High Re Solutions for the 2D Driven Cavity using the Lattice Boltzmann Method

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HIGHLIGHTS

Two-dimensional (2-D) geometry with D2Q9 velocity model

Single relaxation time model (BGK collision term)

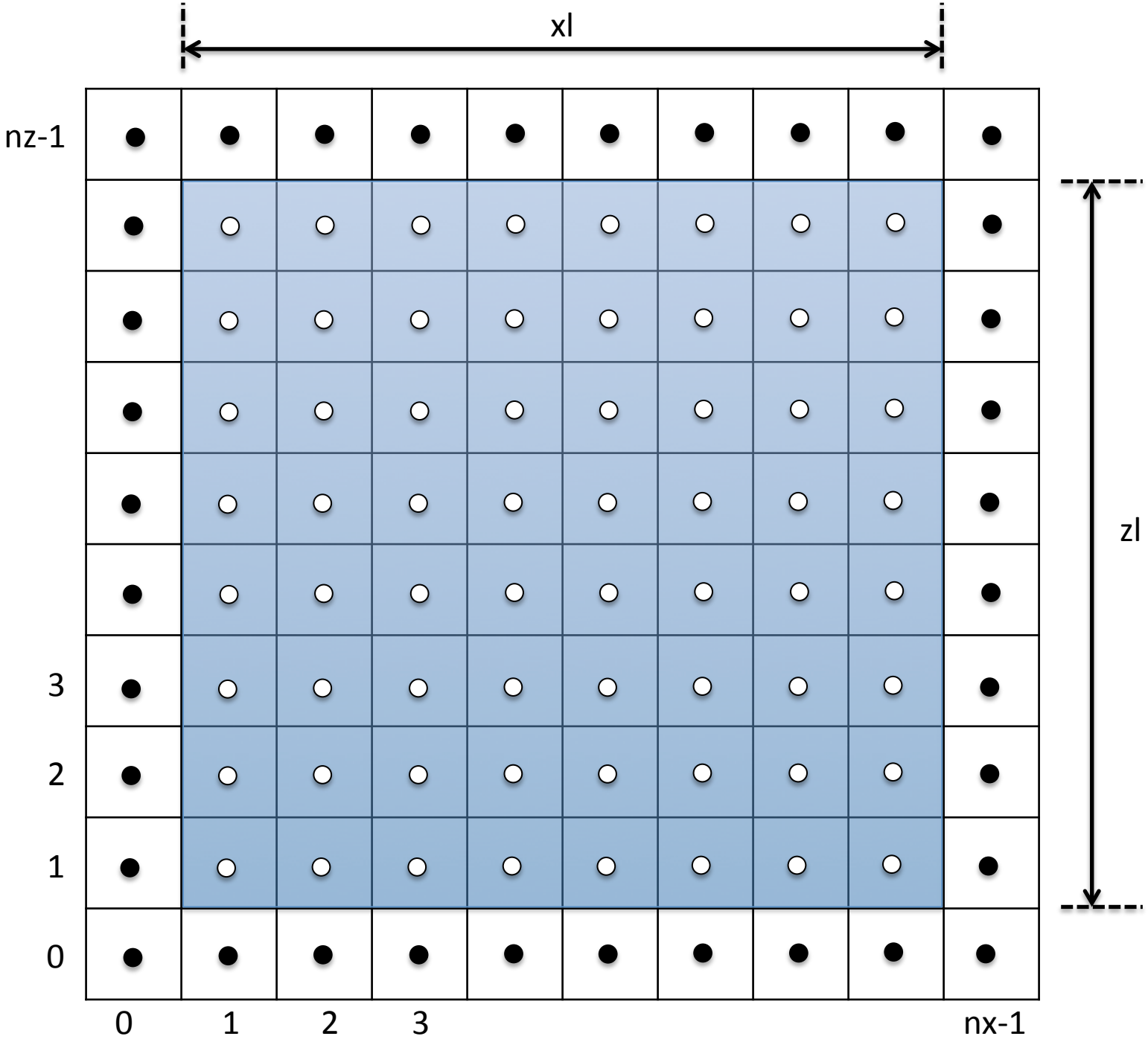
LES model: Smagorinsky (1963) – adapted to LBM in the mid-90s – used in MRT-LBM by Krafczyk et al. (2003) – BGK model implemented by Menon & Soo (2004).

Code written in C++ (developed on Mac OS X)

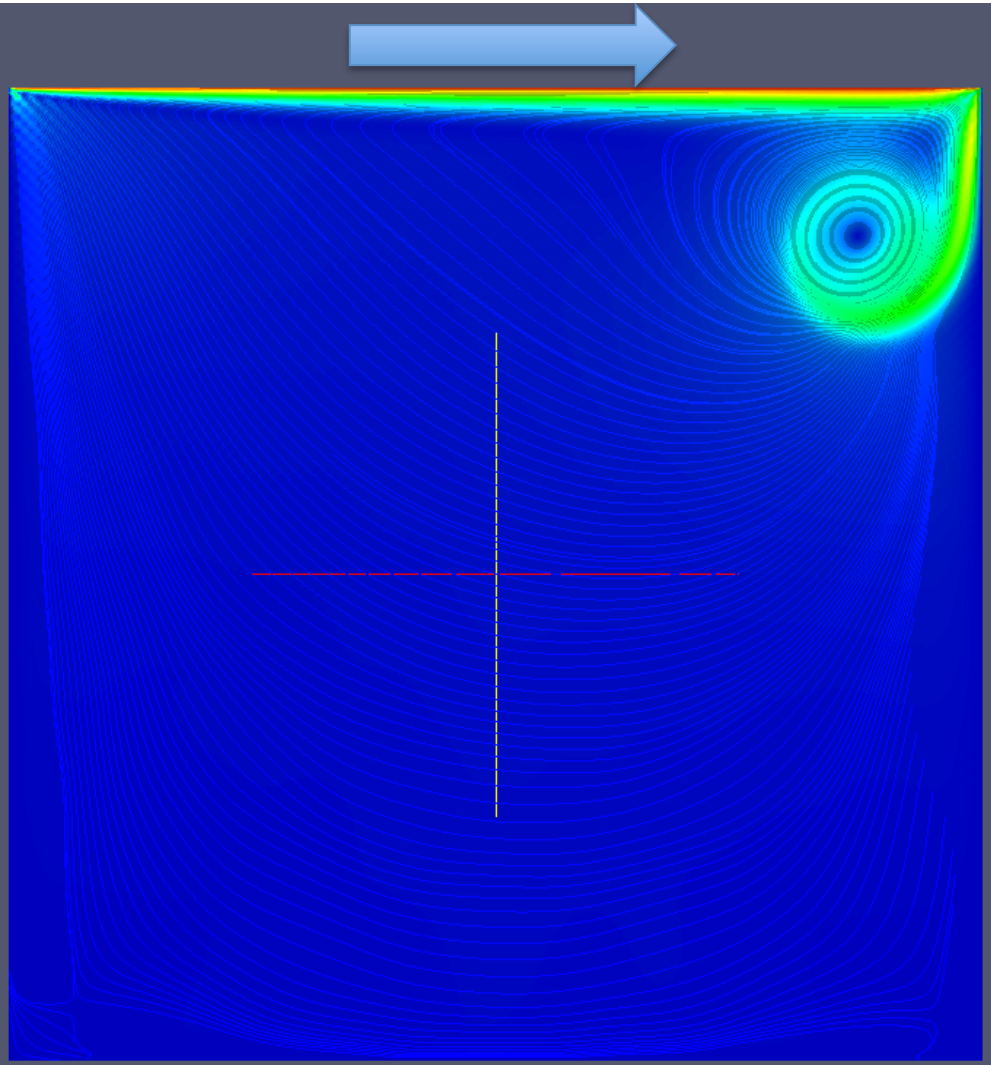
Post-processing using ParaView

Grid size used: 257×257

Maximum Reynolds number simulated: 1,000,000


xl
nz-1
zl
3
2
1
0
0
1
2
3
nx-1

SEEFD 3.30

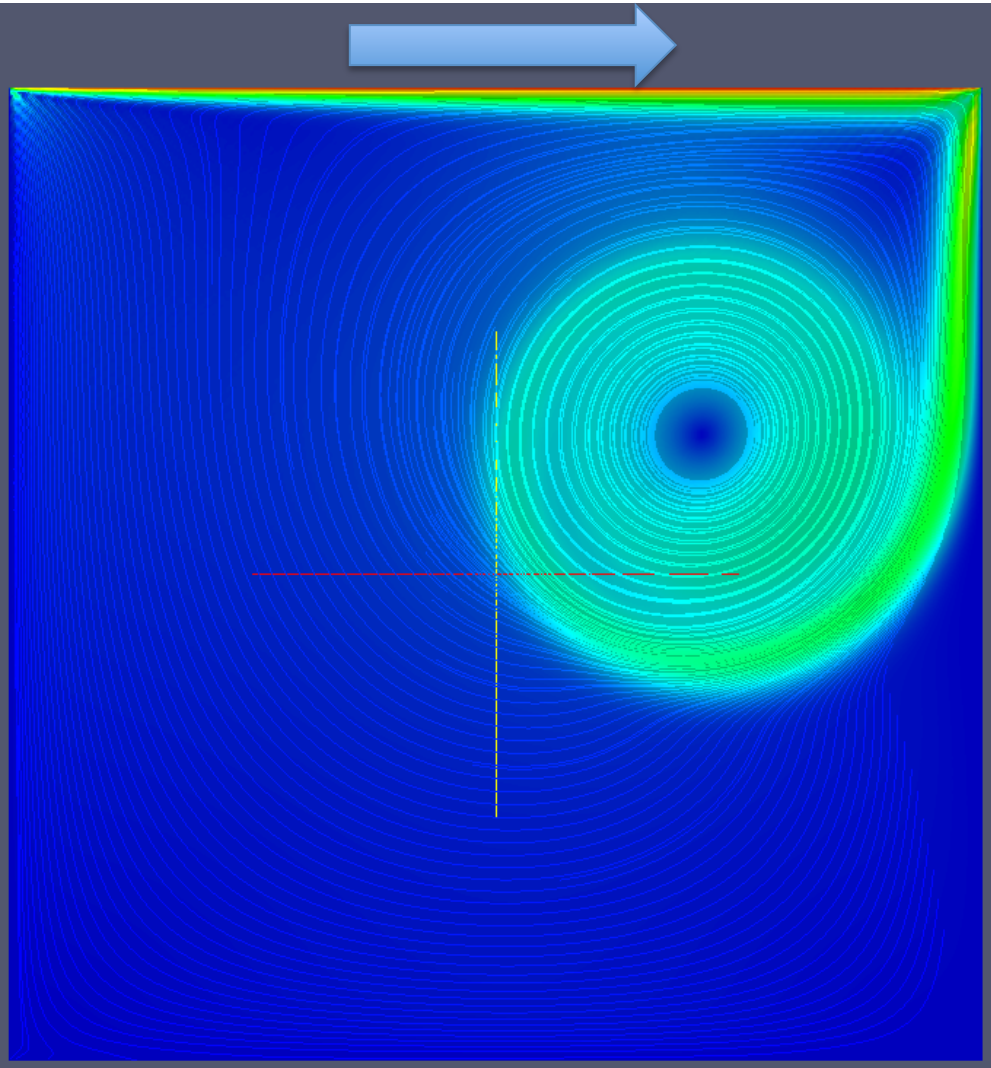


Re = 7,500

257 × 257 grid

t = 10,000

SEEFD 3.30

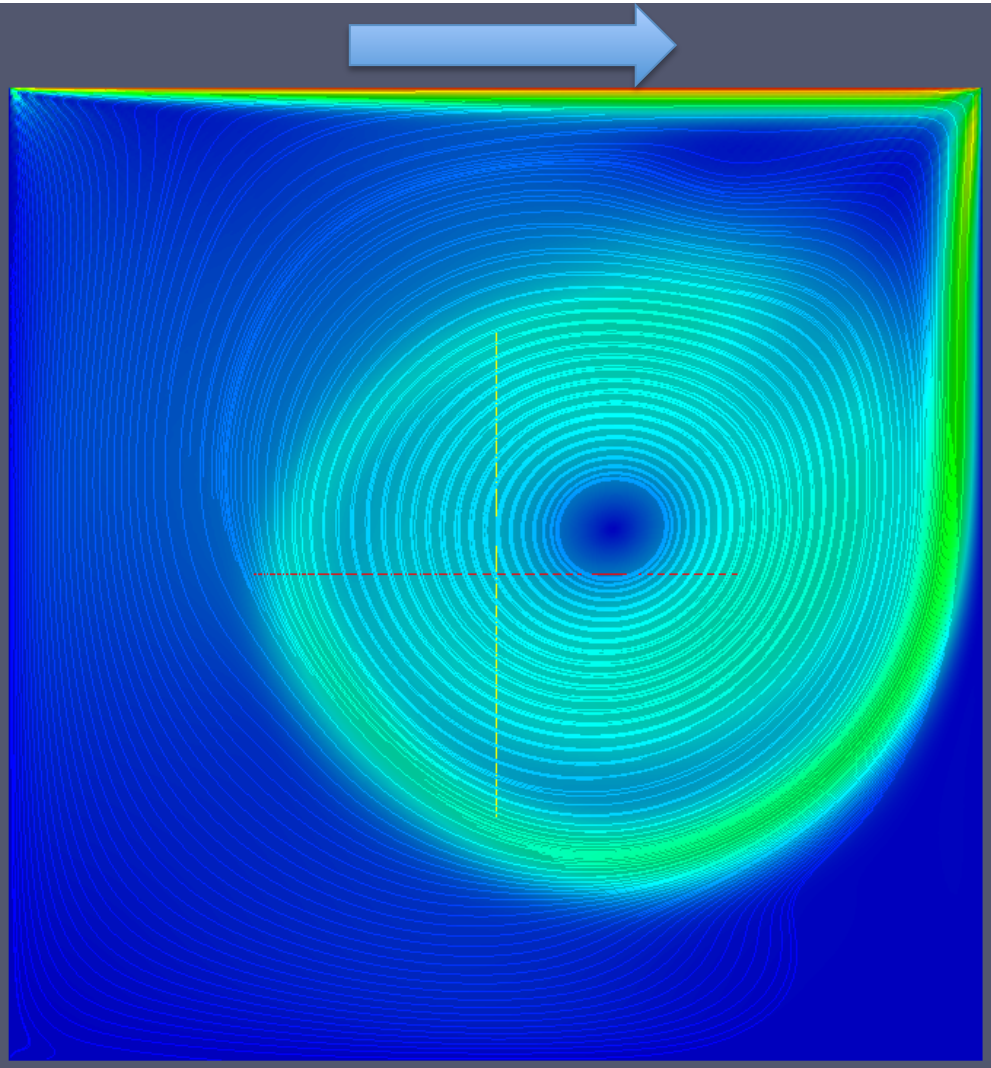


Re = 7,500

257 × 257 grid

t = 40,000

SEEFD 3.30

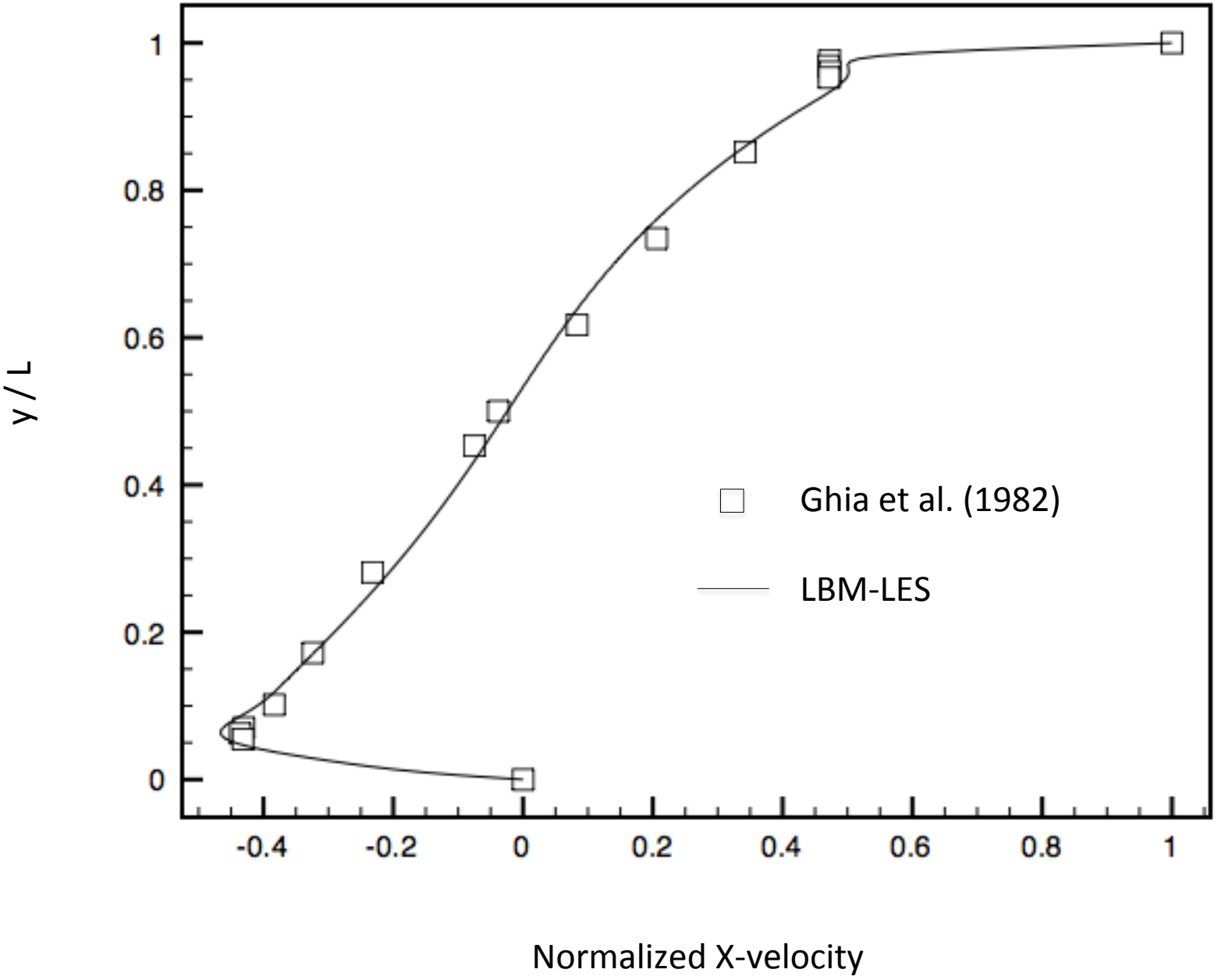


Re = 7,500

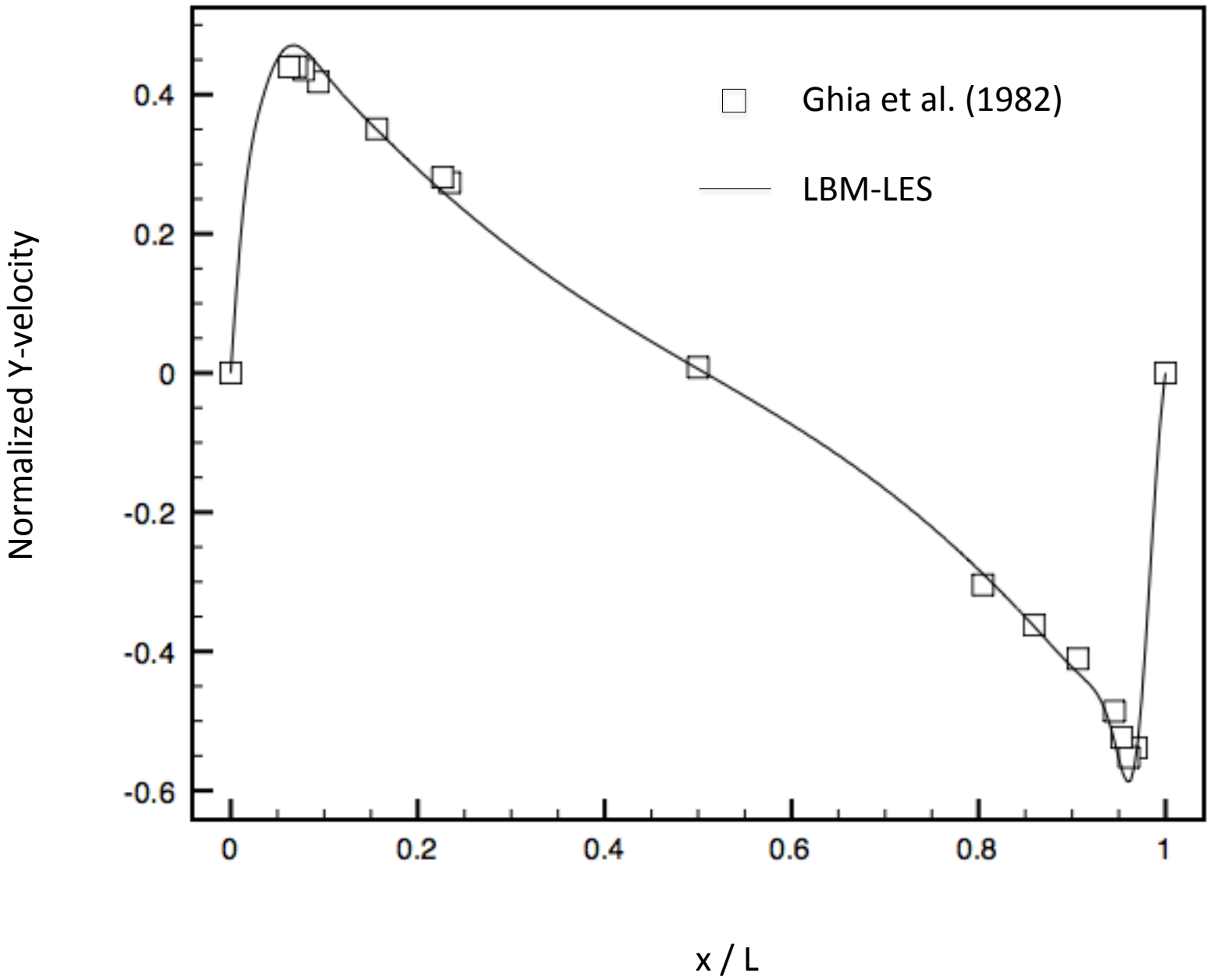
257 × 257 grid

t = 70,000

Re = 7,500


y / L
1
0.8
0.6
0.4
0.2
0
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Ghia et al. (1982)
LBM-LES
Normalized X-velocity

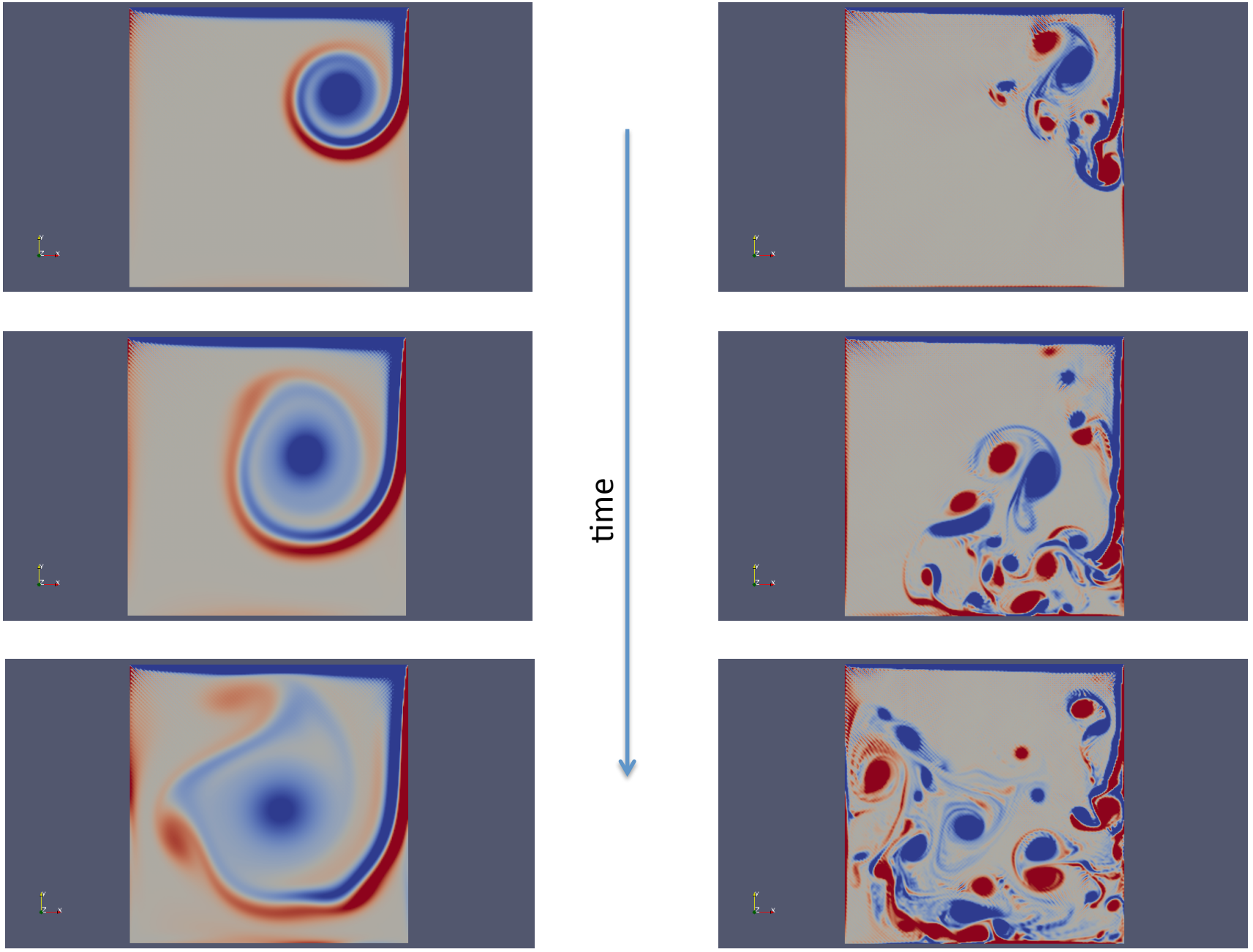
Re = 7,500


Ghia et al. (1982)
LBM-LES
Normalized Y-velocity
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.2
0.4
0.6
0.8
1
x / L

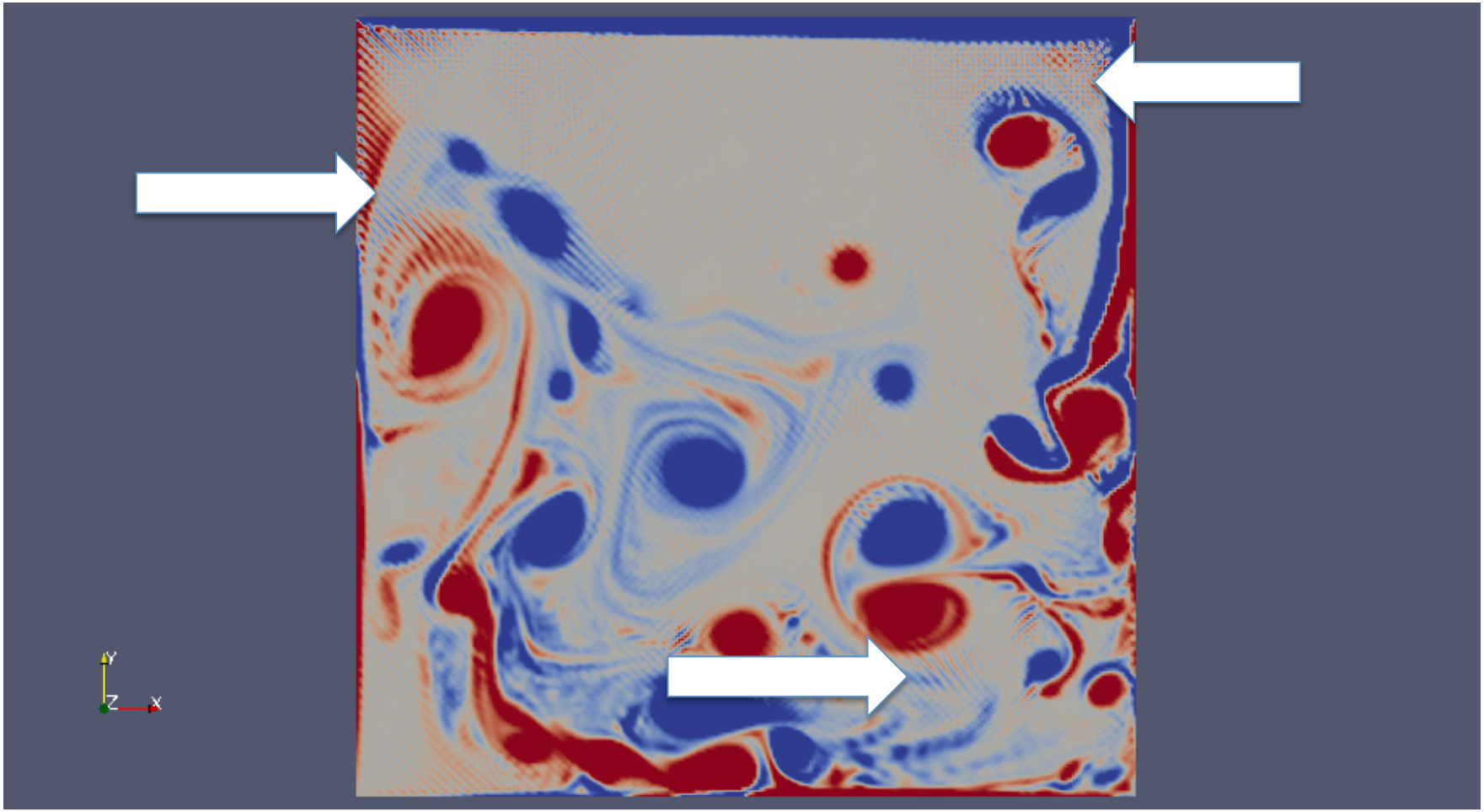
Re = 7,500

VORTICITY EVOLUTION

Re = 1,000,000



Zooming in on the solution for Re = 1,000,000



Note the oscillations in the solution at various places. This is possibly because of the BGK collision term employed. A movie of this simulation can be seen at the following link:

www.youtube.com/watch?v=xfGzGNCxzlk

CONCLUSIONS & FUTURE WORK

The simple Smagorinsky model leads to a robust and stable simulation for Re as high as 1,000,000.

However, there are drawbacks because of using the single-relaxation time LBM, related to oscillations in the fields.

One way to improve the quality of the solution is to use multiple relaxation time (MRT) LBM.

Future work involves extension of the code to 3D, adding in the MRT scheme and making the code parallel.

From the software engineering point of view, there could be several improvements to the code structure, especially since it is written using C++. At the minimum, the code needs to be further modularized and optimized for performance.

REFERENCES

1. J. Smagorinsky, *Monthly Weather Review* **91**, 99 (1963).

2. M. Krafczyk, J. Tölke and L. –S. Luo, *International Journal of Modern Physics B* **17**, 33 (2003).

3. S. Menon and J. –H Soo, *Journal of Turbulence* **5**, 32 (2004).

4. U. Ghia, K. N. Ghia and C. T. Shin, *Journal of Computational Physics* **48**, 387 (1982).