

## ***Interactive comment on “Circum-Indian ocean hydroclimate at the mid to late Holocene transition: The Double Drought hypothesis and consequences for the Harappan” by Nick Scropton et al.***

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The manuscript by Scropton et al. presents a principal component analysis of regional records to understand the spatial pattern of precipitation changes over the 4.2 ka BP event, and the mid-late Holocene transition more broadly. While this analysis is useful and valuable, we wanted to draw attention to some specific errors in this manuscript up for review, so that they might get fixed for the final version. For full disclosure, we are the authors of the Giesche et al., 2019 paper from marine core 63KA (published in this journal, *Climate of the Past*), which is one of the ten records used in the PCA analysis

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conducted by Scropton et al.

Our points can best be illustrated by lines 351-357 of the Scropton et al. manuscript, where the authors write: “The Double Drought hypothesis is consistent with the timing, location, and long-lasting nature of societal change during the decline and abandonment of the Harappan civilization. While this hypothesis is consistent with many paleoclimate records from the Indian subcontinent, it is not always consistent with their prior interpretation. For example, our hypothesis is in direct contrast to that of Giesche et al. (2019) who used foraminifera  $\delta^{18}\text{O}$  records (interpreted as Arabian Sea salinity changes) to hypothesize a temporary reduction in summer rainfall at 4.2 kyr BP, and a longer lasting reduction in winter rainfall at 3.9 kyr BP. To reconcile these ideas, paleohydroclimate proxies with less ambiguous seasonality than speleothems and foraminifera will be required.” (Scropton et al., lines 351-357)

In contrast to what Scropton et al. suggest here, Giesche et al., 2019 did not interpret the 63KA record only in terms of salinity changes. Using *G. ruber* foraminifera to reconstruct sea surface salinity from Indus River discharge was one component of the research (and linking this to a decline in Indian Summer Monsoon at 4.2 ka BP was originally proposed by Staubwasser et al., 2003). However, the main new research contributed by Giesche et al., 2019 was a reconstruction of upper ocean mixing (temperature gradients between species of foraminifera living at different depths), which relates to winter-driven surface evaporation and strength of the Indian Winter Monsoon. The 63KA core is thereby well-suited to resolve seasonal information using two different proxies in the same core. In summary, the Giesche et al., 2019 paper supports a decline in summer rainfall based on a decrease in Indus River freshwater discharge peaking at 4.1 ka BP, and suggests that a pronounced shift from plentiful winter rainfall at 4.3 ka BP to winter drought by 4.1 ka BP led to what we call the “4.2 ka event”. Our main difference to the Scropton et al. interpretation is that we suggest that summer rainfall largely recovered after 3.9 ka BP, whereas winter rainfall does not appear to make a recovery for at least several more centuries.

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More specifically, Giesche et al., did not hypothesize that a winter drought began after 3.9 kyr BP as suggested by Scroxton et al. Rather, Giesche et al., 2019 write clearly about a winter and summer drought over the Indus Region by 4.1 ka BP, and specifically link the decrease in winter rain to impacts on the Indus Civilization. Therefore, it is important that the paper at hand is amended to note that Giesche et al. 2019 previously suggested a version of the double drought hypothesis for Indus Civilization (Harappan) decline in the Indus region.

There are several relevant sections to point to in the abstract and discussion of the Giesche et al., 2019 publication, which are succinctly summarized by a quote from the conclusion of that paper: Conclusion: “We propose that a combined weakening of the IWM and ISM at 4.1 ka led to what has been termed the “4.2 ka BP” drought over northwest South Asia. The intersection of both a gradually weakening ISM since 4.8 ka and a maximum decrease in IWM strength at 4.1 ka resulted in a spatially layered and heterogeneous drought over a seasonal to annual timescale. Regions in the western part of the Indus River basin accustomed to relying mainly on winter rainfall (also via river runoff) would have been most severely affected by such changes.” (Giesche et al., 2019)

We hope the authors of the manuscript will consider our comments, amend the existing errors, and acknowledge the previous research on the topic of a double drought hypothesis with implications for Indus Civilization decline.

Nevertheless, the specific timing and duration of seasonal droughts in our conclusions continue to differ: Scroxton et al. attribute a first drying episode at 4.26 ka BP to winter drought and note a second prolonged summer drought after 3.97 ka BP, while Giesche et al. (2019) found a gradual drying trend in summer monsoon after 4.8 ka BP that peaked by 4.1 ka BP along with a pronounced flip from abundant winter rain to a winter drought from 4.3 to 4.1 ka BP. Despite these differences, we find it broadly encouraging that Scroxton et al.'s PCA analysis of regional paleoclimate records supports the idea that droughts in both seasons of precipitation played an important role in this region

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over the mid-late Holocene transition. This makes the case even more compelling for continued research into this topic from highly resolved and well-dated records with multiple proxies that can differentiate between seasonality.

References:

Giesche, A., Staubwasser, M., Petrie, C., & Hodell, D. (2019). Indian winter and summer monsoon strength over the 4.2 ka BP event in foraminifer isotope records from the Indus River delta in the Arabian Sea. *Climate of the Past*, 15 (1), 73-90. <https://doi.org/10.5194/cp-15-73-2019>

Staubwasser, M., Sirocko, F., Grootes, P. M., & Segl, M. (2003). Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability. *Geophysical Research Letters*, 30(8). <https://doi.org/10.1029/2002GL016822>

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