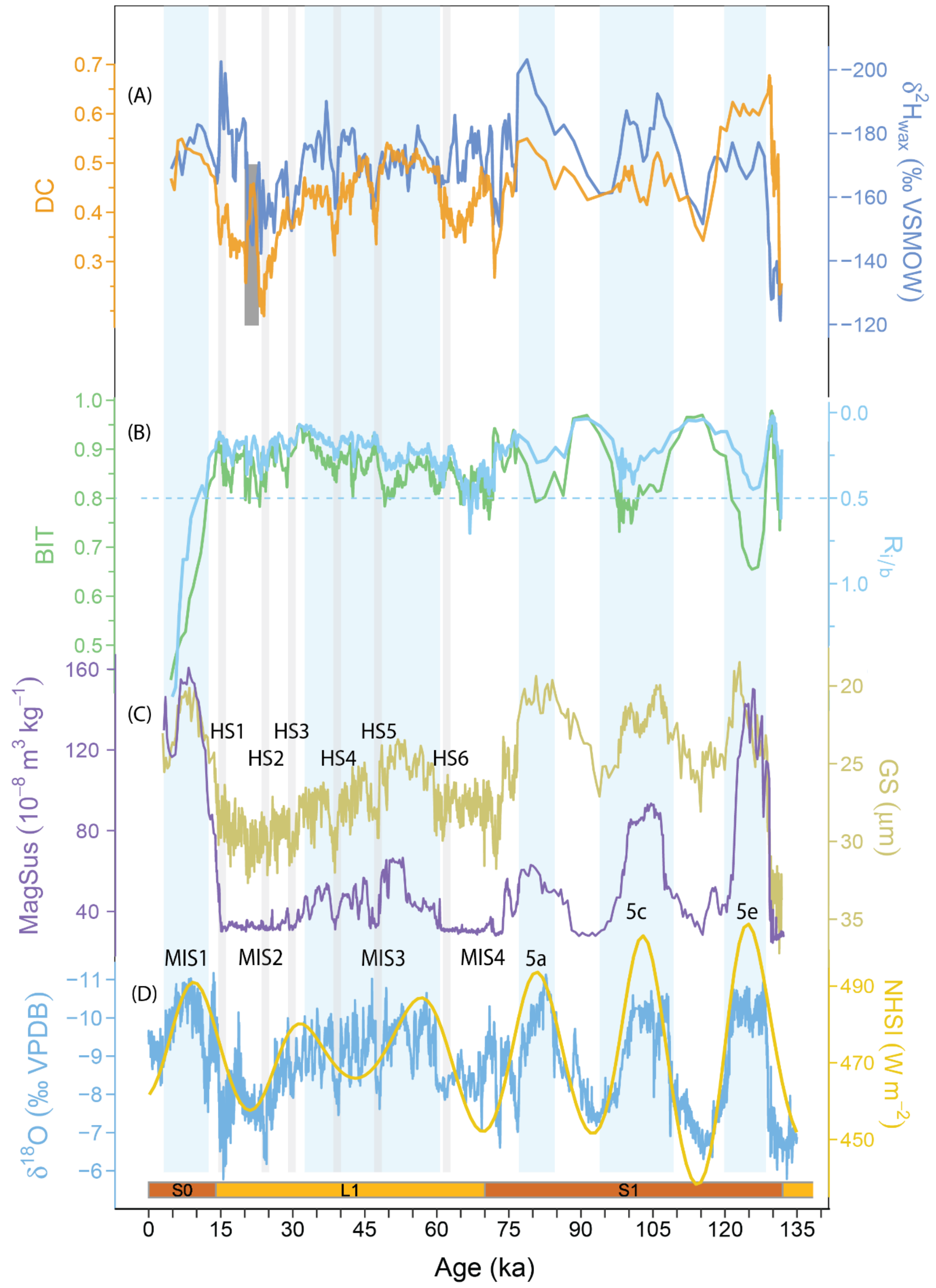
Referee comment #2:

Guo and co-authors present a novel dataset, and apply the DC index as a proxy for precipitation, in alkaline soils from a loess sequence. The paper is in general very well written, the figures are clear and the paper is well structured. The authors did a very good job explaining the result, that at first sight seem to contradict the expected GDGT responses. I do have a few comments that could broaden the interest of the manuscript to users of GDGT proxy ratios.

Reply: We thank the reviewer for their positive evaluation of our work. We have taken your suggestions into careful consideration and will make clarifications accordingly in the revised manuscript. Please find our point-by-point response below in italic.

The discussion of the results is very to-the-point, to a degree where I wonder whether more GDGT ratios (Ri/b and BIT seem obvious choices (see introduction), possibly together with GDGT concentrations or accumulation rates) could have been included.

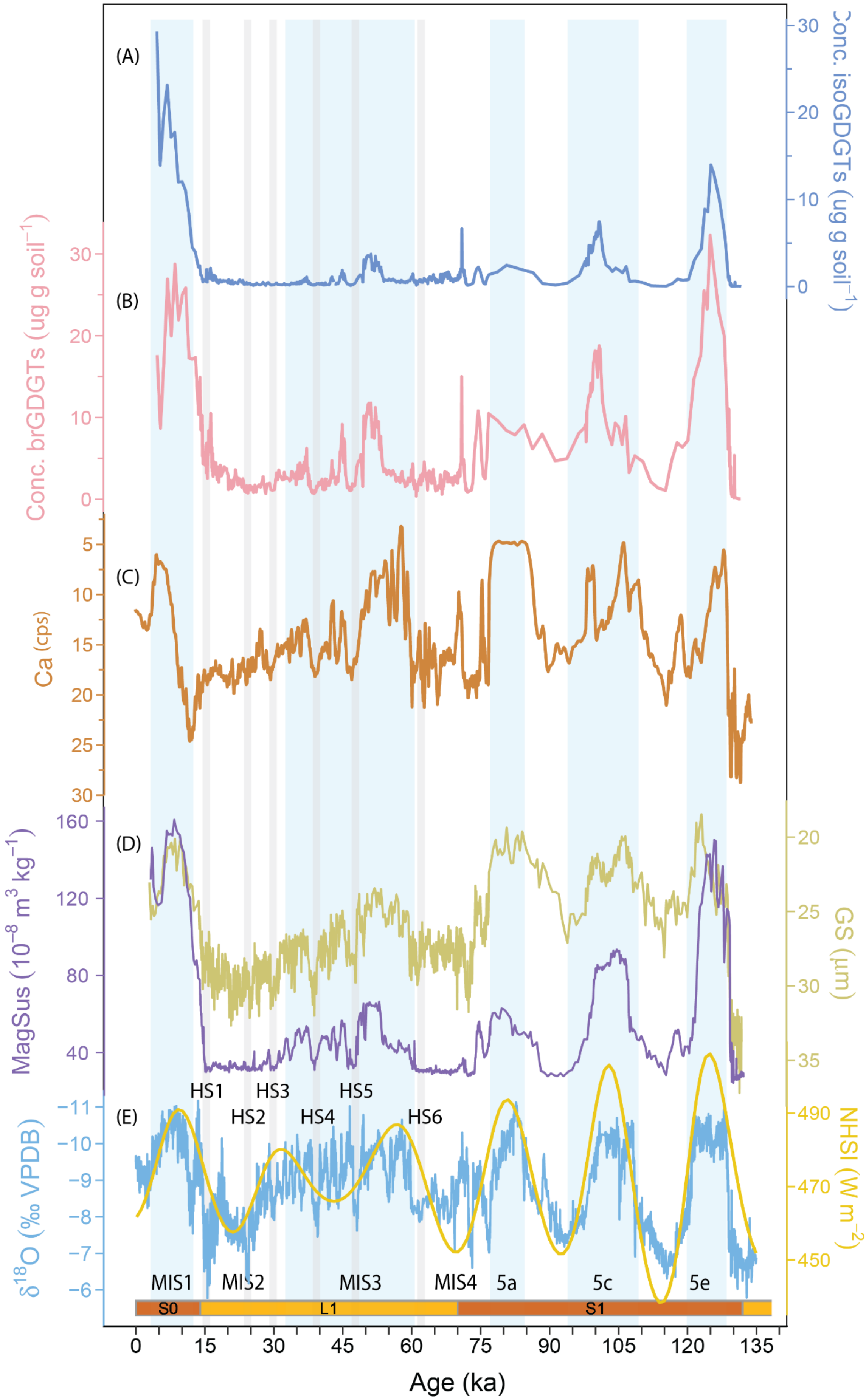
Reply: A similar comment has also been made by Referee #1. Note that the focus on just the DC and the IR as potential proxies for monsoon precipitation is clearly motivated in the introduction of our manuscript. Specifically, although the BIT index and $R_{i/b}$ *have been linked to hydroclimate, in loess-paleosol sequences, they are used as indicators of mega-drought events and only in a qualitative way (e.g., Xie et al., 2012; Yang et al., 2014; Tang et al., 2017). Since the aim of this manuscript is to reconstruct monsoon precipitation quantitatively, we have not included these records here. Nevertheless, the BIT index and* $R_{i/b}$ *in the Yuanbao section are relatively invariable and do not exceed the established threshold values (i.e., 0.5 for the Ri/b; Tang et al., 2017) that indicate the occurrence of mega-drought events at this site over the past 130 kyr (Fig. 1B).*



(A)
DC
0.7
0.6
0.5
0.4
0.3
δ2Hwax (‰ VSMOW)
−200
−180
−160
−140
−120
(B)
BIT
1.0
0.9
0.8
0.7
0.6
0.5
Ri/b
0.0
0.5
1.0
(C)
MagSus (10−8 m3 kg−1)
160
120
80
40
GS (μm)
20
25
30
35
HS1
HS2
HS3
HS4
HS5
HS6
5c
5e
MIS1
MIS2
MIS3
MIS4
5a
(D)
δ18O (‰ VPDB)
−11
−10
-9
−8
−7
−6
NHSI (W m−2)
490
470
450
S0
L1
S1
0
15
30
45
60
75
90
105
120
135
Age (ka)

Fig. 1 *Biomarker- and loess-based records for the past 130 kyr at Yuanbao.* ***(A)*** *Degree of cyclization (DC) of brGDGTs and ice-corrected* δ^2H_{wax} *based on plant waxes in the same lipid extracts (Fuchs et al., 2023).* ***(B)*** *Branched and Isoprenoid Tetraether (BIT) index and ratio of iso- and brGDGTs (*$R_{i/b}$*).* ***(C)*** *Grain size (GS) and magnetic susceptibility (MagSus).* ***(D)*** *NHSI at 35°N (Berger et al., 2010) and the composite speleothem oxygen isotope (*$\delta^{18}O$*) record (Cheng et al., 2016). Dark grey intervals (~23–21 ka) in brGDGT-related records (DC) indicate the transition from the outcrop to the pit and are not considered in the interpretation of the records.*

The GDGT concentrations follow the same trend as magnetic susceptibility (MagSus, Fig. 2), indicating that they are similarly impacted by sedimentation rates (dilution) and/or the rate of soil formation (production) as MagSus. As such, this record does not provide additional paleoclimatic information beyond what MagSus already indicates. If the editor deems this useful, we can add this data to Fig. 2 in the revised manuscript.



(A)
Conc. isoGDGTs (ug g soil^{-1})
(B)
Conc. brGDGTs (ug g soil^{-1})
(C)
Ca (cps)
(D)
MagSus (10^{-8} m^3 kg^{-1})
GS (μm)
(E)
δ^{18}O (‰ VPDB)
NHSI (W m^{-2})
HS1
HS2
HS3
HS4
HS5
HS6
MIS1
MIS2
MIS3
MIS4
5a
5c
5e
S0
L1
S1
Age (ka)

Fig. 2 *Biomarker- and loess-based records for the past 130 kyr at Yuanbao.* ***(A)*** *Concentration of isoprenoid GDGTs.* ***(B)*** *Concentration of brGDGTs.* ***(C)*** *Calcium (Ca) intensity measured by X-ray fluorescence (unit: counts per second, cps) from a nearby drilling core (Guo et al., 2021).* ***(D)*** *Grain size (GS) and magnetic susceptibility (MagSus).* ***(E)*** *NHSI at 35°N (Berger et al., 2010) and the composite speleothem oxygen isotope ($\delta^{18}O$) record (Cheng et al., 2016).*

I would invite the authors to think a bit further about the local paleo-environmental conditions, and whether any of their assumptions can be confirmed with independent measurements. For instance, the authors surmise a link with a change in DC and available Ca in the soil profile. Could this be substantiated by the analysis of the sedimentology of this sequence?

Reply: *We thank the reviewer for their suggestions. We have checked Ca variations in a nearby drilling core at Yuanbao (103.63°E, 35.15°N, 2200 m above sea level; Guo et al., 2021), which was conducted by X-ray fluorescence (XRF) scanning (Fig. 2C).*

As discussed in the manuscript, more cyclic brGDGTs are produced when Ca^{2+} becomes increasingly available under wet conditions due to the dissolution of $CaCO_3$ that is generally present in loess (Line 209-217 in the original manuscript). Indeed, the DC and Ca intensity show a similar trend over the past 130 kyr (Fig. 2A and C).

Although the exact link between available Ca^{2+} and the production of cyclic brGDGTs is currently based on empirical correlations in soils from Scandinavia (Halffman et al., 2022) as well on more global soil datasets (De Jonge et al., 2021, 2024), microbial ecological studies have shown that Ca is a key predictor in shaping the soil microbiome as well as its functionality (e.g., Shepherd and Oliverio, 2024; Neal and Glendining, 2019; Allison et al., 2007). We will add the information on the influence of Ca on the microbial diversity in soils to the revised manuscript.

I also wonder whether the short-lived hydrological shift that resulted in a long impact on the 6-methyl branched GDGTs, could have been caused by ponding (i.e. the creation of a lake)? Is there any evidence for stagnant water (and associated anoxia) based on the sediments?

Reply*: We thank the reviewer for their thoughtful brainstorming. It is indeed an interesting point to consider whether stagnant water might have occurred during the period when the IR shifts. However, this does not appear to be the case at Yuanbao section.*

First, we do not expect stagnant water in loess-paleosol sequences, let alone anoxic conditions. While heavy precipitation may lead to temporary saturation of the topsoil, excess water would likely rapidly evaporate due to the generally warm climate conditions during the monsoon season, penetrate deeper into the soil due the loose texture of loess, or runoff as a result of relief on the CLP. In addition, the shift in 6-methyl brGDGTs occurs during a glacial period, which, on the CLP, is characterized by arid conditions. Moreover, the ratio of GDGT-0/crenarchaeol, which indicates contributions of methanogens when values exceed 2 (Blaga et al., 2009), is 0.1–1.7 in the Yuanbao section. Also the grain size record does not show any indications for a change in depositional environment. Taken together, we exclude the presence of stagnant water at this location during this time interval.

The different signal between pit and outcrop is also interesting, and points to the large impact local (hydroclimate/ vegetation) changes have on the GDGT signal.

Reply*: We agree with the reviewer that the large shift in brGDGT signals during the transition from the outcrop to the pit is intriguing. However, the other proxies from the same section (i.e., traditional loess proxies, δ^2H_{wax} from leaf waxes and isoGDGTs) do not show this difference, therefore it may be an overinterpretation to draw conclusions based solely on* *the shift in brGDGTs. Nevertheless, we have clarified that the transition between the pit and outcrop is not considered in our discussion (Line 182-184 in the original manuscript).*

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