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Chemical composition of Earth's primitive mantle and its variance

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We present a new statistical method to construct a model for the chemical composition of Earth's mantle along with its variance. Our method essentially follows the so-called pyrolite approach; the primitive mantle is located on the melting trend exhibited by mantle peridotites, using cosmochemical constraints on the relative abundances of refractory lithophile elements. Compared to other approaches, this pyrolite approach involves the least amount of assumptions other assumptions and is thus probably most satisfactory. Its previous implementations, however, suffer from questionable statistical treatment of scattered geochemical data, leaving the uncertainty of model composition poorly quantified. In order to properly take into account how scatters in peridotite data affect this geochemical inference, we combine the following three statistical techniques: (1) modeling a nonlinear melting trend in the multidimensional compositional space through the principal component analysis, (2) determining the primitive mantle composition on the melting trend by simultaneously imposing all of cosmochemical constrains with least squares, and (3) mapping scatters in original data into the variance of the final composition model through the Monte Carlo bootstrap resampling method. Our compositional model is similar to previous models in terms of major element concentrations, but is substantially depleted in a number of minor and trace elements. Based on this new model, we then critically review all of major geochemical arguments for layered mantle convection, most of which rest on the presumed model of Earth's composition. The new compositional model indicates that, contrary to common belief, the global heat budget as well as the global noble gas budget can be consistent with the large-scale homogeneity of Earth's mantle.