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Extension of a Non-Hydrostatic Dynamical Core into the Thermosphere

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The Met Office Unified Model dynamical core ENDGame (Even Newer Dynamics for General Atmospheric Modelling of the Environment) is being developed to become a whole-atmosphere model that is capable of simulating the atmosphere from the surface to the top of the thermosphere at 600km, which will have applications in space weather forecasting and chemical climate modelling. Initial attempts to raise the top boundary of ENDGame above $\sim$100km give rise to instabilities. This presentation will first explore a number of the potential causes of these instabilities using ray tracing techniques to look into numerical effects on wave propagation. Then, the results of extending a 1D vertical column version of ENDGame (ENDGame1D) using a fully coupled implementation of molecular viscosity are presented, and progress made towards including molecular viscosity in the full 3D version of ENDGame follows.

It is well known that numerical methods can affect wave propagation in various ways. Ray tracing techniques can take into account the numerical effects on wave propagation, and have been used to show that ENDGame's numerics produce unrealistically large wave amplitudes, have a tendancy towards the excessive focussing of wave energy towards vertical propagation, and have poor handling of large amplitude waves.

A key result of the ray tracing experiments is that the physical process of molecular viscosity has the effect of preventing the excessive growth of wave amplitudes in the thermosphere in ENDGame, which is crucial to improving ENDGame's stability. Therefore, a fully implicit-in-time implementation of molecular viscosity in ENDGame1D is developed. Molecular viscosity is a very fast acting process in the thermosphere, so a new scheme is developed to deal with the viscous terms with the dynamics terms in a fully coupled way to avoid time-splitting errors that may arise.

It is found that the combination of a small amount of off-centering of ENDGame1D's semi-implicit formulation and the inclusion of molecular viscosity act to make ENDGame1D significantly more stable, as long as the simulation is able to remain stable up to the point where molecular viscosity begins to have a signficant damping effect at an altitude of $\sim$130km. Progress towards the 3D implementation of molecular viscosity will also be discussed.