Potential and pitfalls of orbital tuning of loess sequences across Eurasia

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Rationale

Several correlative timescales for Eurasian loess, based on different proxy data including magnetic susceptibility (MS), grain size indices and colour, have been proposed. These are, however, not all consistent (**Fig.1**), preventing a comparison of different loess geoarchives and comparison to marine and other proxy data and models. A quantitative comparison to other geoarchives is relevant for the understanding of driving mechanisms of loess-paleosol formation and for paleoclimatic reconstructions across the Eurasian continent.

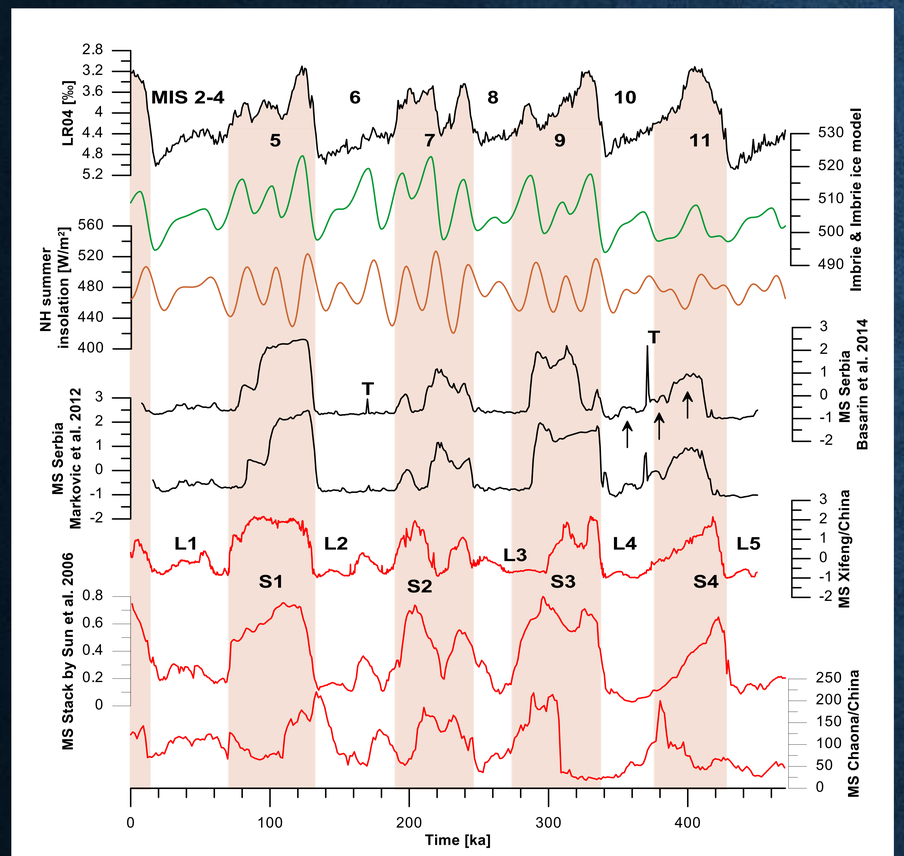

Figure 1: Comparison of several correlation targets (top) with magnetic susceptibility records on their individual time scales.

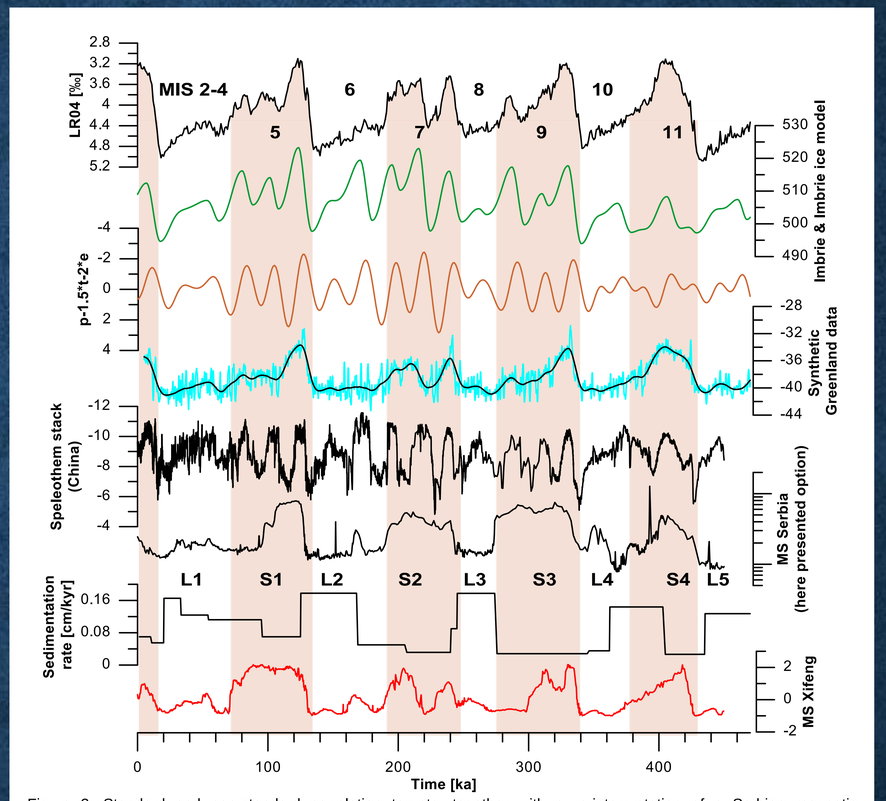

Figure 2: Standard and non-standard correlation targets, together with a re-interpretation of a Serbian magnetic susceptibility record and resulting sedimentation rates.

Challenges of correlative time scales for MIS 3

The **right Figure** shows different correlation targets for MIS 3. As can be seen, the selection of a suitable target is not straightforward, and different often similar (in)appropriate options exist.

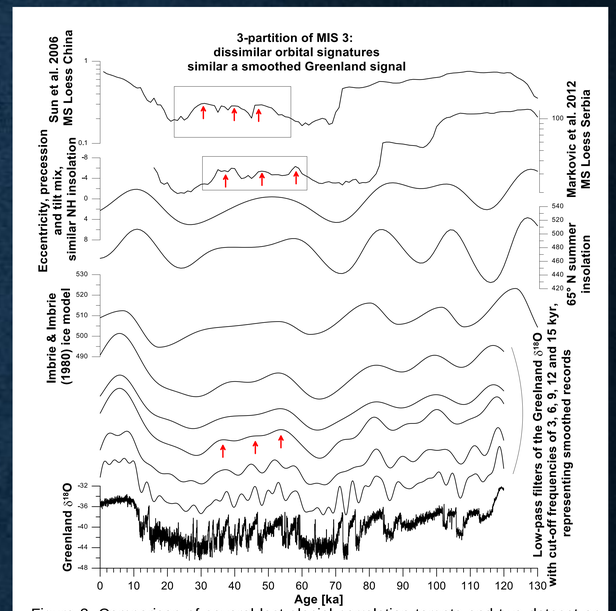

Figure 3: Comparison of several last glacial correlation targets and two dataset on their time scales.

Towards a solution

Several very good suggestions have been made concerning the timing of loess-paleosol sequences, i.a. Heslop et al. (2000), Ding et al. (2002), Sun et al. (2006), Guo et al. (2009). These were based on different proxy data records and are therefore not directly applicable to all other loess proxy data records. In Fig. 2 standard- and less conventional correlation targets are presented (top) together with a suggested span of paleosols as represented by high MS values. This implies that the loess records may require adjustment in their timing.

Especially the individual paleosols within the S2 and S3 pedocomplexes show that these correspond to warm phases spanning 3 precession cycles in high sedimentation rate and rather dry environments (north-western China, Tajikistan; Ding et al. 2002, Sun et al. 2006). Overall, similarity of transitions from loess to paleosols and global climate records (see reference records in Figs. 1, 2) suggests a timing similar to the benthic $\delta^{18}O$ record, and speak against a dominant direct orbital insolation forcing (and timescales derived from these).

Discussion points:

Does the last interglacial soil complex (S1, related to MIS 5) show soil formation during the whole MIS 5, or during MIS 5e only, as reported from high sedimentation areas (Chen et al. 1999)? Care must be taken with an interpretation when no high resolution data can support one of these interpretations.

May other interglacials represented in loess as pedocomplexes have a timing and/or duration dependent on location and/or sedimentation rate? Yet there seems no indication, but more high-resolution data from Europe may change this.

Especially in the L4 loess and S4 pedocomplex, proxies shows more variablility than the LR04 stack, the search for more suitable correlation target is ongoing, the Imbrie & Imbrie (1980) ice model, individual $\delta^{18}O$ datasets, and a synthetic Greenland record may represent suitable model alternatives.

Conclusions :

Correlative time scales for loess are challenging, resolution can often not be better than several kyr. Anchoring by (more precise) radiometric ages is clearly of high value, and especially suitable for MIS 3.

MIS 3 can be correlated to different reference datasets, and care must be taken not to overinterpret time scale accuracy.

A common time scale for loess, marine- and ice core records and also models is necessary to faciliate comparison and further analysis.

Key references: Barker, S., Knorr, G., Edwards, R.L., Parrenin, F., Putnam, A.E., Skinner, L.C., Wolff, E., Ziegler, M., 2011. 800,000 Years of Abrupt Climate Variability. Science 334, 347–351. doi:10.1126/science.1203580; Basarin, B., Vandenberghe, D.A.G., Marković, S.B., Catto, N., Hambach, U., Vasiliniuc, S., Derese, C., Rončević, S., Vasiljević, D.A., Rajić, L., 2011. The Belotinac section (Southern Serbia) at the southern limit of the European loess belt: Initial results. Quat. Int. 240, 128–138. doi:10.1016/j.quaint.2011.02.022; Ding, Z.L., Ranov, V., Yang, S.L., Finaev, A., Han, J.M., Wang, G.A., 2002. The loess record in southern Tajikistan and correlation with Chinese loess. Earth Planet. Sci. Lett. 200, 387–400. doi:10.1016/S0012-821X(02)00637-4; Guo, Z.T., Berger, A., Yin, Q.Z., Qin, L., 2009. Strong asymmetry of hemispheric climates during MIS-13 inferred from correlating China loess and Antarctica ice records. Clim. Past 5, 21–31.; Hao, Q., Wang, L., Oldfield, F., Peng, S., Qin, L., Song, Y., Xu, B., Qiao, Y., Bloemendal, J., Guo, Z., 2012. Delayed build-up of Arctic ice sheets during 400,000-year minima in insolation variability. Nature 490, 393–396. doi:10.1038/nature11493; Heslop, D., Langereis, C.G., Dekkers, M.J., 2000. A new astronomical timescale for the loess deposits of Northern China. Earth Planet. Sci. Lett. 184, 125–139. doi:10.1016/S0012-821X(00)00324-1; Imbrie, J., Imbrie, J.Z., 1980. Modeling the Climatic Response to Orbital Variations. Science 207, 943–953. doi:10.1126/science.207.4434.943; Laskar, J., Robutel, P., Joutel, F., Gastineau, M., Correia, A.C.M., Levrard, B., 2004. A long-term numerical solution for the insolation quantities of the Earth. Astron. Astrophys. 428, 261–285. doi:10.1051/0004-6361:20041335; Lisiecki, L.E., Raymo, M.E., 2007. Plio–Pleistocene climate evolution: trends and transitions in glacial cycle dynamics. Quat. Sci. Rev. 26, 56–69.; Sun, Y., Chen, J., Clemens, S.C., Liu, Q., Ji, J., Tada, R., 2006. East Asian monsoon variability over the last seven glacial cycles recorded by a loess sequence from the northwestern Chinese Loess Plateau. Geochem. Geophys. Geosystems 7, Q12Q02. doi:10.1029/2006GC001287