Gung-Ho Dynamics:

High-resolution test case reference solutions using a version of the ENDGame shallow water model

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1 Introduction

The more interesting and discriminating test cases do not have analytical solutions. Therefore, it is useful to have available reference solutions generated by a well-tested and trusted scheme run at high spatial and temporal resolution. In particular, it is useful to have the reference solution on the test model grid allowing error fields to be calculated.

These notes accompany a version of the ENDGame shallow water model set up to generate reference solutions for the surface height field for Williamson et al. (1992) test case 5. The code can easily be adapted for other test cases.

(As an alternative, the ICON group have provided a version of the NCAR spectral transform shallow water model set up to compute a reference solution of test case 5:

`http://icon.enes.org/swm/stswm/index.html`)

2 Overview

There are three steps to generating and using a reference solution:

1. Create a file (or files) containing the coordinates of the grid (or grids) on which the reference solution is required.
2. Modify the ENDGame code to read the grid file and run to create the reference solution.
3. Read the reference solution and compare with the test solution (e.g. compute differences).

3 Defining the grid(s) on which the reference solution is needed

The user should create a simple unformatted file specifying the grid on which the reference solution is required. The file contains an INTEGER defining the number of grid points, followed by a list of pairs of REAL*8 numbers giving the longitude and latitude (in radians) of the grid points. The order of the grid points does not matter; the reference solution values will be generated in the same order.

For example, the code to dump the coordinate of ENDGame's own longitude-latitude grid is simply:

```
WRITE(88) nx*ny
DO j = 1, ny
  DO i = 1, nx
    WRITE(88) geolonp(i,j), geolatp(i,j)
  ENDDO
ENDDO
```

If the reference solution is required on several grids then each should be defined in a separate file.

4 Running the ENDGame shallow water code

The resolution used to generate the reference solution should be sufficiently finer, in space and time, than the test resolutions, so that it can be regarded as accurate. The code provided is set up to run at 1024 by 512 resolution with a time step 225 s. To change the spatial resolution modify `MODULE grid`. The code has been tested with resolutions of the form 2^p by 2^{p-1}, 3×2^p by $3 \times 2^{p-1}$, and 5×2^p by $5 \times 2^{p-1}$. To change the time step used and the final time of the integration, modify the values of `dt` and `tstop` in `SUBROUTINE timing`.

The code provided is currently set up to run Williamson et al. test case 5. (BUT NOTE: the mountain is centred at longitude $\pi/2$ rather than $3\pi/2$ for convenience of plotting. This can easily be changed by modifying the value of `longc` in `SUBROUTINE initial`.) Code to initialize for the Rossby Haurwitz wave case (test case 6) and the Galewsky et al. (2004) barotropic instability test case is also included and these can be selected by changing the value of `ic` in `SUBROUTINE initial`. It will also be necessary to choose a suitable value for the semi-implicit reference value of geopotential: see the comments in `SUBROUTINE setconst`.

In `SUBROUTINE writeref` the user should specify the number of grids on which the reference solution is required (PARAMETER `ngref`) and the names of the files containing the descriptions of those grids (the elements of the CHARACTER array `ygc`). For each of those grids the user should also provide a prefix for the names of the files that will contain the reference solution in CHARACTER array `yrefpre`, for example `'TC5ref_hex__0000000642'`. It is a good idea to generate the reference solution on all required grids in a single run, simply because a high resolution reference run is expensive.

Also in `SUBROUTINE writeref`, the user should specify the number of times at which the reference solution is required (PARAMETER `nreftime`) and the actual times at which the reference solution is required (the elements of array `reftime`). At each required time the reference solution is interpolated to all of the required grids using cubic Lagrange interpolation. The reference solution is written to a file whose name is constructed by appending the time to the prefix supplied by the user, e.g. `'TC5ref_hex__0000000642_0000086400.dat'`.

5 Reading the reference solution

On each grid and at each required time the reference solution is written simply as a list of unformatted REAL*8 values:

```
DO if0 = 1, nface
  WRITE(49) href(if0)
ENDDO
```

Therefore, in order to use the reference solution the user simply has to provide code to read the reference solution file.

References

Galewsky, J., Scott, R.K., and Polvani, L.M., 2004: An initial-value problem for testing numerical models of the global shallow-water equations. Tellus, 56A, 429-440.

Williamson, D.L., Drake, J.B., Hack, J.J., Jakob, R., and Swarztrauber, P.N., 1992: A standard test set for numerical approximations to the shallow water equations in spherical geometry. J. Comput. Phys., 102, 211-224.