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A mass-conserving and multi-tracer efficient transport scheme in the online integrated Enviro-HIRLAM model.

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A new advection scheme for the online integrated chemical-weather prediction model Enviro-HIRLAM is presented. The new scheme is based on the Locally Mass Conserving Semi-Lagrangian method (LMCSL), where the original two-dimensional scheme has been extended to a fully three-dimensional version. This means that the three-dimensional semi-implicit semi-Lagrangian scheme which is currently used in Enviro-HIRLAM, is largely unchanged. The HIRLAM model is a computationally efficient hydrostatic operational short term Numerical Weather Prediction (NWP) model, which is used as the base for the online integrated Enviro-HIRLAM, however, some of the properties originally considered negligible, has an impact on ACT modeling, e.g. mass conservation. The new scheme is shown to be efficient, mass-conserving, and shape-preserving while only requiring minor alterations to the original code. It still retains the stability at long time steps, which the semi-Lagrangian schemes are known for, while handling the emissions of chemical species accurately.

The properties of mass-conservation, shape-preservation, and multi-tracer efficiency, are important for on-line integrated NWP/ACT models. Mass conservation is of importance, since spurious numerical sources and sinks of chemical species reduce the forecast credibility. Shape preservation is also important, since non-linear chemistry introduces spurious reactions initiated solely by the deficiencies of the numerical scheme. The term multi-tracer efficiency is related to the amount of additional cost for each additional advected tracer. When introducing tens or hundreds of new tracers, it is crucial that the scheme can transport the tracers with as little computational overhead as possible.

The new scheme is shown to be almost as efficient as the original scheme, i.e. the additional computational cost is less than 1 %, while improving on several of the so-called desirable properties, in particular mass conservation. When run with full chemistry, the results demonstrate that, even for short lead times, the mass conservation and shape preserving properties of a numerical scheme significantly affects the chemistry. The last point addressed is the performance of the emission method. It is shown that the semi-Lagrangian scheme can have accurate emissions, even while using long time steps (Courant numbers up to 5).