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Land subsidence prediction with uncertainty analysis by a smoother algorithm with a multiple calibration-constrained null-space Monte Carlo method

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Predicting the future land subsidence caused by groundwater abstraction is necessary for the planning and decision-making of groundwater usage in coastal area. Although numerical modeling is expected to quantitatively predict land subsidence, a single calibrated model cannot provide a reliable prediction because of the uncertainty on properties and conditions in the subsurface. In addition, applying ensemble Kalman filter or ensemble smoother to land subsidence modeling is not straightforward because of the highly nonlinear and hysteric characteristics in clay compaction process.

This study developed a smoother algorithm with a multiple calibration-constrained null-space Monte Carlo method for a numerical simulator of groundwater mass balance with modified Cam-clay model. The developed algorithm calibrates a model ensemble using a newly obtained observed value in each observation step. Based on the calibration-constrained null-space Monte Carlo method, a new model ensemble in the null-space is produced in each observation step. In this step, both the current and past state as well as parameters in the model are updated like ensemble smoother in order to follow the hysteretic behavior in the soil compaction. The produced ensemble can be used not only for prediction uncertainty analysis at that step but also as initial estimates of a multiple calibration-constrained null-space Monte Carlo method in the next observation step.

The proposed method was applied to the land subsidence modeling in the Tokyo lowland area, Japan. The proposed method could make model ensemble with satisfactory good reproducibility and show the range of uncertainty of future prediction for several scenarios of future groundwater level change.

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