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# Conditional nonlinear optimal perturbation and its applications to predictability, stability and sensitivity studies

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Conditional nonlinear optimal perturbation (CNOP) is the optimal combined mode of initial perturbations and model parameter perturbations, which causes the largest departure from a given reference state, in terms of a measurement defined by a cost function with physical constraint conditions. CNOP has two special cases. One is CNOP-I that only links with initial perturbations and has the largest nonlinear evolutions at prediction time; while the other is CNOP-P and only associated with model parameter perturbations, which cause the largest departure from the given reference state at prediction time. The CNOP approach allows us to investigate not only the first kind of predictability problem but also the second kind of predictability problem. Furthermore, the CNOP approach can be applied in sensitivity and stability studies. This talk will introduce the CNOP approach and its applications to the following problems: (1) the "spring predictability barrier" for El Nino-Southern Oscillation, (2) the nonlinear instability and sensitivity of a theoretical grassland ecosystem to the finite-amplitude perturbations, and (3) the targeting observation of Typhoon and ensemble forecast.