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Exploring El Niño variability with unevenly spaced data: implications for global sedimentary sequences

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The El Niño-Southern Oscillation (ENSO) is a driver of global atmosphere-ocean dynamics, but projections of frequency and magnitude in different climate states remain uncertain. Paleoclimate records offer the potential to improve our understanding of ENSO behavior but most are fragmentary, suffer low resolution, and/or typically do not cover periods warmer than present day. Here we report a continuous, inter-annually resolved record of hydroclimate spanning 220-80 ka from Lynch's Crater in tropical northeast Australia, a region highly-sensitive to ENSO, allowing the exploration of inter-annual to multi-millennial variability across the last two glacial-interglacial cycles [Kershaw et al., 2007]. Lynch's Crater is a volcanic crater maar located on the Atherton Tablelands in Queensland, northeastern Australia has been filled with lake and peat deposits to a depth of over 60 m with major vegetation changes identified in the sediments spanning the past 230,000 years [Kershaw et al. 2007]. A multi-proxy study of the lowermost $\sim$40 m finely laminated, organic-rich lake sediments is presented based on an XRF-generated elemental profile at 200 μm resolution, combined with LOI, magnetic susceptibility, and pollen analyses, with a robust geochronological framework compiled using 8 optically stimulated luminescence (OSL) ages [Rieser and Wu¨st, 2010] and imported isotope ages from ODP-820. The XRF core scanning data were used to reconstruct hydrological changes and patterns of detrital influx, with titanium used as a precipitation proxy. To investigate changes in high-frequency variability (specifically the ENSO periodicity bands) in the obtained dataset over glacial-interglacial cycles we used spectral analysis to quantify and extract spectral peaks in the data. With the applied age model returning a non-linear sedimentation rate, the data required manipulation to create an equidistant dataset to enable these spectral analysis techniques. However, potentially important biases were identified with both an interpolation and a binning strategy. Crucially, this is only problematic when looking for frequencies close to the Nyquist frequency (Nf), which is defined as the frequency equal to half the sampling rate of a system, and the highest frequency that spectral peaks can be robustly identified (with an average sampling rate here of Δt=2.5 yrs, Nf=5 yrs). While identifying spectral peaks with quasi-equidistant data appears robust, comparing data with different accumulation rates near their Nyquist frequency presents a considerable challenge, with major implications for global sedimentary sequences.