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Application of an Adjoint Technique for Finding Effective Parameter Perturbations in Climate Models

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Climate models contain numerous parameters for which the numeric values are uncertain. Tools for analyzing the effect of these uncertainties are the adjoint and tangent linear equations. Usually, the tangent linear equations are derived for deviations in the state space variables only. However, perturbations in model parameters can be included as well. This is done by extending the vector containing the variables in state space with the variables in parameter space. Then, the adjoint and tangent linear equations can be calculated for the extended variable space. With the use of the adjoint and tangent linear equations, the parameter perturbations that lead to the largest deviation of the reference orbit in state space can be found for short term integrations. There is evidence that sensitivities based on short term integrations are relevant for changes in long term statistics. Therefore, in order to find parameter or forcing perturbations to which the climate is sensitive, use can be made of the sensitivitiy of short-term evolutions to such perturbations. This technique was applied both to the simple Lorenz 63 climate model, and to a more realistic QG model of the atmosphere.