# CFD Assignment 2
# AEM-ADV19

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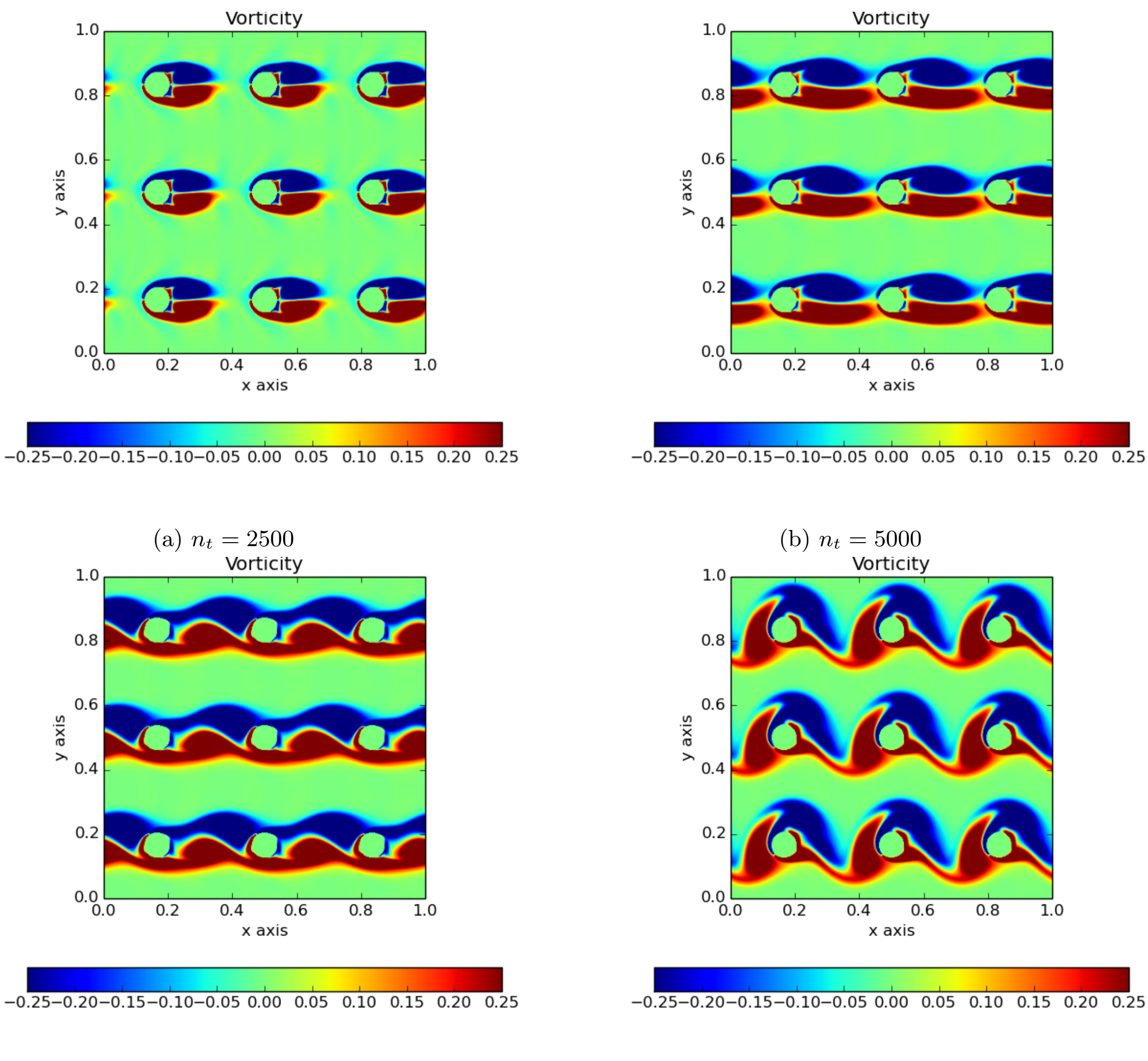
# 1

**Run a first simulation with $Re = 200$ (line 646 of the `2D_compressible.f90` file) and $n_x \times n_y = 129 \times 129$ for $n_t = 10000$ time steps with a second order Adams-Bashforth scheme (itemp=1) and a CFL equal to 0.25. Generate 4 visualisations of the vorticity field for $n_t = 2500, 5000, 7500, 10000$. Briefly comment on the results in less than 100 words. (Note : The code should be configured for this question, no changes are needed).**




(a) $n_t = 2500$

(b) $n_t = 5000$

(c) $n_t = 7500$

(d) $n_t = 10000$

Figure 1: Vorticity plots, CFL = 0.25, Adams-Bashford Scheme, 2$^{\text{nd}}$ order accuracy derivatives.

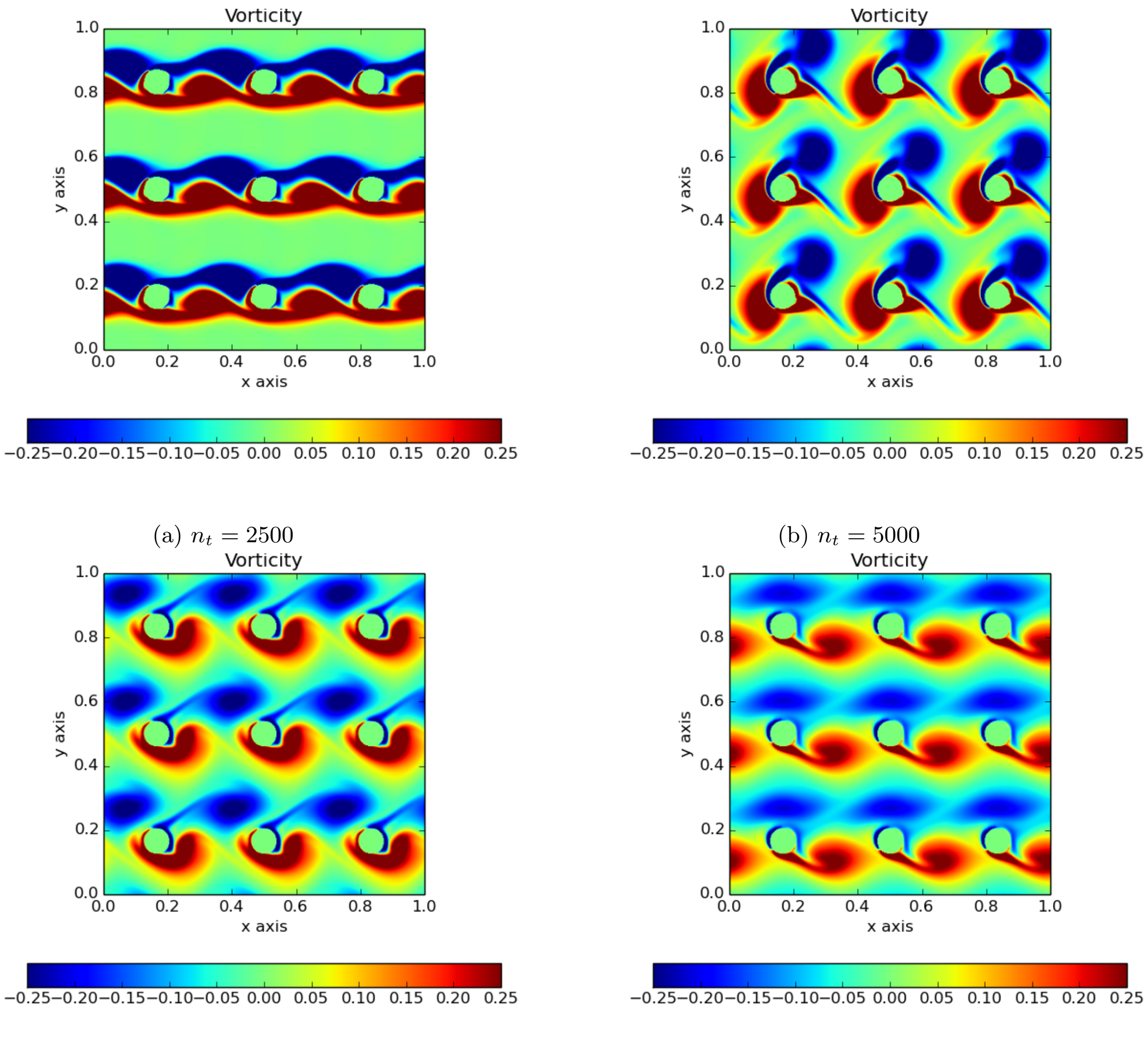
# 2

**We want to increase the CFL number in order to reduce the cost of the simulation. Using the same second order Adams-Bashforth scheme (`itemp=1`), is it possible to run a simulation with a CFL of 0.75? If yes, generate 4 visualisations of the vorticity field for $n_t = 2500, 5000, 7500, 10000$ and briefly comment on the results in less than 100 words. If not, try to explain why in less than 100 words.**

It is not possible to run the simulations with a CFL of 0.75.

# 3

**Complete the subroutine `rkutta` in which a third-order Runge-Kutta scheme will be used for the me advancement (use the skeleton provided in the code). The scheme is described in sec on 4.3. Run a simulation with the same parameters as in the first simulation but with a $CFL = 0.75$ and the newly implemented third-order Runge-Kutta scheme ($itemp = 2$, line 38 of the `2D_compressible.f90` file)). Generate 4 visualisations of the vorticity field for $nt = 2500, 5000, 7500, 10000$. Briefly comment on the results in less than 100 words and copy-paste the subroutine `rkutta` in your report.**




(a) $n_t = 2500$

(b) $n_t = 5000$

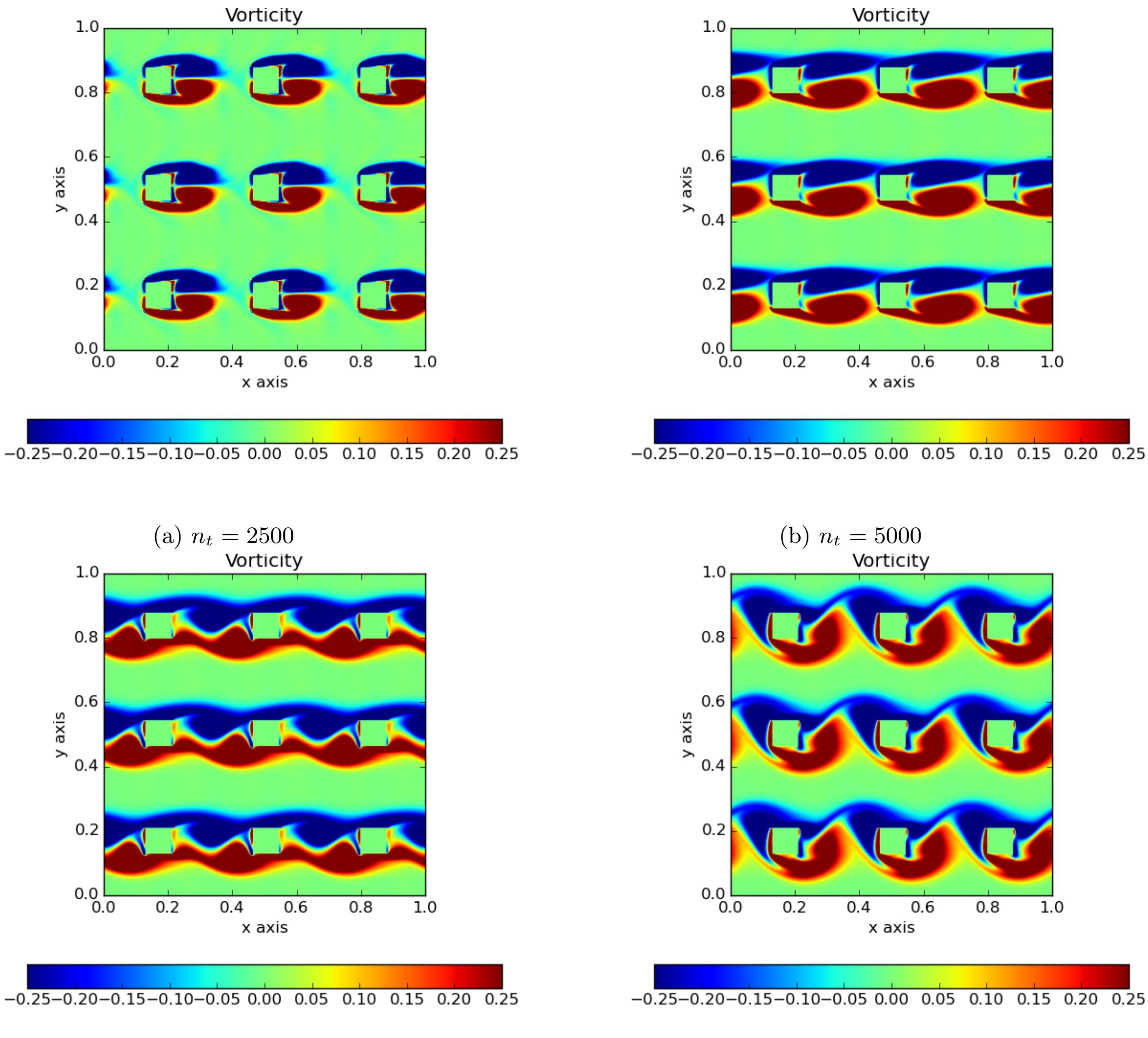
(c) $n_t = 7500$

(d) $n_t = 10000$

Figure 2: Vorticity plots, CFL = 0.75, 3$^{rd}$ order Runge-Kutta Scheme, 2$^{nd}$ order accuracy derivatives.

# 4

**Instead of circular cylinders, run a simulation using the same parameters as in the first simulation (second order Adams-Bashforth scheme, `itemp=1`, $CFL = 0.25$) but with square cylinders. The subroutine `initl` needs to be modified, in particular for the array `eps`. For example, you can define `imin,imax,jmin,jmax` where (`imin,jmin`) is the bottom left corner of the square, (`imin,jmax`) the bottom right corner, (`imax,jmin`) the top left corner and (`imax,jmax`) the top right corner. The length of the square will be equal to the diameter d of the circular cylinder. Generate 4 visualisations of the vortcity field for $nt = 2500, 5000, 7500, 10000$. Copy-paste the new 2D loop for the square cylinder in your report and briefly comment on the results in less than 50 words.**




(a) $n_t = 2500$

(b) $n_t = 5000$

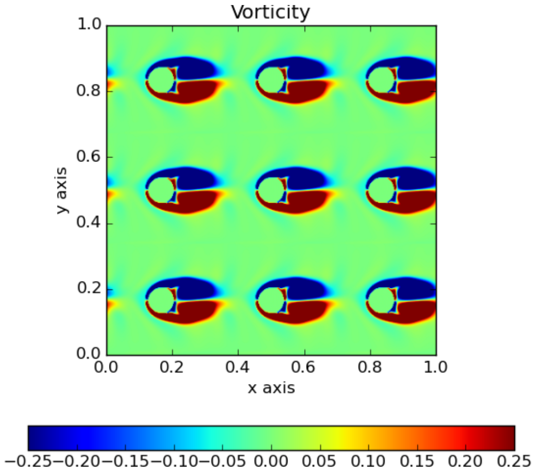
(c) $n_t = 7500$

(d) $n_t = 10000$

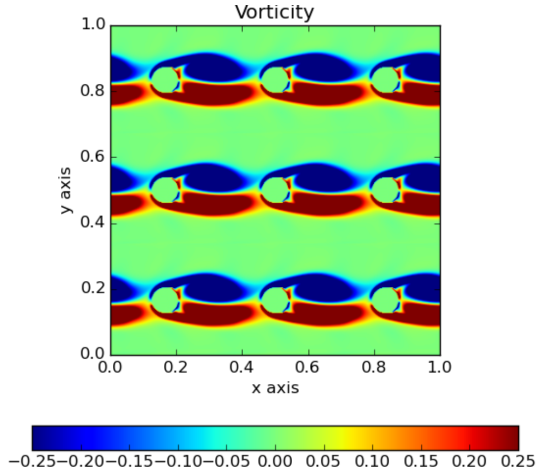
Figure 3: Vorticity plots, CFL = 0.75, 3$^{\text{rd}}$ order Runge-Kutta Scheme, 2$^{\text{nd}}$ order accuracy derivatives.

# 5

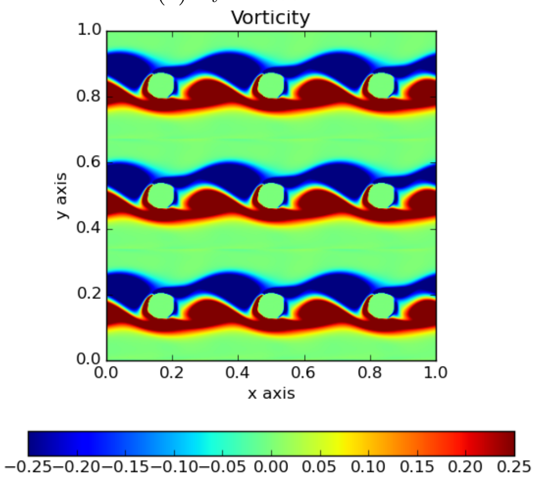
**We want to use centered fourth-order schemes for the first and second derivatives in the two spatial directions. Write four new subroutines, using the skeletons provided in the code : `derix4`, `deriy4`,`derxx4` and `deryy4`. In the subroutine `fluxx`, replace the second-order first and second derivatives with the new fourth-order ones. Then run a simulation with same parameters as the first simulation (question 1) but with the new the fourth-order schemes. Generate 4 visualisations of the vorticity field for $nt = 2500, 5000, 7500, 10000$. Briefly comment on the results and discuss the differences (if any) with the first simulation (question 1) in less than 100 words. Copy-paste the four new subroutines in your report.**



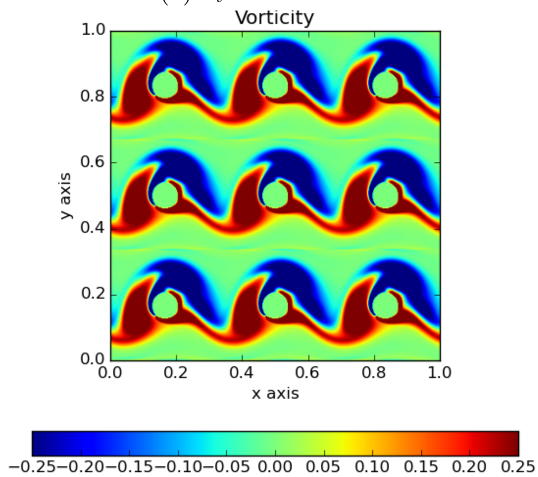

(a) $n_t = 2500$




(b) $n_t = 5000$




(c) $n_t = 7500$




(d) $n_t = 10000$

Figure 4: Vorticity plots, CFL = 025, Adams-Bashford Scheme, 4$^{\text{th}}$ order accuracy derivatives.

# 6

**What will happen to the flow if you run the simulation in question 1 for a very long time? Justify your answer in less than 100 words.**

Running the simulation for a long period of time would see the decay of any flows. This due to the truncation behaving as a dissipative term and as the simulation is using periodic boundary conditions there is no velocity added as $t \to \infty$.