Examining erosion in New Zealand over millennial timescales using in-situ $^{10}$Be and $^{14}$C

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Landslides are the major erosional process in many orogens, and one of the most sensitive erosional process to tectonic and climatic perturbations. However, it remains extremely difficult to constrain long-term or past rates of landslide activity, and hence their contribution to long-term landscape evolution and catchment sediment fluxes, because the physical records of landsliding are often removed in $<10^2$ yrs. Here, we use the in-situ $^{10}$Be and in-situ $^{14}$C concentrations of recent landslide deposits and catchments from the Fiordland and the Southern Alps of New Zealand to: (a) estimate landslide frequencies over $10^3$-$10^4$ yr timescales, which we compare against landslide inventories mapped from air photos ($<10^2$ yrs) to estimate changes in landslide activity, (b) quantify catchment-averaged erosion rates, and landslide's contribution to those erosional fluxes, and (c) test whether paired $^{14}$C/$^{10}$Be measurements can be used to trace erosional depth-provenance and identify transient erosion rate changes. We show that $^{10}$Be concentrations on landslide deposits can be used to estimate landslide recurrence intervals and frequency over $10^1$ yr timescales, and that $^{14}$C/$^{10}$Be ratios reflect the depth-provenance of sediment, and possibly transient changes in erosion rates. The comparison of our $^{10}$Be-based long-term landslide frequencies with short-term published inventories suggests that landslide frequencies have increased towards the present by up to an order of magnitude. We compare sediment fluxes inferred from these long- and short-term landslide inventories with sediment flux estimates derived from $^{10}$Be catchment-averaged erosion rates, which allows us to examine fluctuations in erosion rate estimates from $10^1$ to $10^3$ yrs timescales.