ENDGame, a Tropical Tropopause Layer warm bias, and Lagrange vs Hermite

Chris Smith, John Thuburn and Nigel Wood

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This presentation will start by briefly reviewing the ENDGame dynamical core of the Met Office's Unified Model and describe where it is on its journey to becoming operational for both weather and climate predictions.

On that journey it became apparent that ENDGame suffered from a more severe Tropical Tropopause Layer (TTL) warm bias than its predecessor, the New Dynamics. After considerable investigation the cause of this detriment was tracked down to a change in the discretization of the vertical advection of potential temperature. ENDGame used a standard semi-Lagrangian scheme employing cubic Lagrange interpolation and is therefore asymptotically third-order accurate. New Dynamics instead uses a non-interpolating-in-the-vertical scheme which, for small vertical Courant numbers, is similar to a centered, second-order accurate scheme.

Characterizing the dynamics of the TTL as oscillatory vertical motion, a simple but novel analysis (supported by simplified numerical experiments) shows that a key ingredient in representing accurately the effect of this oscillatory motion is to maintain continuity not just of the reconstructed temperature profile but also of its first derivative. This is naturally achieved with a centered scheme but is not satisfied by cubic Lagrange interpolation. As a result of the analysis, a cubic Hermite scheme has been implemented in ENDGame (in the vertical direction only) and the positive impact that this has had on the TTL warm bias will be demonstrated. The cubic Hermite scheme would appear to be a good compromise between what is needed for a good advection scheme and what is needed to accurately capture wave-like motion.

The cubic Hermite scheme employed is one order of accuracy lower than the cubic Lagrange scheme. The presentation will close by discussing options for improving the accuracy of the scheme but also demonstrating that this appears not to be effective for reasons that are not yet fully understood.