Geophysical Research Abstracts, Vol. 7, 08234, 2005
SRef-ID: 1607-7962/gra/EGU05-A-08234

Extreme Value Models for dating Moraines in Bolivia

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Currently there is a tremendous scientific research effort in the area of climate change. In this paper, our motivation is to improve the understanding of historical climatic events such as the Little Ice Age (LIA), a period of relatively cold weather around 1450-1850 AD. Although the LIA is well-documented in Europe, its extent and timing are not known in areas of the globe where climatological records were not kept during this period.

To study the climate which predates historical records, proxy climate records must be used. A proxy record for the timing of climatic cooling events are the ages of the moraines left behind by glacial surges. Unfortunately, to determine the ages of these moraines in alpine environments there is little material available but lichens. Hence, lichenometry was developed to determine the ages of glacial landforms by using lichen measurements. To our knowledge, this article provides the first attempt at deriving a comprehensive spatio-temporal statistical model for lichenometry. Our model foundation is based on extreme value theory because only the largest lichens are measured in lichenometry studies. This application is novel to extreme value theory because the quantities of interest (the ages of climatic events) are not the measured quantities (lichen diameters), i.e. it is a inverse problem.

We model the lichen measurements with the generalized extreme value (GEV) distribution, upon which a Bayesian hierarchical model is built. The hierarchical model enables estimation of the hidden covariate ages of the moraines. The model also allows for pooling of data from different locations and evaluation of spatial differences in lichen growth. Parameter inference is obtained using a straightforward Markov Chain Monte Carlo method. Our procedure is applied to data gathered from the Cordillera Real region in Bolivia.