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Complex landscape evolution and transient denudation rates: potentials of an R based modelling approach to facilitate the analysis of cosmogenic nuclide data in complicated geomorphological settings

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We survey the usefulness of a new modelling approach based on a prospective extension package to be contributed to the R environment for statistical computing. Based on a first set of routines that have been implemented and assembled into libraries, we demonstrate different numerical simulation examples encompassing the evolution of terrestrial cosmogenic nuclide (TCN) concentrations in complex and dynamically developing terrains. We discuss which basic requirements are to be fulfilled for the further development of our algorithms into a full R extension package and which essential functionalities are considered to be expedient.

Emerging research topics involving the use of terrestrial cosmogenic nuclide data in geomorphological studies are commonly characterized by an increasing complexity of the systems and processes under investigation. In early times, the evaluation of TCN records focussed on the most simplified assumption of the cosmogenic isotopes being produced under the conditions of a steadily eroding outcrop surface. Yet, it is commonly agreed that this assumption is invalid in most environments and for most lithologies. Moreover, the study of transient landscapes has become highly topical in view of their capacities to record the influence of climate change, human activities, and tectonic forcing. Processing TCN data nowadays often requires considerable effort to account for dynamic system behaviour or to conduct scenario tests. However,

as a drawback, most of the advanced and modelling based interpretive strategies yet presented are essentially ephemeral, written for a single piece of data analysis. Stand-alone applications and spread sheet based solutions commonly lack flexibility and turned out to be unsuitable to be interconnected or integrated into extended evaluation schemes.

In this contribution we outline our concept for an assembly of numerical routines that aim to facilitate the build up of user-specified models and procedures for data analysis related to the application of terrestrial cosmogenic nuclides in geomorphological studies. Due to the intended final users, a free simulation platform was important and R was a natural candidate. R is a rapidly developing language and environment for statistical computing that is freely available under the GNU General Public License. In specific, R is highly extensible through the use of packages, which are user-submitted libraries for specific functions or specific areas of study. The final goal of our research activities will be to contribute a full R extension package for TCN related computations.

At current stage, a set of basic algorithms for TCN related data analysis and statistical evaluations has been programmed in the R language and is assembled in libraries. Our contribution will demonstrate some aspired key features like (i) the computation of TCN concentrations (^{10}Be, ^{26}Al) in transient landscapes (accounting for both continuous erosion with time variant erosion rates and discontinuous erosion events with variable thickness of the detached layers, i.e. chipping of blocks or grains and / or shallow bedrock and regolith landslides), (ii) nonlinear Error propagation using Monte Carlo simulation and Bootstrap techniques, and (iii) application of formal sensitivity analysis with respect to parameter estimation, experimental planning and optimization of sampling schemes.