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Various applications of Markov random field model to earth sciences

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Recent development of measurement and observation techniques makes it possible to obtain a large amount of spatial and temporal data sets in earth sciences. However, it has still been difficult to extract geological and geophysical information, because available data usually have large noise and uncertainty. Therefore, the statistical analyses of data sets are essential for the objective and quantitative geological and geophysical interpretation. The Markov random field (MRF) model is a Bayesian stochastic model using a generalized form of Markov chains that is often applied to the analysis of images, particularly in the detection of visual patterns or textures (e.g., Geman and Geman 1984). The MRF model assumes that the spatial or temporal gradients of physical properties are relatively small compared with the measurement noise and analytical uncertainty. The MRF model acts as a low-pass filter to extract accurate spatial or temporal variations of physical properties. By the Markov chain Monte Carlo (MCMC) approach, this model can determine the appropriate bandwidth from the statistical properties of the observed data. Recently, several studies have used the MRF model to extract the true physical properties from noisy observational data sets, for example, in brain science (e.g., Watanabe et al. 2009). By the Bayesian probabilistic approach and their flexible formulation, the MRF model has a potential to deal with non-statistical uncertainty. Moreover, it can incorporate prior information into analyses quantitatively. We apply the MRF model to two inversion problems in earth sciences: one is a pressure-temperature inversion from compositional data of zoned minerals (Kuwatani et al., in press), and the other is an inversion of fluid distributions from observed seismic velocity structure. In this presentation, we will discuss effectiveness and broad applicability of the MRF model in earth sciences.