A SIMPLE PROCEDURE FOR KRIGING LEFT-CENSORED DATA

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ABSTRACT

Kriging is a widely applied geostatistical prediction methodology. Many forms of kriging are used to obtain accurate predictions from observed spatial data. This paper discusses the problem of kriging spatial data that include some left-censored values. Limitations of measurement instruments or high noise levels may censor some observations so that one only knows that the values are less than reported thresholds. Naively ignoring this type of data typically over-predicts the spatial surfaces. Stein (1992) presented a Monte Carlo method for estimating the high-dimensional integrals required to calculate the predictive, conditional distributions. This paper presents a simple procedure that can be used with existing complete-data kriging algorithms. We present an analysis of seismic Lg-phase amplitude residuals from Chinese earthquakes. The final results yield a broadened low-amplitude zone across Tibet, increasing predicting power in areas from which poor Lg are observed. We anticipate the method will be useful for creating amplitude correction surfaces for use in estimating magnitudes and evaluating Comprehensive Test Ban discriminants.

Key Words: imputation, Lg phase amplitudes, spatial statistics

OBJECTIVE

Regional seismic characterization is a major research area of the Comprehensive Nuclear-Test-Ban Treaty Program. Kriging techniques are being used to produce spatial corrections for travel times, and various amplitudes. The objective of this research is to produce a two-stage kriging algorithm, which could incorporate poor signal- to-noise data or below-detection-threshold (left-censored) data.

The two-stage kriging algorithm is demonstrated using amplitudes of seismic Lg phases recorded in China. Lg is a collection of shear modes trapped in the earth's crust and is often found in seismograms collected at distances between 300 and 2000 km from the source. Lg is known to exhibit dramatic variations in behavior in tectonically complex areas and can be severely attenuated or blocked by transitions between oceanic and continental crust (Press and Ewing 1952) or by continental structures such as the edge of the Tibetan plateau (Ruzaikin et al. 1977). Because good signal-to-noise data originating behind a blockage zone is rare, our ability to map propagation efficiency is greatly reduced in these areas. The inclusion of left-censored data information will increase the number of constraining data points in such areas, leading to better prediction and less reliance on unconstrained extrapolation. Corrections based on propagation maps will be important for estimating magnitudes (Nuttli 1986) and reducing the scatter in phase and spectral ratios used to discriminate between natural and man-made seismic events (Pomeroy et al. 1982); thus, such corrections will be useful for monitoring the Comprehensive Nuclear-Test-Ban Treaty.

RESEARCH ACCOMPLISHED

This paper presents a simple procedure that can be used with one's favorite complete-data Kriging algorithm. Stein's (1992) procedure obviates existing algorithms and software when faced with left-censored data. We formulate a two-stage procedure under the Simple Kriging assumptions; however, application to Ordinary Kriging situations is immediate. For comparison, we present examples of simulated data sets with just one left-censored datum, with much left-censored data (Stein's 1992 simulated data), and with Lg-phase amplitude residuals from Chinese earthquakes (Phillips 1999). This research has been submitted for publication in The Journal of Computational and Graphical Statistics, and is available as a PNNL technical report (PNNL-12206).

CONCLUSIONS AND RECOMMENDATIONS

The application of the procedure to Chinese seismic data produced broadened regions of poor Lg efficiency, which would not have been seen had left-censored data been ignored. The most efficient raypaths originate from northwest, northeast and southeast quadrants, the Baikal Rift in particular. These paths cross older and geologically stable regions, consistent with the observed efficient propagation. Little Lg is observed for Tibet events (a well-known blockage). Shallow trench events on either side of Taiwan, whose raypaths cross oceanic crust, also produce little Lg. Regions of poor Lg efficiency are broadened by the procedure. In particular, central and western areas of Tibet are characterized by lower Lg values because of the influence of censored data. Previously, predictions for these areas were solely based on extrapolation because too few events were large enough to produce Lg exceeding the signal-to-noise threshold.

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