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Debris flow grain size scales with sea surface temperature over glacial-interglacial timescales

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Debris flows are common erosional processes responsible for a large volume of sediment transfer across a range of landscapes from arid settings to the tropics. They are also significant natural hazards in populated areas. However, we lack a clear set of debris flow transport laws, meaning that: (i) debris flows remain largely neglected by landscape evolution models; (ii) we do not understand the sensitivity of debris flow systems to past or future climate changes; and (iii) it remains unclear how to interpret debris flow stratigraphy and sedimentology, for example whether their deposits record information about past tectonics or palaeoclimate. Here, we take a grain size approach to characterising debris flow deposits from 35 well-dated alluvial fan surfaces in Owens Valley, California. We show that the average grain sizes of these granitic debris flow sediments precisely scales with sea surface temperature throughout the entire last glacial-interglacial cycle, increasing by ~ 7 % per 1 ˚C of climate warming. We compare these data with similar debris flow systems in the Mediterranean (southern Italy) and the tropics (Rio de Janeiro, Brazil), and find equivalent signals over a total temperature range of ~ 14 ˚C. In each area, debris flows are largely governed by rainfall intensity during triggering storms, which is known to increase exponentially with temperature. Therefore, we suggest that these debris flow systems are transporting predictably coarser-grained sediment in warmer, stormier conditions. This implies that debris flow sedimentology is governed by discharge thresholds and may be a sensitive proxy for past changes in rainfall intensity. Our findings show that debris flows are sensitive to climate changes over short timescales ($\leq 10^4$ years) and therefore highlight the importance of integrating hillslope processes into landscape evolution models, as well as providing new observational constraints to guide this. Finally, we comment on what grain size represents in debris flow systems, and evaluate the extent to which grain size is correlated with event size. If the effects of past climate changes on debris flow stratigraphy are taken as a guide, future warming is likely to result in intensified storms and larger, coarser debris flows.