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Using a scale selective tendency filter and forward-backward time stepping to calculate consistent semi-Lagrangian trajectories

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In semi-Lagrangian models used for climate and NWP the trajectories are normally/often determined kinematically. Here we propose a new method for calculating trajectories in a more dynamically consistent way by pre-integrating the governing equations in a pseudo-Lagrangian manner using a short time step. Only non-advective adiabatic terms are included in this calculation, i.e. the Coriolis and pressure gradient force plus gravity in the momentum equations, and the divergence term in the continuity equation. This integration is performed with a forward-backward time step. Optionally, the tendencies are filtered with a local space filter, which reduces the phase speed of short wave gravity and sound waves. The filter relaxes the time step limitation related to high frequency oscillations without compromising locality of the solution. The filter can be considered as an alternative to less local or global semi-implicit solvers.

Once trajectories are estimated over a complete long advective time step the full set of governing equations is stepped forward using these trajectories in combination with a flux form semi-Lagrangian formulation of the equations.

The methodology is designed to improve consistency and scalability on massively parallel systems, although here it has only been verified that the technique produces realistic results in a shallow water model and a 2D model based on the full Euler equations.