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Source contributions from quantitative mixture modeling of detrital geochronology age spectra

Joel Saylor (1) and Kurt Sundell (1,2)

(1) University of Houston, Department of Earth and Atmospheric Sciences, United States (jesaylor@uh.edu), (2) University of Arizona, Department of Geosciences, United States

Detrital zircon U-Pb geochronology is an invaluable technique in addressing source-to-sink questions of sediment provenance. However, methods of data interpretation have typically been based on qualitative assessment of age distributions which lack the ability to identify subtle differences in age distributions. We present new methods of quantitative comparison of age distributions using the Kolmogorov-Smirnov (KS) test D statistic and the Kuiper test V statistic on cumulative distribution functions (CDFs), and the Cross-correlation coefficient of mixture distributions (i.e. probability density plots (PDPs), kernel density estimates (KDEs), or kernel functional estimates (KFEs)). These metrics are used for quantitative intersample comparison, and implemented in an inverse Monte Carlo (MC) mixture model capable of determining relative contributions of potential sediment source samples by randomly scaling potential sediment source sample age distributions to mixed basin samples. We demonstrate the capacity of these approaches first through a series of tests on synthetic data, then on source-to-sink systems of Colombian modern river, loess samples from central China, and highly nuanced age distributions from Cenozoic stratigraphy in the northernmost Peruvian Altiplano. Intersample comparison of synthetic data shows the Cross-correlation coefficient applied to PDPs is more sensitive to subtle differences in age distributions than other metrics applied to PDPs and KDEs (e.g., Likeness and Similarity), as well as the KS and Kuiper test D and V statistics applied to CDFs. Proof-of-concept and applied testing shows the MC model is capable of reproducing known proportions of highly-complex age distributions when both source and mixed samples are well-characterized. Results from modern-river sand and loess samples cannot be perfectly matched, which provides a cautionary note of inadequate characterization of sediment sources and/or mixed samples. Further, this point highlights the importance of such characterization for accurate interpretation of sediment provenance, while also providing a tool to identify incomplete source data sets. Results from the Peruvian Altiplano reveal distinct up-section sediment provenance information consistent with independent geologic observations likely to have been missed through qualitative assessment. Sample size appears to be a major control on mixture model results; small ($n < 100$) detrital data sets may lead to misinterpretation of sediment provenance. These methods have been developed into a MATLAB-based graphical user interfaces (GUI) as stand-alone executable (.exe file) and application (.app) programs DZstats and DZmix. The GUIs and source codes are openly available to the scientific community.