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Nonlinear instability and sensitivity of a theoretical grassland ecosystem to the finite-amplitude perturbations

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Conditional nonlinear optimal perturbations (CNOPs) is a new approach proposed by Mu et al to study predictability and sensitivity problems in climate research. CNOP is the initial perturbation whose nonlinear evolution attains the maximal value of the cost function, which is constructed according to the physical problems of interests. In this research, approach of CNOP is employed to investigate the instability and sensitivity of grassland ecosystem described by the theoretical model of Zeng et al to the finite-amplitude perturbations. It is shown that for each value in the interval of moisture index, there exist a CNOP and a local CNOP of grassland equilibrium state, and these CNOPs describe the most unstable (or most sensitive) mode in grassland ecosystem. A critical value of the moisture index, μ_c, is found. In case that the moisture index is larger than μ_c, the CNOP and local CNOP of the grassland equilibrium state are attracted back to the grassland equilibrium state. When the moisture index is less than μ_c, the behaviors of the evolutions of CNOPs are different from the above case. In this situation, there exists a critical value of the magnitudes of the initial perturbations(δ_c). When the magnitude of CNOP is larger than δ_c, the CNOP of the grassland equilibrium state evolves to the desert equilibrium state, while the local CNOP evolves back to the grassland equilibrium state, which suggests that the CNOPs become more and more unstable with the increasing amplitudes of initial perturbations. However, if the magnitude of CNOP is smaller than δ_c, the CNOP and local CNOP all recover back to the grassland equilibrium state too. These results demonstrate the nonlinear characteristic of instability and sensitivity of grassland ecosystem to finite amplitude perturbations , and suggest the potential applicability of CNOP in the study of impact of human activities on grassland ecosystem.