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Exact solution of the linear, 4D-discrete, implicit, semi-Lagrangian dynamic equations with orographic forcing

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Exact general solution of the linear, completely discrete in 3 spatial and 1 temporal dimension (4D-discrete), implicit, semi-Lagrangian equations of atmospheric dynamics with given orographic forcing is constructed. The general solution includes both the stationary solution and non-stationary solution with optional initial conditions.

The basic state, in respect to which the linearization is carried out, is described by the reference temperature $T^r(p)$ and horizontal wind vector $\vec{U}(p)$, which both are optional (given) functions of the pressure

The solution is constructed as the 4D trigonometric series of finite lengths. At that, the series members are treated as continuous (analytical) trigonometric functions of discrete arguments, which allows for continuous interpolations of solution to the intergrid space.

Special attention is paid to stationary case. The solving draws back to vertical eigenvector specification for each horizontal orthogonal mode. Efficient solution method for eigen-problem is presented, which takes into consideration the upper radiative boundary condition.

The derived solution can be used to study the stratification effects on orographic flow pattern. As a test-bed, the solution can be used for testing of the adiabatic cores of limited area NWP models. The approach is also suited for analytical investigation of different numerical effects to the solution accuracy, like the spectral smoothing, Asselin time-filtration, and departure-arrival point de-centring in semi-Lagrangian numerical algorithms.