Modelling the effect of climate, dust deposition and ice sheets on paleosol development on the Chinese Loess Plateau

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The Chinese loess-paleosols sequences are important archives of the Quaternary paleoclimate and paleoenvironmental information. Loess was deposited during glacials, with a rate of high dust addition. Paleosols underwent strong pedogenesis during interglacials in response to strong summer monsoon and low dust influx rate. Most previous studies of paleosols in the CLP focused on paleoclimate-paleosol linkages by analyzing bulk paleosol characteristics, however much remains unknown about their relationship in terms of relative contributions of paleoclimatic conditions (e.g. precipitation, temperature, evapotranspiration, vegetation and dust addition). Soil formation is controlled by various environmental factors (e.g. dust input, climatic conditions) over an interglacial period; thereby, deducing such interpretations is complex. This motivates us to quantitatively examine relative contributions of precipitation, temperature, evapotranspiration, vegetation and dust addition on paleosol development in the CLP. As far as climate is concerned, ice sheets play an important role in regulating glacial-interglacial cycles during the Quaternary period and have been found to be closely linked with paleosol development in the CLP. However, how ice sheet-induced climate change has affected paleosol development is still unclear. We use SoilGen2-LOVECLIM process-based soil-climate models to simulate paleosol development using time series of climate data (e.g. precipitation, temperature, dust input) for a given interglacial. A sensitivity analysis was done to quantitatively assess the relative contributions of these factors on paleosol development. The sensitivity experiment includes simulations for each climatic factor alone, combined climatic factors (e.g. precipitation and evapotranspiration) and a reference simulation (Pre-Industrial climate). The results were analyzed by calculating the mean absolute error between each of the sensitivity simulation and the actual simulation (combination of all soil forming factors), % of gain compared to the reference simulation, and a visual comparison of depth distributions of soil properties. We set two experiments with ice (OrbGHGIce) and without ice sheets (OrbGHG) to examine the paleosol response to ice sheet-induced climate changes. All the simulations were done on two contrasting interglacials, MIS11 and MIS13. Our results show that the simulated soil properties (mass of calcite and clay) are sensitive to precipitation, dust addition and potential evapotranspiration in a different order of sensitivity. The simulated calcite content in both interglacials shows a greater sensitivity to precipitation, dust addition and potential evapotranspiration in decreasing order. The simulated clay content is influenced in the order of dust addition, precipitation and potential evapotranspiration for MIS11. In MIS13, there is no single factor for clay but a combination of factors and evapotranspiration had a considerable impact. Our results indicate that ice volume changes strongly influence the simulated climate and soil properties. Both MIS11 and MIS13 interglacial paleosols show strong carbonate leaching and clay migration to the end of interglacials in response to ice sheets. However, both paleosols were less developed in the first several thousands of years in response to large ice sheets. Compared to MIS11, ice sheet-induced climate has caused greater carbonate leaching and clay migration during MIS13.