Some results of the sensitivity studies using the adjoint version of the ALADIN model

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Introduction

The work presented in this Newsletter is based on the master thesis of Roland Steib, who completed his university studies as meteorologist during this summer. The main objective of the recent work was to complement and continue the work on adjoint sensitivity studies started by Cornel Soci for his PhD work. It is emphasised that the performed work gave just very preliminary results, without detailed analysis of them, due to the limitations of the framework of such a master thesis.

The main emphasis was put on the one hand to the exploration of a critical summer forecast case, when the operational ALADIN model was especially wrong, and on the other hand to the reproduction and further investigation of another case, which was already studied by Cornel Soci in his earlier ALATNET stay in Budapest. In the latter case the main further consideration was the application of the simplified and regularised physical parameterisation package in the adjoint model version as developed by Marta Janiskova.

Methodology

The applied methodology was very similar as it was used by Cornel, therefore only its main aspects and some differences are mentioned briefly :

-- The diagnostic (cost) function measuring the quality of the numerical weather prediction model's forecast (ALADIN) was computed as the quadratic difference between the model forecast and a reference analysis (the reference analysis for our case was the ALADIN 3d-var analysis; note that Cornel used the ARPEGE analysis as the true state of the atmosphere). The norm used in the experiments was the dry total energy norm.

-- The adjoint sensitivity study was performed by a nonlinear integration to obtain the trajectory needed for the adjoint model, the evaluation of the gradient at the final forecast time and then by the adjoint integration to the initial time for providing the gradient (sensitivity) fields (some target domains were used in order to concentrate only some specific areas, where the operational forecast was especially bad) with respect to initial conditions. All the simplified parameterisation schemes were tried in the course of the adjoint integration. The obtained gradients were renormalised into perturbations and then added to the original initial state providing new initial conditions for the nonlinear model run. Finally nonlinear model integration were performed and the new forecasts were compared to the original ones.

-- The ALADIN model version used was AL15 and two domains were applied : the old (extended Carpathian Basin) and new (Europe) ALADIN/HU domains (8 and 6.5 km horizontal resolution respectively). The new domain was used for the first case study and the old one for the second one.

Main results

As mentioned above two case studies were examined : the first one was related to an extremely bad ALADIN operational forecast during July 2002, the other one was an older case (June 2001), when the results earlier obtained by Cornel Soci were complemented by those ones using the simplified parameterisation schemes in the adjoint model.

1st case: 18th of July, 2002

For this summer case the operational ALADIN forecast failed to predict a heavy convective precipitation event over the middle part of Hungary already for a 6 h forecast period. At the same time a false precipitation signal appeared in the south-western part of the country. In terms of dynamical fields the most spectacular deficiencies in the operational model was found to be the forecast of the 2m-temperature field and the low-level meridional wind field. Adjoint sensitivity studies (in order to obtain 6 h gradients of the forecast-error cost function to the initial conditions) were run having the adiabatic version of the adjoint model and then several experiments were carried out using vertical diffusion, gravity wave drag, cloudiness, convection and large-scale precipitation simplified parameterisations in the adjoint model.

While examining the gradient (sensitivity) fields, one can immediately state that there was just very small advection for the given situation, i.e. the system was governed by local effects (locally triggered convection). By switching on the different parameterisation schemes in the adjoint model : the precipitation parameterisation schemes have a relatively large impact on the gradient fields (certainly it cannot be excluded that there are some numerical instabilities appearing in the gradient fields, this aspect should be further examined). The nonlinear sensitivity runs (when the initial conditions were improved by the renormalised gradients) showed that the best results were obtained, when both the large-scale precipitation and the convection scheme were switched on during the integration of the adjoint model.

As a summary it can be said that for this event, as it was anticipated, the precipitation-related parameterisation schemes had an important role and with their application in the adjoint model the forecast was successfully improved in some extent. Nevertheless it is a bit strange that the best results were obtained with the combined use of large-scale and convective precipitation, when the event was clearly a convective one (this behaviour was also noticed by Cornel Soci). Nevertheless this aspect (beside others) needs to be further investigated.

2nd case: 22nd of June, 2001

This case was already partially investigated by Cornel Soci during his ALATNET stay in Budapest : now a new model version was tried and the simplified parameterisation schemes were switched on during the adjoint model integration. Regarding the situation : a wrong precipitation forecast occurred at the south-eastern part of the country (the model erroneously gave around 15 mm precipitation to that area of Hungary, while in the reality there was just very small amount of rain). The related wind and temperature forecast was extremely bad giving for instance in some areas more than 22 m/s wind difference with the reality. While examining the sensitivity (gradient) patterns with respect to the initial conditions, first of all the strong advection is becoming clear, i.e. the meteorological system was rather a frontal one, with strong advective features. Regarding the application of the different parameterisation schemes, already the gradient of the adiabatic adjoint model version was able to correct the bad forecast and the other parameterisation schemes didn’t have any influence with respect to the adiabatic case. The main conclusion for this case was that this event was mainly conducted by dynamical forcing, when the effect of the simplified parameterisation schemes in the adjoint model were rather small.

Conclusions

The described work served just as a very preliminary investigation on the applicability of the different simplified parameterisation schemes in the adjoint model. Unfortunately we couldn’t explore with enough scientific details the obtained results, therefore at that stage it is considered that the main outcome of the work is not the deep dynamical analysis of the results, but the demonstration of the feasibility of the applicability of the simplified schemes in the context of the adjoint model together with the hope that it can be later successfully used while computing singular vectors for short-range ensemble forecasts or in the process of four-dimensional variational data assimilation.

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