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On the similarity and apparent cycles of isotopic variations in East Antarctic snow and ice cores

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Oxygen and hydrogen isotope ratios in polar ice typically show variations over a large range of timescales. Since the isotope ratios are interpreted as a proxy for atmospheric temperatures, their variations can provide essential information about the natural climate variability and cycles. Nowadays high-resolution isotope samplings corresponding to depth intervals below or around the local accumulation of snow per year are routinely performed, and observed variations in the isotopic composition at a given site have frequently been interpreted as the reflection of the seasonal cycle in temperature and also to indicate multi-year quasi-periodic climatic cycles. However, studies from strongly different accumulation conditions in East Antarctica reported similar isotopic variability and comparable apparent cycles in isotope profiles with typical wavelengths of around 20 cm, which is inconsistent with a climatically driven origin. Here we show, based on spectral analysis, that these features do not correspond to truly or quasi-periodic cycles. In addition, the typical wavelengths increase with depth for most East Antarctic sites, which is inconsistent with the effect of burial and compression on a climatic cyclic signal. We explain these results by isotopic diffusion acting on a noise-dominated isotope signal. The firn diffusion length is rather stable across the Antarctic Plateau, leading to similar power spectral densities of the isotopic variations, and increases with depth in the near-surface firn. Since the first moments of the spectral density govern the characteristic spacing of the extrema of a time series – a fundamental relationship known as Rice's law – the similar isotope spectra in turn imply similar average distances between the isotopic minima and maxima that get larger with increasing depth. Our results bear important implications for the interpretation of isotope records in terms of cyclical climate variability. They underline that simply counting isotopic extrema is not sufficient to detect periodicities, instead robust spectral analyses have to be applied in order to differentiate between true climate cycles and the apparent cycles created in the diffusion process. This has consequences for the dating of ice-core records, which is often based on or underpinned by counting isotopic maxima, but also for the detection and interpretation of quasi-periodic climate phenomena on longer timescales. Finally, the general implications of our findings are not restricted to ice cores but likely also apply to other paleo-climate archives, as other smoothing processes, e.g. the bioturbational smoothing of proxy records from marine sediments, might lead to similar apparent cycles.