Geophysical Research Abstracts
Vol. 14, EGU2012-6090, 2012
EGU General Assembly 2012

A method for improving time-stepping numerics

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In contemporary numerical simulations of the atmosphere, evidence suggests that time-stepping errors may be a significant component of total model error, on both weather and climate time-scales. This presentation will review the available evidence, and will then suggest a simple but effective method for substantially improving the time-stepping numerics at no extra computational expense.

The most common time-stepping method is the leapfrog scheme combined with the Robert–Asselin (RA) filter. This method is used in the following atmospheric models (and many more): ECHAM, MAECHAM, MM5, CAM, MESO-NH, HIRLAM, KMCM, LIMA, SPEEDY, IGCM, PUMA, COSMO, FSU-GSM, FSU-NRSM, NCEP-GFS, NCEP-RSM, NSEAM, NOGAPS, RAMS, and CCSR/NIES-AGCM. Although the RA filter controls the time-splitting instability in these models, it also introduces non-physical damping and reduces the accuracy.

This presentation proposes a simple modification to the RA filter. The modification has become known as the RAW filter (Williams 2011). When used in conjunction with the leapfrog scheme, the RAW filter eliminates the non-physical damping and increases the amplitude accuracy by two orders, yielding third-order accuracy. (The phase accuracy remains second-order.) The RAW filter can easily be incorporated into existing models, typically via the insertion of just a single line of code. Better simulations are obtained at no extra computational expense.

Results will be shown from recent implementations of the RAW filter in various atmospheric models, including SPEEDY and COSMO. For example, in SPEEDY, the skill of weather forecasts is found to be significantly improved. In particular, in tropical surface pressure predictions, five-day forecasts made using the RAW filter have approximately the same skill as four-day forecasts made using the RA filter (Amezcua, Kalnay & Williams 2011). These improvements are encouraging for the use of the RAW filter in other models.

References

PD Williams (2011) The RAW filter: An improvement to the Robert–Asselin filter in semi-implicit integrations. *Monthly Weather Review* **139**(6), pp 1996–2007.

J Amezcua, E Kalnay, and PD Williams (2011) The effects of the RAW filter on the climatology and forecast skill of the SPEEDY model. *Monthly Weather Review* **139**(2), pp 608-619.