Machine learning accelerates parameter optimization and uncertainty assessment of an ecosystem model

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The performance of land surface models (LSMs) or ecosystem models strongly depends on their unknown parameter values so that it is necessary to optimize them. Here I present a globally applicable and computationally efficient method for parameter optimization and uncertainty assessment of the LSM by combining Markov Chain Monte Carlo (MCMC) with machine learning. First, I performed the long-term (decadal scales) ensemble simulation of the LSM, in which each ensemble member has different parameters' values, and calculated the gap between simulation and observation, or the cost function, for each ensemble member. Second, I developed the statistical machine learning based surrogate model, which is computationally cheap but accurately mimics the relationship between parameters and the cost function, by applying the Gaussian process regression to learn the model simulation. Third, we applied MCMC by repeatedly driving the surrogate model to get the posterior probabilistic distribution of parameters. Using satellite passive microwave brightness temperature observations, both synthetic and real-data experiments in the Sahel region of west Africa were performed to optimize unknown soil and vegetation parameters of the LSM. The primary findings are (1) the proposed method is 50,000 times as fast as the direct application of MCMC to the full LSM; (2) the skill of the LSM to simulate both soil moisture and vegetation dynamics can be improved; (3) I successfully quantify the characteristics of equifinality by obtaining the full non-parametric probabilistic distribution of parameters.

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