Damping of fast growing gravity waves generated by imbalance of initial mass and wind fields and diabatic forcing

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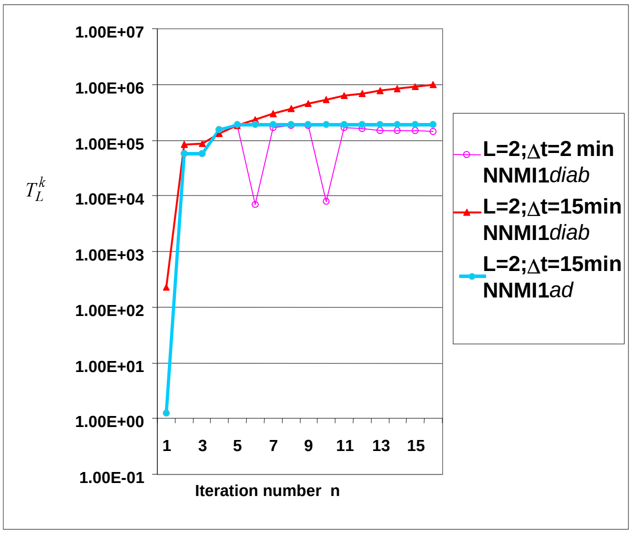
Numerical solutions of the equations of atmospheric hydro- and thermodynamics contain high-frequency noise, which arises, firstly, because of the inconsistency of initial meteorological fields and, secondly, due to diabatic forcing. To damp the noise, nonlinear normal mode initialization (NNMI) procedures (Machenhauer, 1982) are widely used now. They assume that time derivatives of the amplitudes of "fast" modes with frequencies above some given threshold must be set zero at the initial time moment. Then we come to nonlinear equations solved by iterations. However, to ensure a convergence of this iterative process quite strong conditions must be satisfied, e.g., only of a limited number of vertical modes can be initialized or time-averaged diabatic fluxes must be used in a model. At the same time, the diabatic processes can affect the divergent component of the atmospheric circulation (vertical motions) considerably and increase the effect of gravitational waves onto Rossby components in the numerical solution of the primitive equation diabatic model. Thus, the diabatic forcing must be taken into account in order to obtain the correctly balanced initial fields. With this purpose we developed a new diabatic nonlinear normal mode initialization procedure based on a specific selection of most rapidly growing gravitational waves. The procedure can be applied to the entire spectrum of gravitational modes with allowance for the real order of magnitude of physical phenomena present in the atmosphere. A series of numerical experiments was performed with the Hydrometcenter of Russia global spectral model T85L31 with different initialization procedures starting from the 1996 ECMWF objective analysis data. A convergence of the iterative process during initialization and coincidence of the initial data fields were estimated with the help of a characteristic T_L^k (*L* is the number of the vertical mode, *k* the iteration number) suggested by Rasch, 1985. T_L^k can be considered as a typical time scale of the gravitational waves corresponding to the L*th* gravitational mode), and if it decreases from iteration to iteration, it means that the iterative process does not converge. It can be assumed that the initial data are balanced well and do not generate high-frequency modes if T_L^k is high enough (~$3 \cdot 10^4$ c). As to the convergence of the iterative processes, the numerical experiments showed the following (see the Figure, where NNMI0 denotes the experiment with the Machenhauer initialization procedure; NNMI1*ad* and NNMI1*diab* stand for the experiments with new initialization procedure, adiabatic and diabatic versions, respectively). First, .the time step Δt is important for the NNMI1 performance. At small Δt~2 min, NNMI0 and NNMI1*ad* are equally successful in balancing the initial pressure and wind fields (the values of T_L^k are of the same order). In this case, a change of the initialization procedure practically does not affect the forecast skill. At Δt equal to the model step (15 min), the NNMI0 procedure diverges, while NNMI1 improves the balance between wind and pressure initial fields (T_L^k increases) and, hence, the forecast skill. Second, an application of NNMI1*diab* results in a significant growth of T_L^k. The improvement was most striking for the planetary-scale modes (L=1, 2). Third, the best results were obtained by NNMI1*diab* for 5-7 initialized modes, and from 15 to 20 iterations were necessary to converge the process.



Variations of T_L^k in the iterative processes

The numerical experiments with T85L31 model and NNMI1 demonstrate that the most intensive divergent eddies are usually simulated in the regions with great orographic slopes or in zones of intense convective mixing. The adiabatic initialization, on average, leads to weaker divergent circulation within the tropical and baroclinic mid-latitude zones in the vicinity of large sources of convective heating. It retains main features of the atmospheric circulation above the mountains without considerable decrease of its intensity. In its turn, the diabatic initialization gives divergent circulation components that are closer to the actual ones in the regions with intense diabatic fluxes.

An application of the proposed initialization procedure ensures smooth numerical solutions of the model with minimal changes of initial fields, especially, the divergent components of the atmospheric circulation. Important, that the introduction of diabatic factors, firstly, convective heating, into initialization procedure gives a noticeable improvement of initial field balance (as compared to that obtained with the adiabatic initialization) within mid-latitude baroclinic zones.

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