AFiD example : Rayleigh Bénard convection in a laterally periodic cartesian domain

This document is intended to serve as an example to simulate three dimensional Rayleigh Bénard (RB) convection in a laterally periodic cartesian domain using the code AFiD (van der Poel *et al.*, 2015). For the purpose of this example we will set the Rayleigh number $Ra = 10^8$, Prandtl number of the liquid $Pr = 1.0$ and the aspect ratio of the box $\Gamma = 2.0$.

Setting up the simulation:

1. Download and install the code using the tarball and installation guide on the main page of the code.

2. Input parameters are set in the file bou.in. Changing these parameters does not require a recompilation of the code. Description of the input settings can be found in the corresponding guide found on the main page in the attachments.

3. For this example, we choose the grid resolution as NXM = 256, NYM = NZM = 512. Note that the X-direction is parallel to gravity. Since the aspect ratio is chosen to be $\Gamma = 2.0$, set YLEN = ZLEN = 2.0 while XLEN = 1.0.

4. An indication of the required resolution of the boundary layer and bulk can be obtained with the attached python file 'blres.py' . This does require an estimate of the Nusselt number Nu which can be obtained with the Grossmann-Lohse theory (Stevens *et al.*, 2013), amongst other methods. It is advised to use 20%-50% more points in the boundary layer than the file 'rbres.py' provides.

5. Computationally, one is free to choose any vertical grid size. However, FFT's are used in the horizontal directions and these are much faster when the resolutions adheres to $2^i \times 3^j \times 5^k$, where i,j,k are integers. The attached file 'fftoptres.py' is useful is choosing the number of grid points in the vertical direction.

6. Another important grid-related parameter is the grid streching (STR3). The lower this parameter is, the more grid points are clustered near the walls. A maximum value of STR3 can be calculated with the script 'getstr3.py'Ṅote that a very low value of STR3 can result in an under-resolved bulk or an inefficient time step. For this example we set it to 20.0.

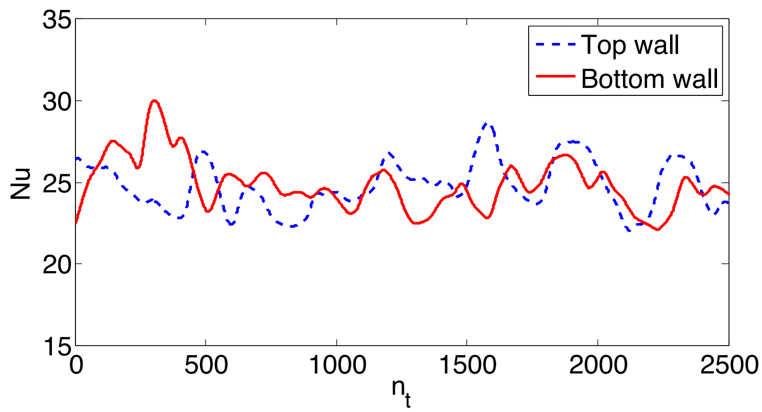

Figure 1: Time series of the Nusselt number on the top wall and bottom wall. Data is collected after the simulation has achieved statistical stationarity.

Running the simulation:

1. Incase you are running the simulation for the first time or not reading in any files to start the simulation ensure that NREAD is set to 0 in the input file.

2. You can then start the simulation.

3. A list of output files generated by the code is given in the main page of the code. Note that this depends on the input parameters STATON and BALANCEON.

With the parameters used in this example, in figure 1 we plot the time series of the Nusselt number on the top wall and the bottom wall. This figure shows part of the output from the file 'nu_plate.out' .

References

van der Poel, E. P., Ostilla-Mónico, R., Donners, J. & Verzicco, R. 2015 A pencil distributed finite difference code for strongly turbulent wall-bounded flows. *Computers & Fluids* **116**, 10–16.

Stevens, R.J.A.M., van der Poel, E.P., Grossmann, S. & Lohse, D. 2013 The unifying theory of scaling in thermal convection: the updated prefactors. *J. Fluid Mech.* **730**, 295–308.