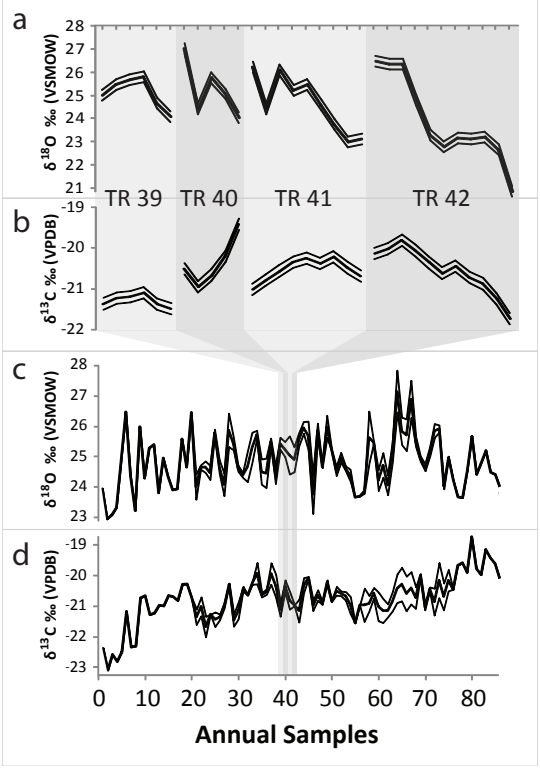

Fig. 1. Figure 1. Subannual and annual-resolution time series records of tree-ring cellulose ïĄď18O and ïĄď13C. Subannual resolution a) δ18O record, and b) δ13C record, of four tree rings (TR 39âĂŤ42). Lines above

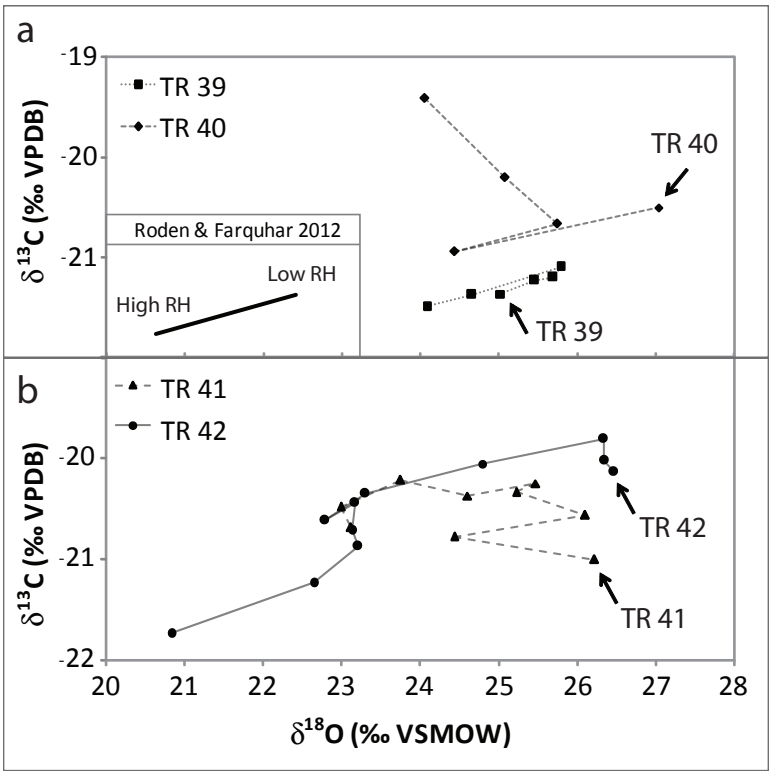

Fig. 2. Figure 2. Scatterplots of dual-isotope data for four tree rings (TR 39âĂŤ42), showing trends of δ18O and δ13C within a growing season. Arrows point to the start of each numbered tree ring (earlywood), l