Improving the mass conservation in the semi-Lagrangian scheme of the IFS/HARMONIE model

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The global forecast model, Integrate Forecast System (IFS), of the European Center for Medium-Range Weather Forecast (ECMWF), and the limited-area model, Hirlam Aladin Mesoscale Operation NWP in Europe (HARMONIE), developed by Aladin and Hirlam groups, both solved the 3D primitive equations and the evolution of the components of the atmosphere which are described by a continuity equation whose conserved quantity is the total mass of each component.

These NWP models have the same dynamic kernel, use hydrostatic pressure as the basis of its vertical coordinate and both introduce orography via a terrain-following vertical coordinate at the lowest model levels.

Equations are discretized using a two-time level semi-implicit (SI) semi-Lagrangian (SL) numerical scheme for the 3D primitive equations. The mixing ratio evolution of the constituents of the atmosphere is two-time level SL advection equation.

The SL scheme is not designed to preserve the total mass of dry air or the other constituents of the atmosphere without source and sink terms, therefore it is importan to search for new alternatives to the present formulation of the SL numerical scheme in order to improve the conservation in the continuity and constituents of the atmosphere.

In the global model (IFS), total dry air mass and total mass of each constituent should remain constant throughout the simulation period if there are no source or sinks (10 day), while in the limited-area, HARMONIE this does not apply. Hence, the improvements in the conservation of the dry air and total mass of the constituents of the atmosphere verifiable in the IFS should be applicable to the HARMONIE limited-area version because the dynamic kernel is the same for both models.

We present several modifications in the SL scheme of IFS/HARMONIE models for improving the mass conservation of the total mass of dry air and the total mass of any constituents of the atmosphere throughout the simulation period.

We present several modifications in the SL numerical scheme of IFS/HARMONIE models in the continuity equation and we will show which are the terms of this equation that most contribute to the non-conservation of the dry air.

For the atmosphere constituents, different kinds of interpolations have been implemented to obtain the field value at the departure point of the SL trajectory and we will display how the change to improve the mass conservation of the atmosphere constituents throughout the simulation period.

We further show the behaviour of these modifications with several spacial resolutions of the model.

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