Sensitivity analysis of meteorological models with the adjoint method

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Sensitivity analysis is an effective tool to examine a model's response to perturbed initial and/or boundary conditions as well as model parameters. It can help to improve the accuracy of the results by showing the weaknesses to the developers. There are two basic methods to make sensitivity analyses. One of them is the most obvious method is direct sensitivity analysis, where the examined model is rerunned with the perturbed conditions, after the basic simulation. By the end of the simulations the results by different settings are compared to find the best fitting scheme. The advantage of this method is that it is relatively easy to carry out, but it can reveal only the effect of the altered conditions on the results. However the main disadvantage of the method is that – in case of great number of investigated parameters – it is very expensive to rerun a complex model several times to achive a comprehensive picture, and also by this method the parameter choices are made empirically.

The other way to perform a sensitivity analysis of a model is the adjoint or inverse method. The adjoint method works in a somewhat opposite way as the direct one. Here a response functional is defined, which is usually a function of the output variables. Then the sensitivity of this response to all selected parameter and/or condition changes can be determined by usage of the adjoint functions. The advantage of this method is that for many parameters it is much cheaper than the previous one, because it does not need to rerun the model for every single parameter to be investigated. The result can be computed by a simple integration. Also the adjoint functions are able to give an insight in the development of the perturbed result, showing the process of signal transmission from the perturbed conditions. The disadvantage of the method is that – in case of noncontinuous functions – might be difficult to define the adjoint operator, and also a preliminary linearization is necessary, which can limit the usability of the method. The existence and applicability of a nonlinear operator's adjoint in meteorology, is one of that questions, which could be important to be investigated.