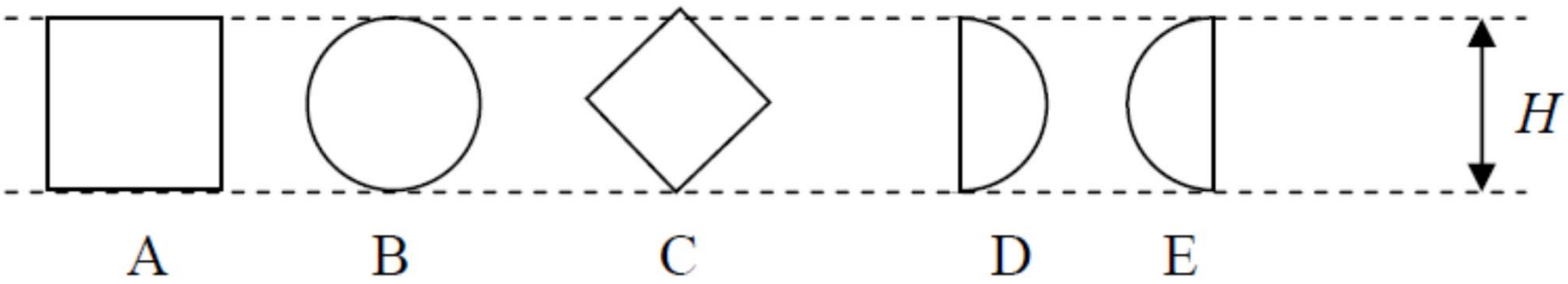
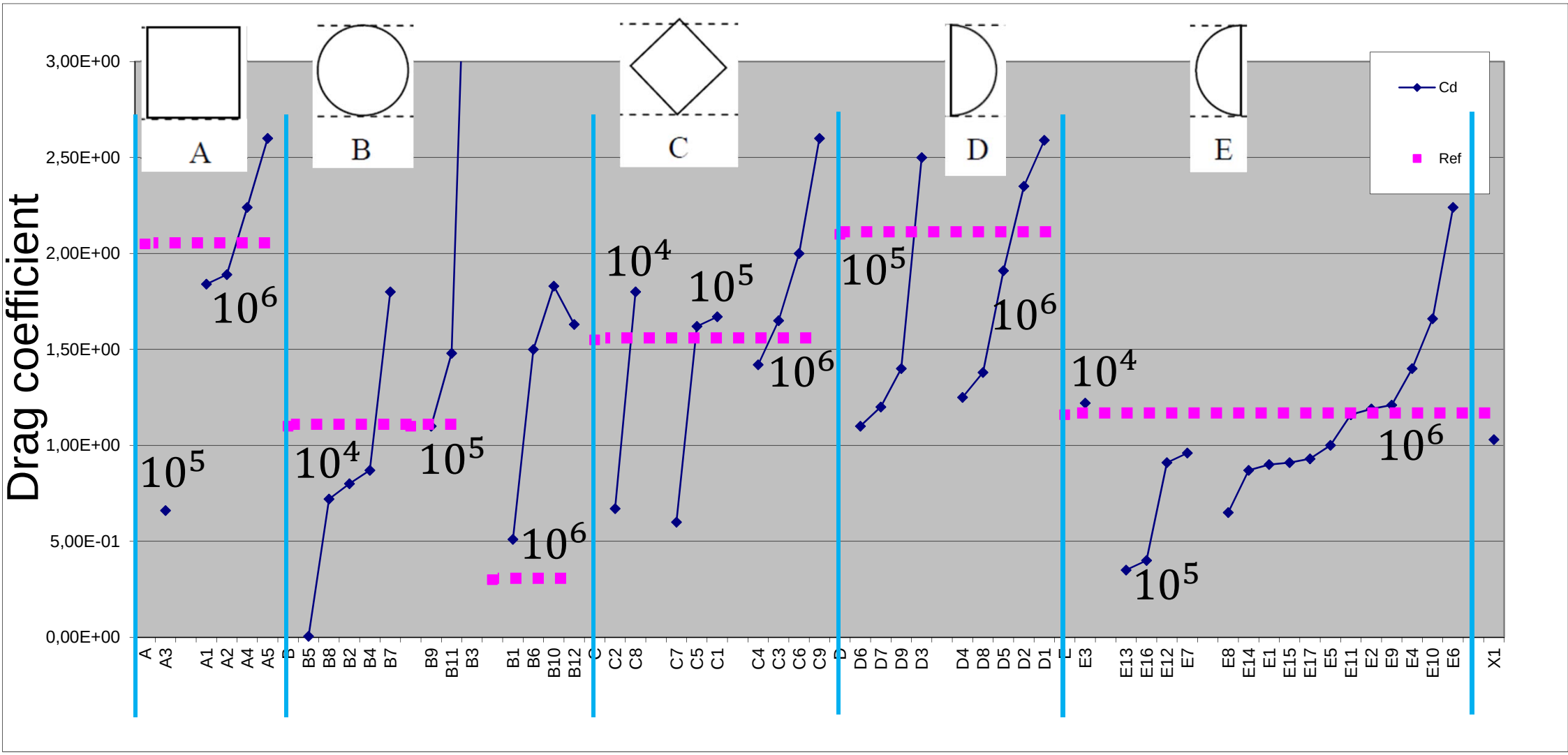
Individual task

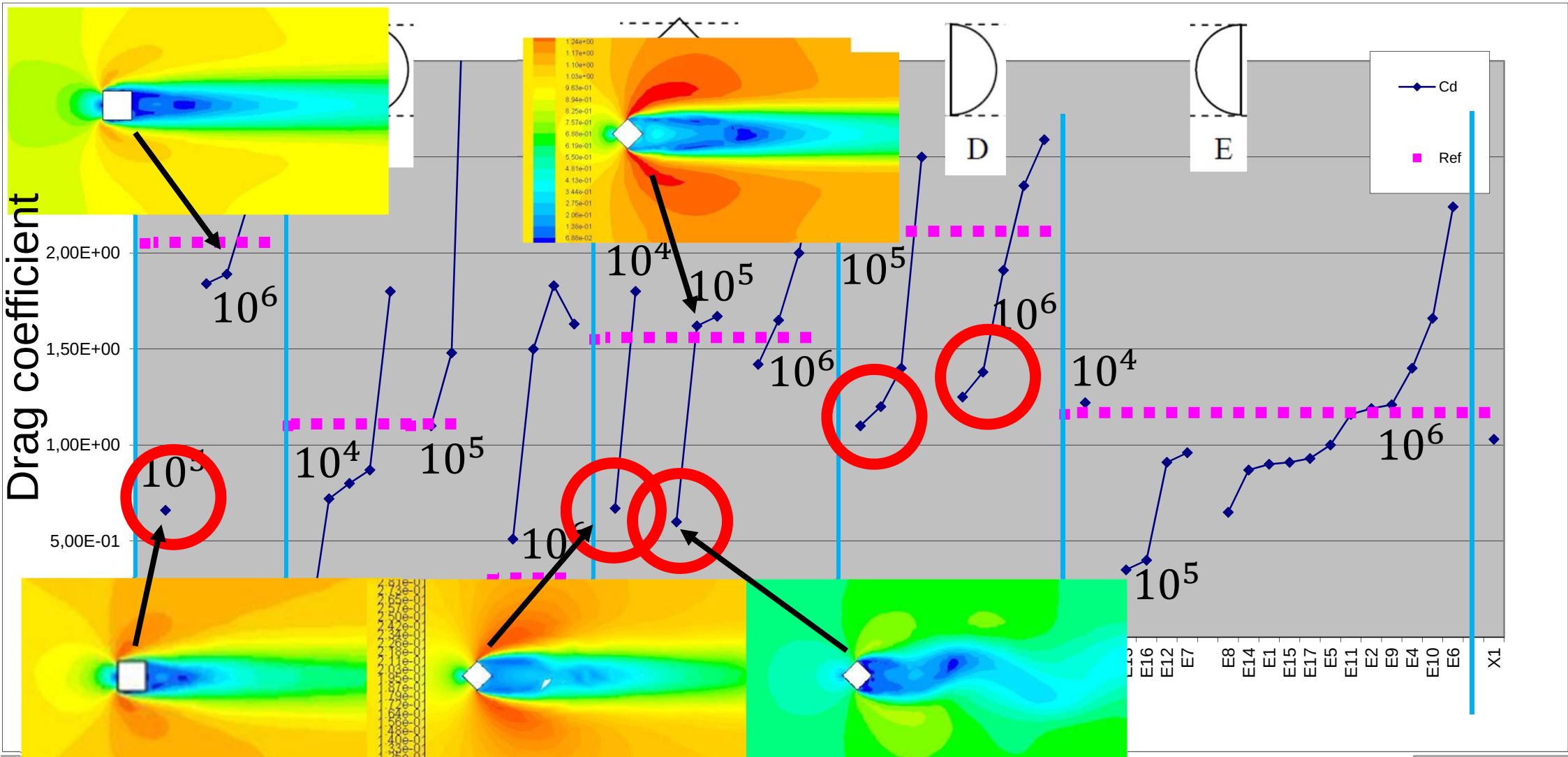
- **Feedback**



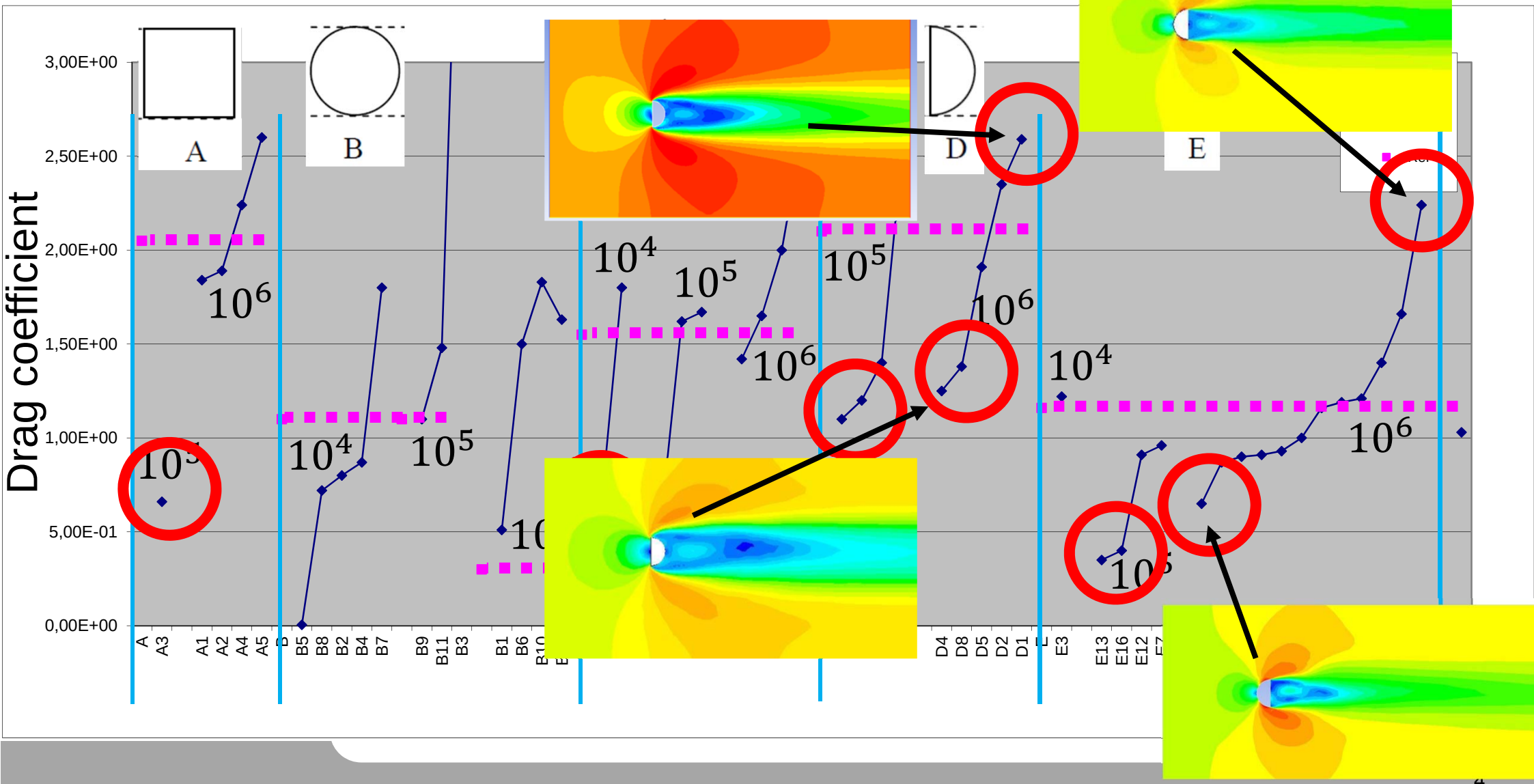
What can we learn?



Scaling?


Drag coefficient
2,00E+00
1,50E+00
1,00E+00
5,00E-01
D
E
Cd
Ref
10^6
10^4
10^5
10^4
10^5
10^6
10^6
10^4
10^6
10^5
E16
E12
E7
E8
E14
E1
E15
E17
E5
E11
E2
E9
E4
E10
E6
X1

Scaling?


Drag coefficient
3,00E+00
2,50E+00
2,00E+00
1,50E+00
1,00E+00
5,00E-01
0,00E+00
A
B
D
E
10^4
10^5
10^6

What is the question?

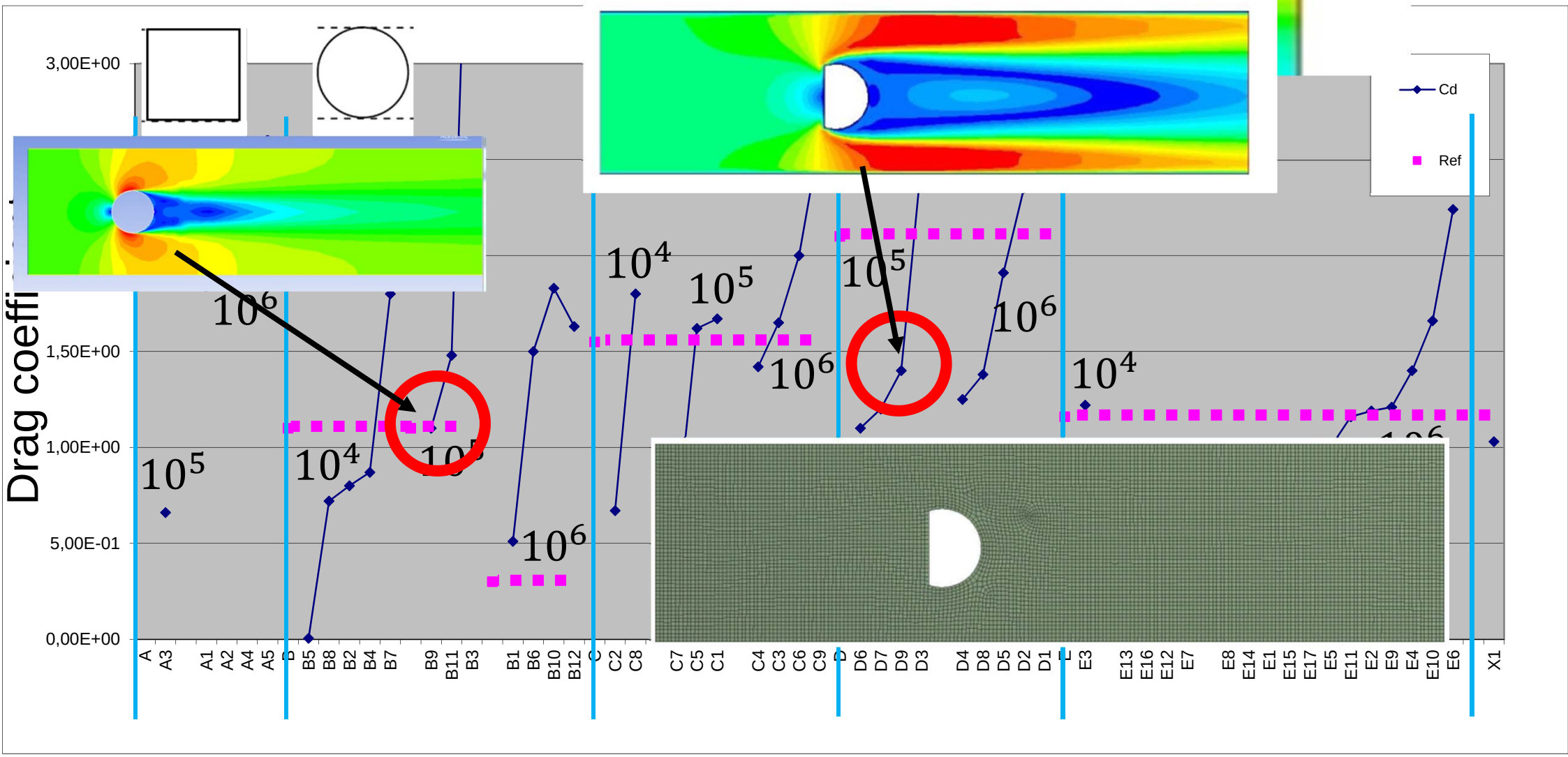
- Drag coefficient

$$C_D = \frac{2D}{\rho U^2 H}$$

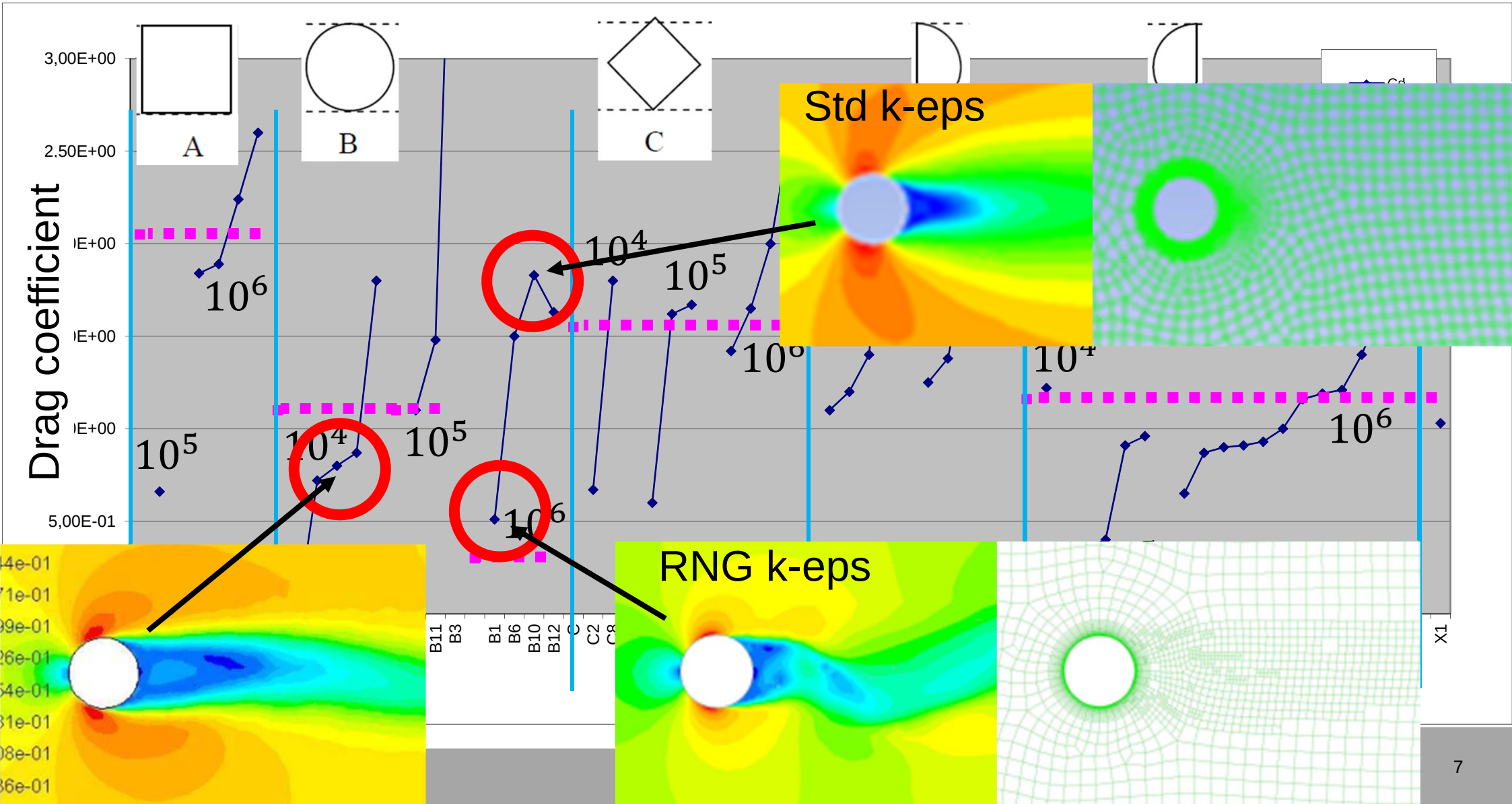
- D=1.2, ρ=1.2, U=2, H=0.5 -> Cd=1.0, not 2.0 or 1.2

```
Forces

                         Forces (n)
Zone                     Pressure                                        Viscous
object                   (1.2247356 -0.056028187 0)                      (-0.0087259216 4.0672516e-05
------------------------ ----------------------------------------------- ----------------------------
Net                      (1.2247356 -0.056028187 0)                      (-0.0087259216 4.0672516e-05

Forces - Direction Vector (1 0 0)
                         Forces (n)                                      Coefficients
Zone                     Pressure        Viscous         Total           Pressure        Viscous
object                   1.2247356       -0.0087259216   1.2160097       1.9995684       -0.01424640
------------------------ --------------- --------------- --------------- --------------- -----------
Net                      1.2247356       -0.0087259216   1.2160097       1.9995684       -0.01424640
```

Setup

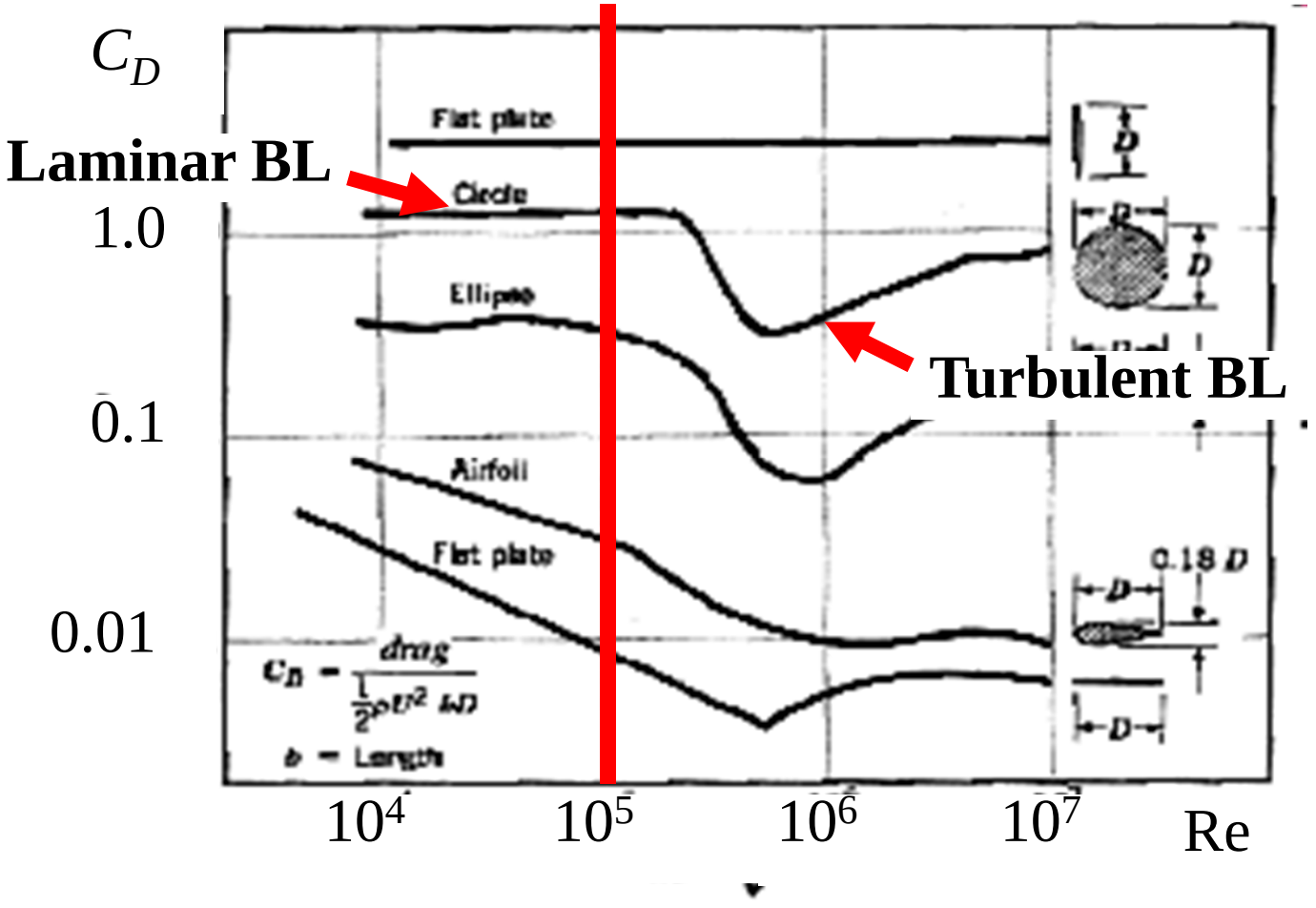

3,00E+00
1,50E+00
1,00E+00
5,00E-01
0,00E+00
Drag coeffi
Cd
Ref
10^5
10^4
10^6
10^4
10^5
10^6
10^5
10^6
10^4
A A3 A1 A2 A4 A5 B B5 B8 B2 B4 B7 B9 B11 B3 B1 B6 B10 B12 C C2 C8 C7 C5 C1 C4 C3 C6 C9 D D6 D7 D9 D3 D4 D8 D5 D2 D1 E E3 E13 E16 E12 E7 E8 E14 E1 E15 E17 E5 E11 E2 E9 E4 E10 E6 X1

Systematic / modelling error



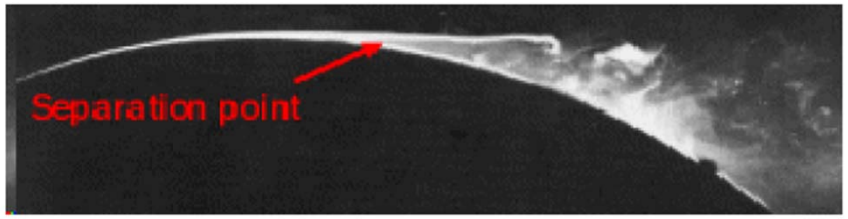
Transition?

- Reynolds number L=1m, U=1m/s, air -> Re~10^5

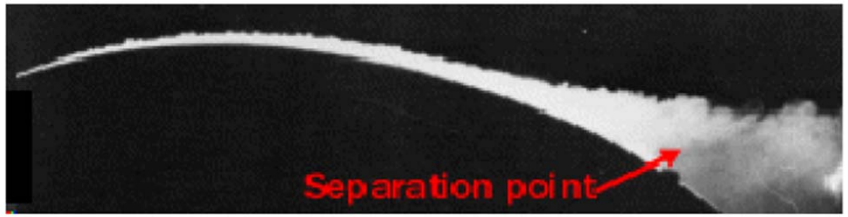


Transition?

- Subcritical $Re \lesssim 200.000$
  - Laminar boundary layer
  - Early separation
- Supercritical $Re \gtrsim 400.000$
  - Turbulent boundary layer
  - Late separation
- RANS model
  - Cannot predict transition
  - Often assumed fully turbulent
  - No difference between $Re = 10^5$ or 10^6
- LES (or DNS)
  - Expensive 3D and time dependent
  - Can predict transition and Re effect

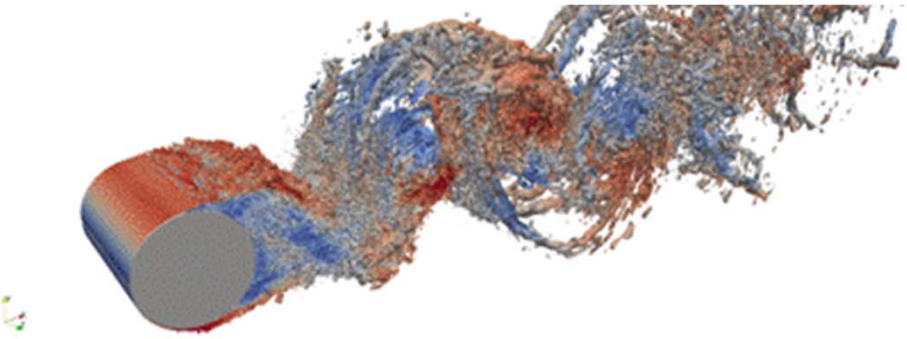


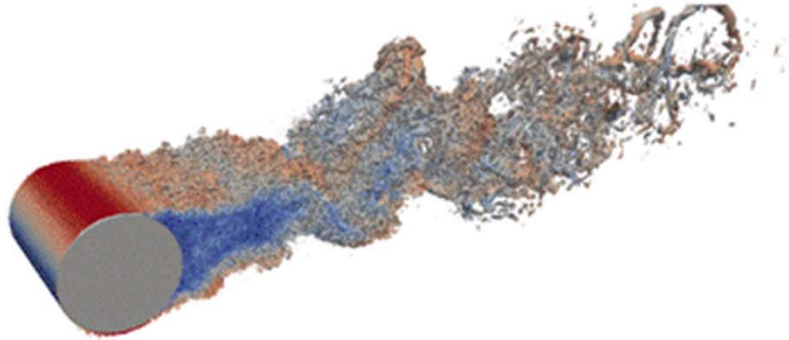
Laminar Separation

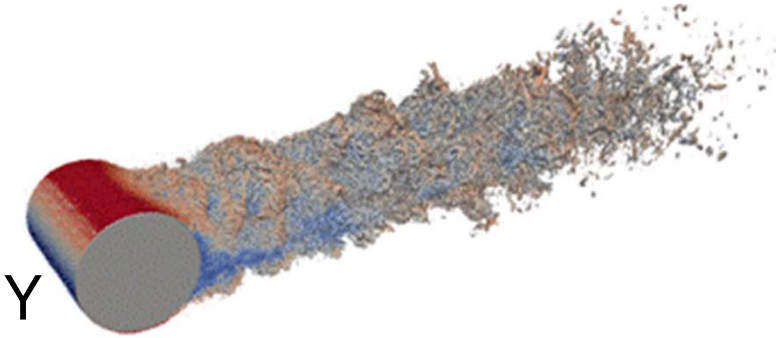


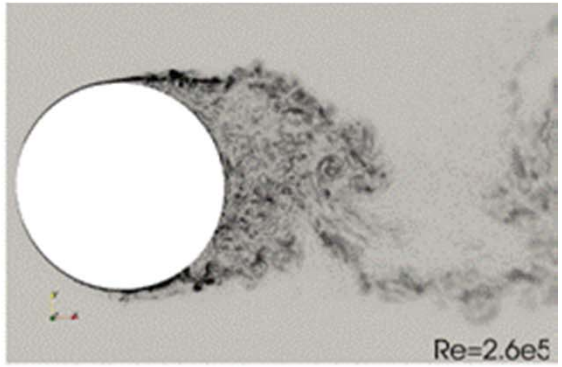
Turbulent Separation

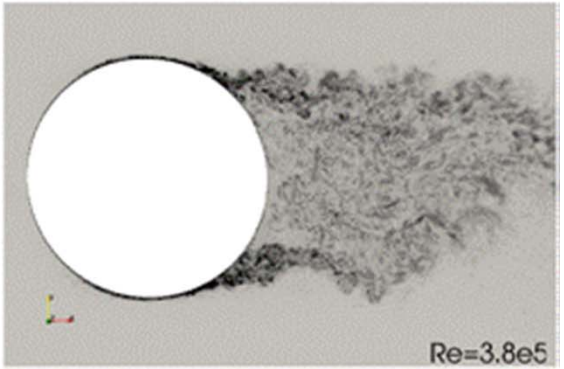
LES – cylinder drag

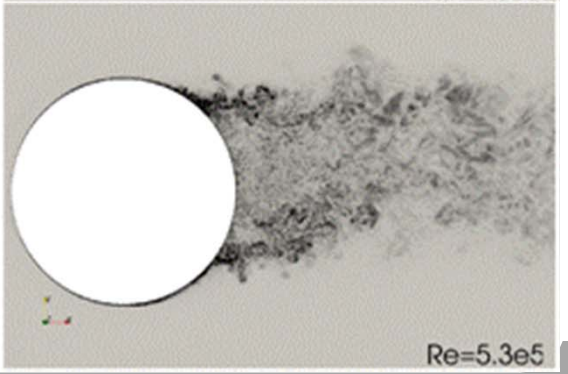












LES at Polytech Univ. Catalonia

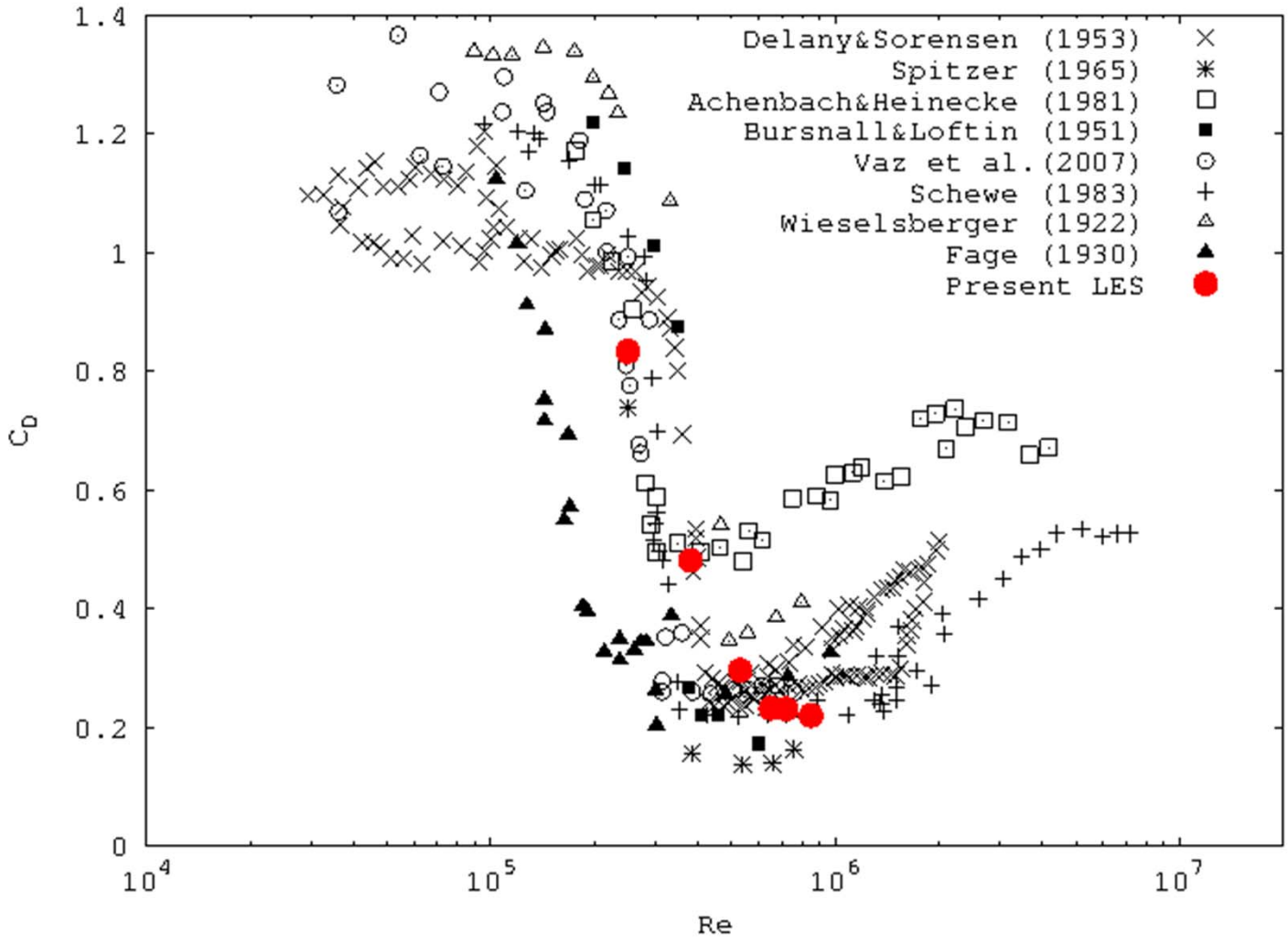
340 M nodes

5000 CPUs

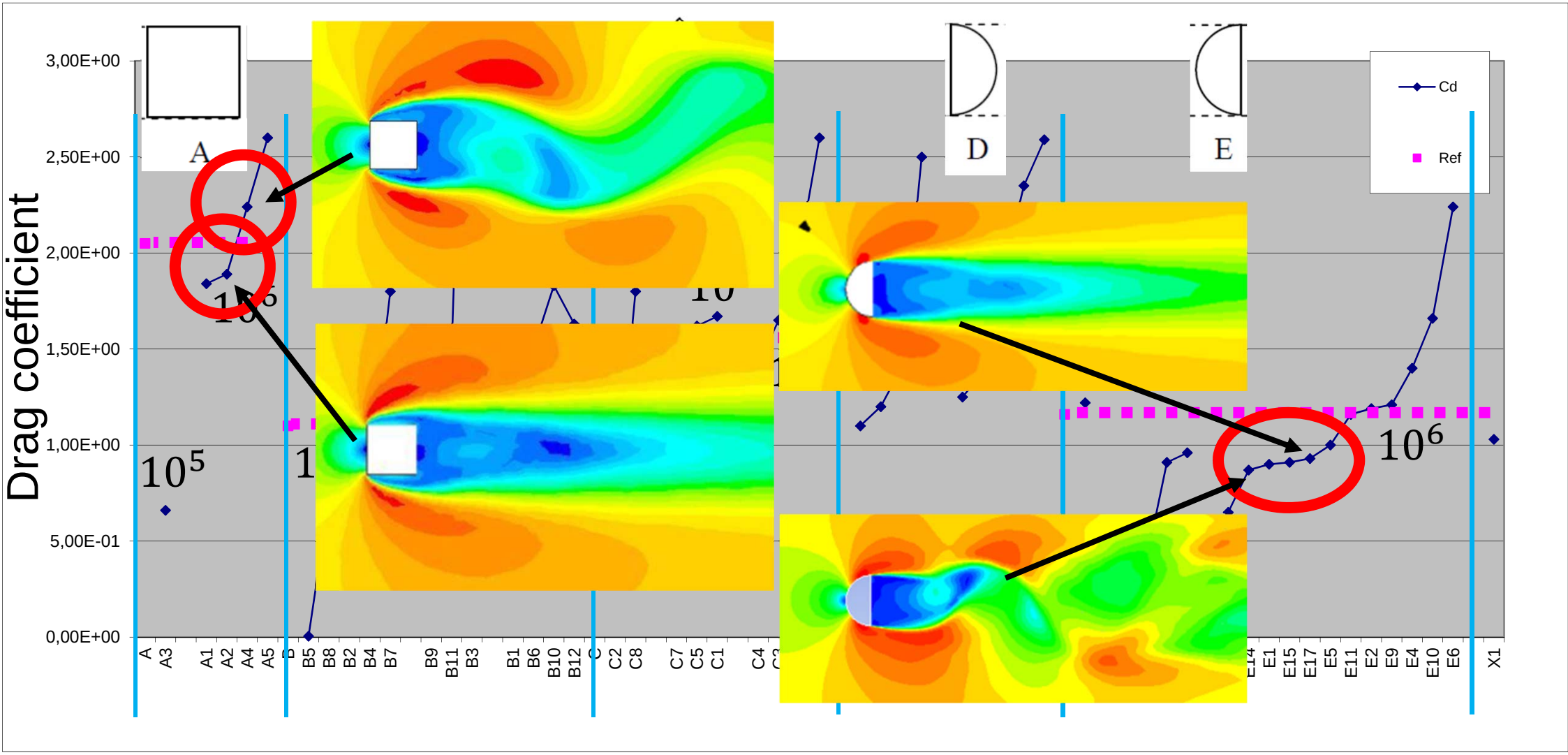
25M CPU h's

3000 CPUs in 1Y

Cylinder drag – LES and exp

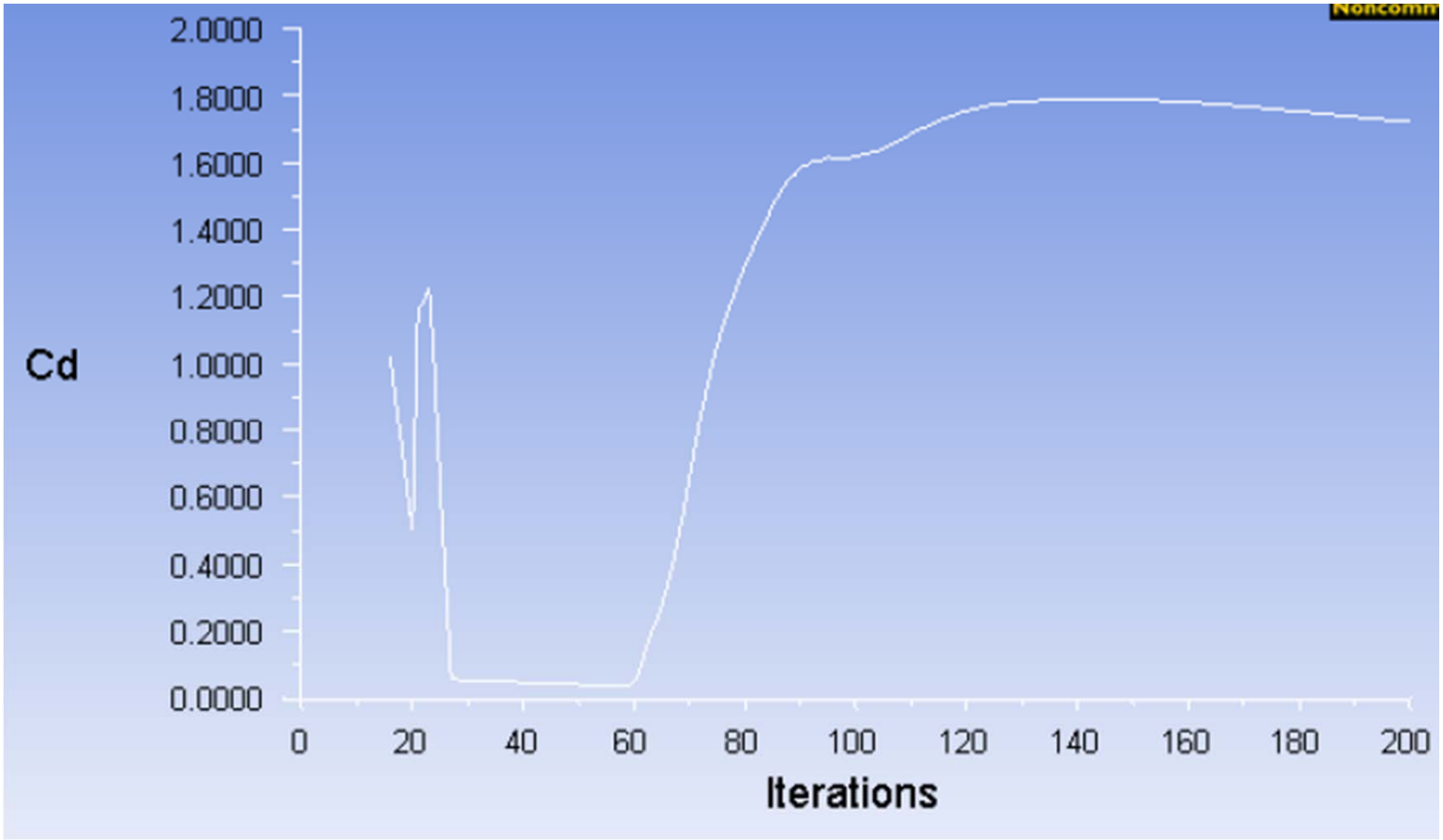


Modelling / resolving?

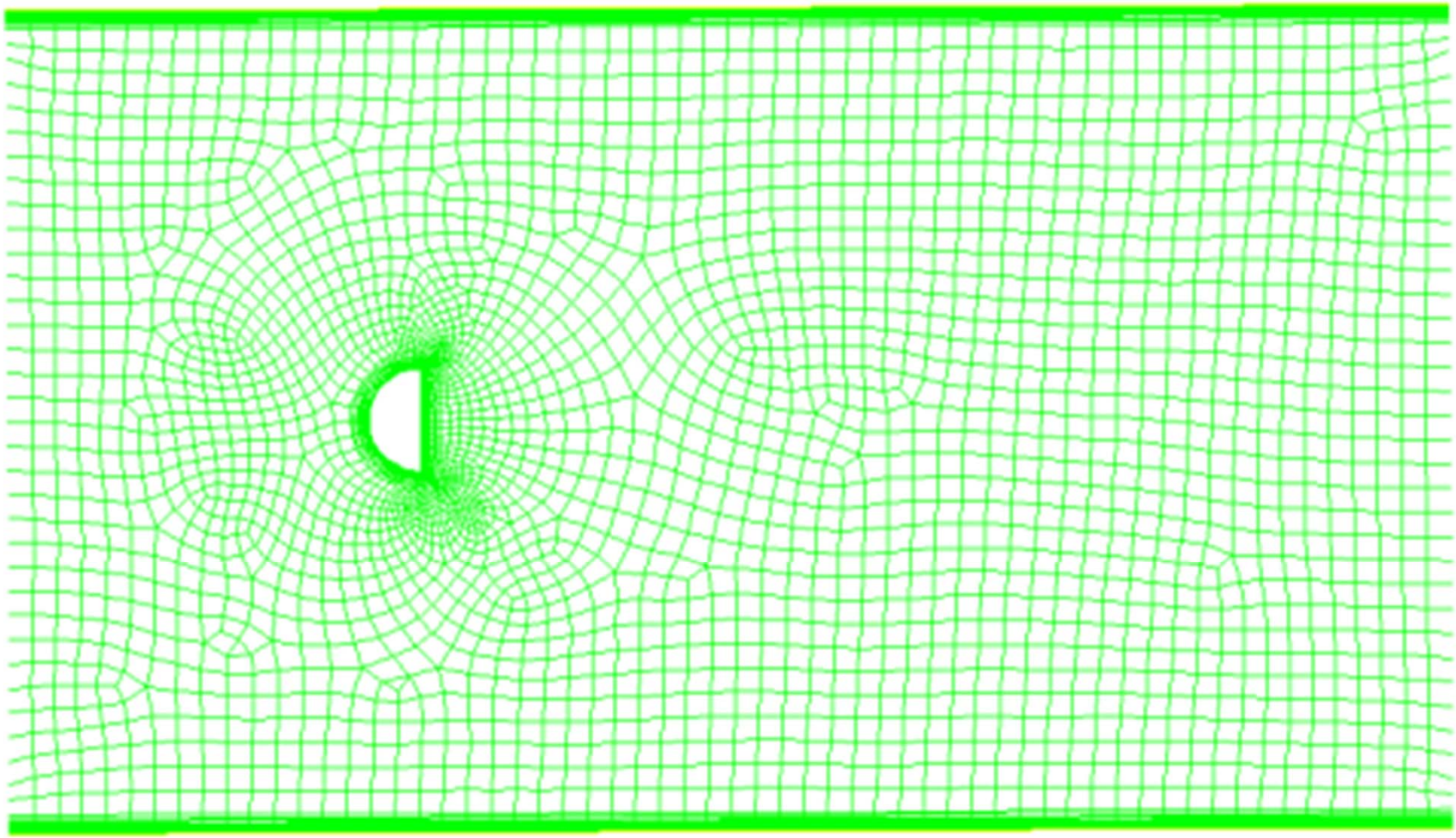


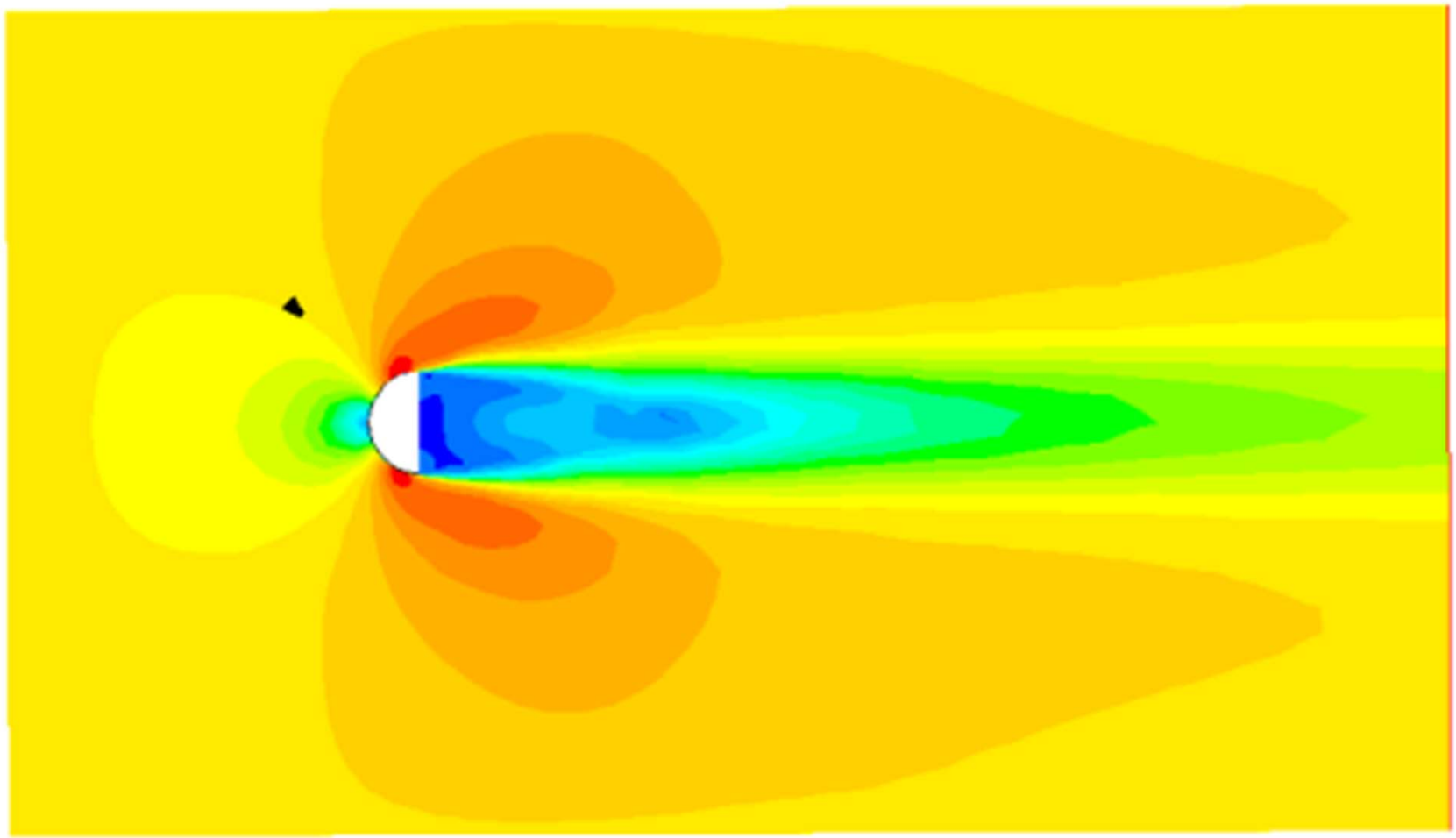
Convergence?

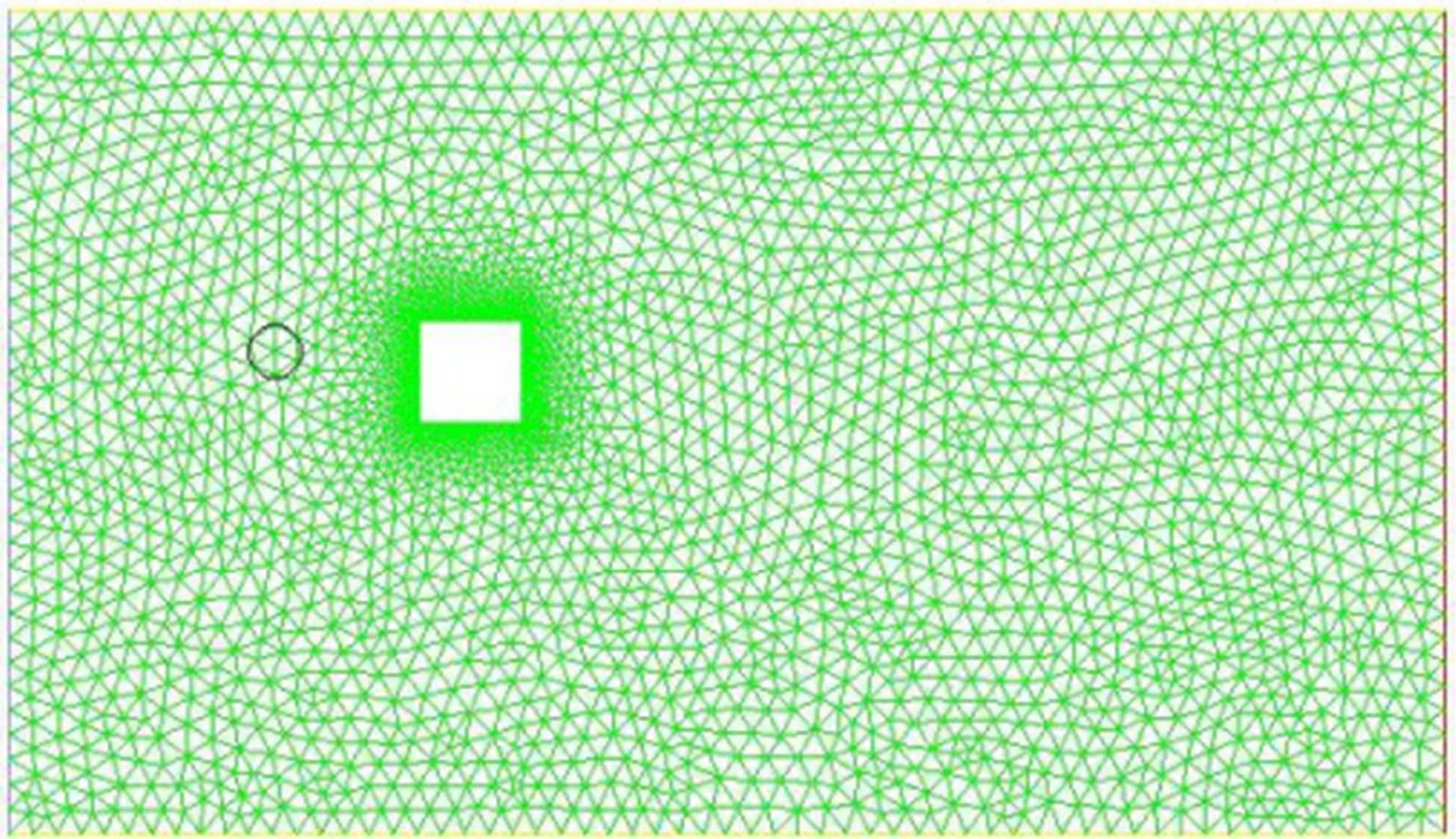
- Quantities of interest should not change with iteration

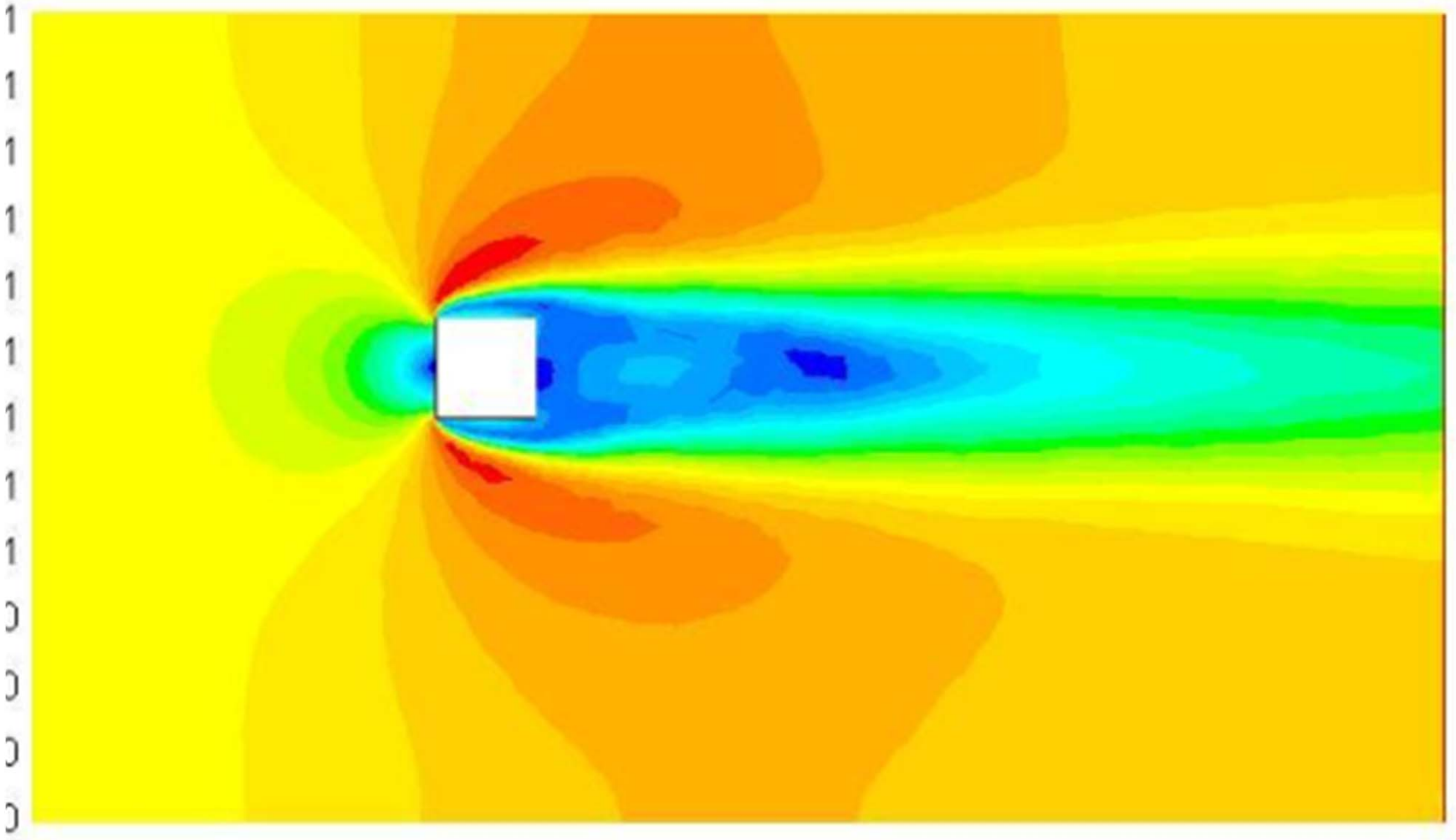


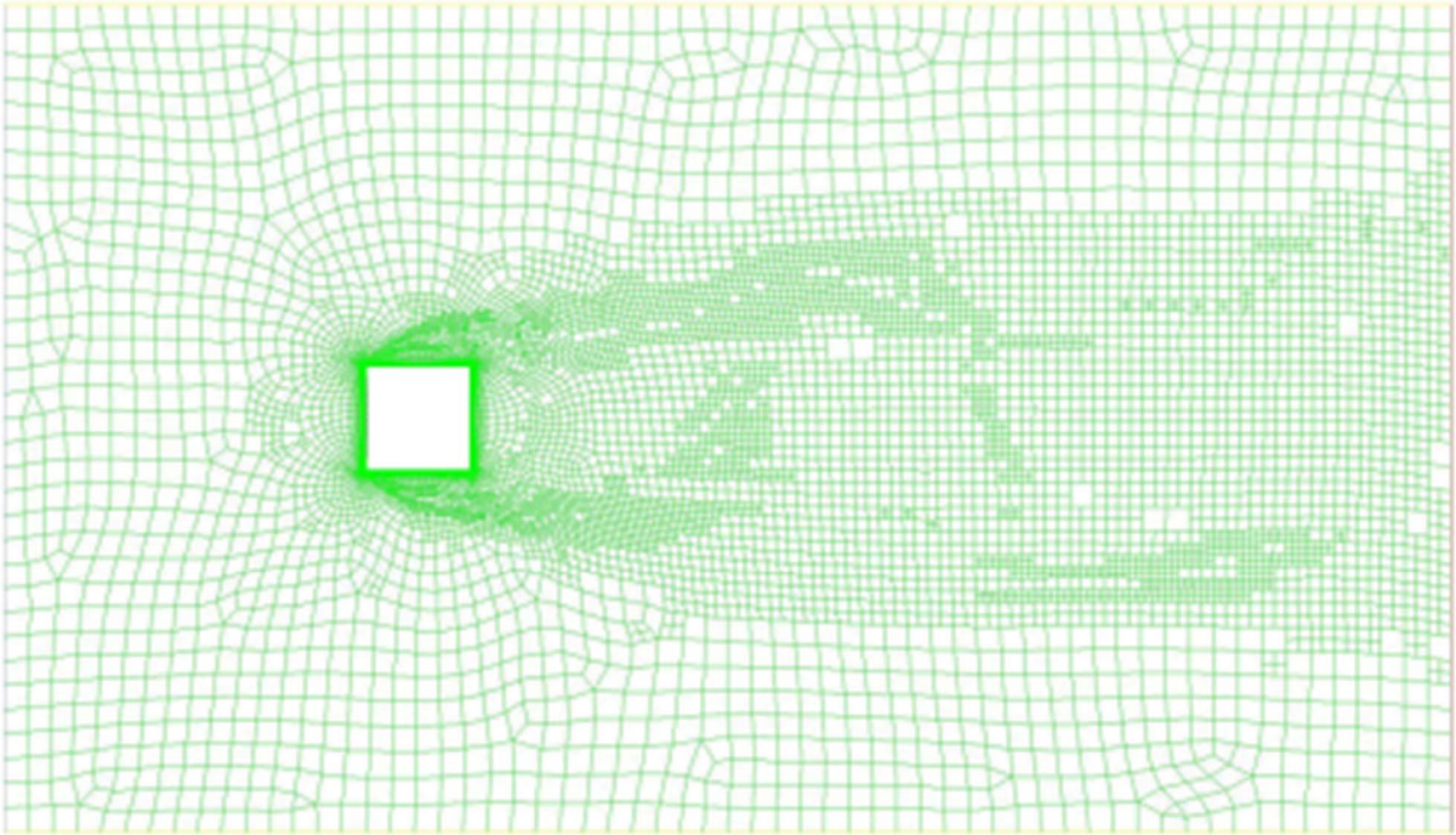
Grids

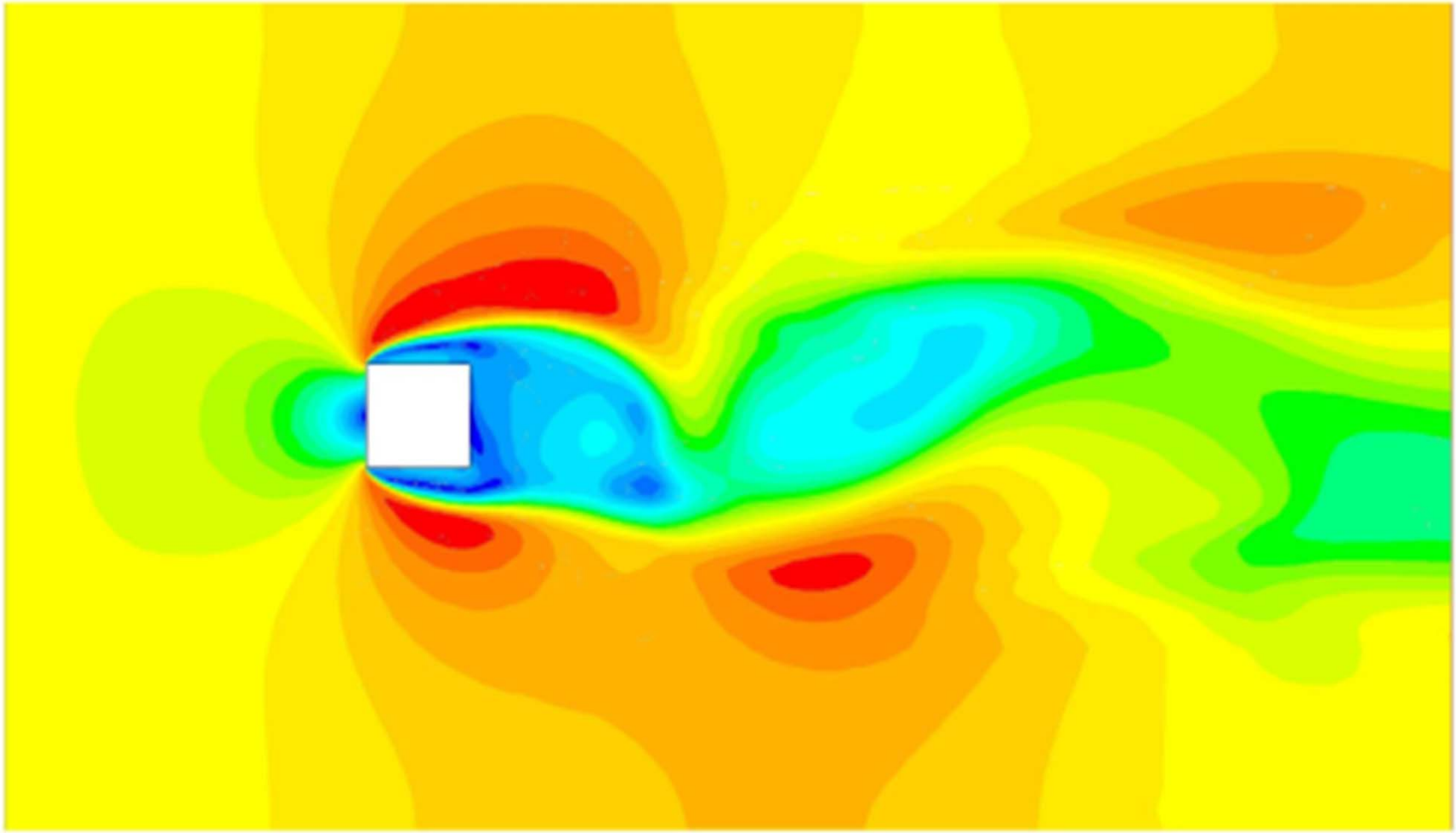


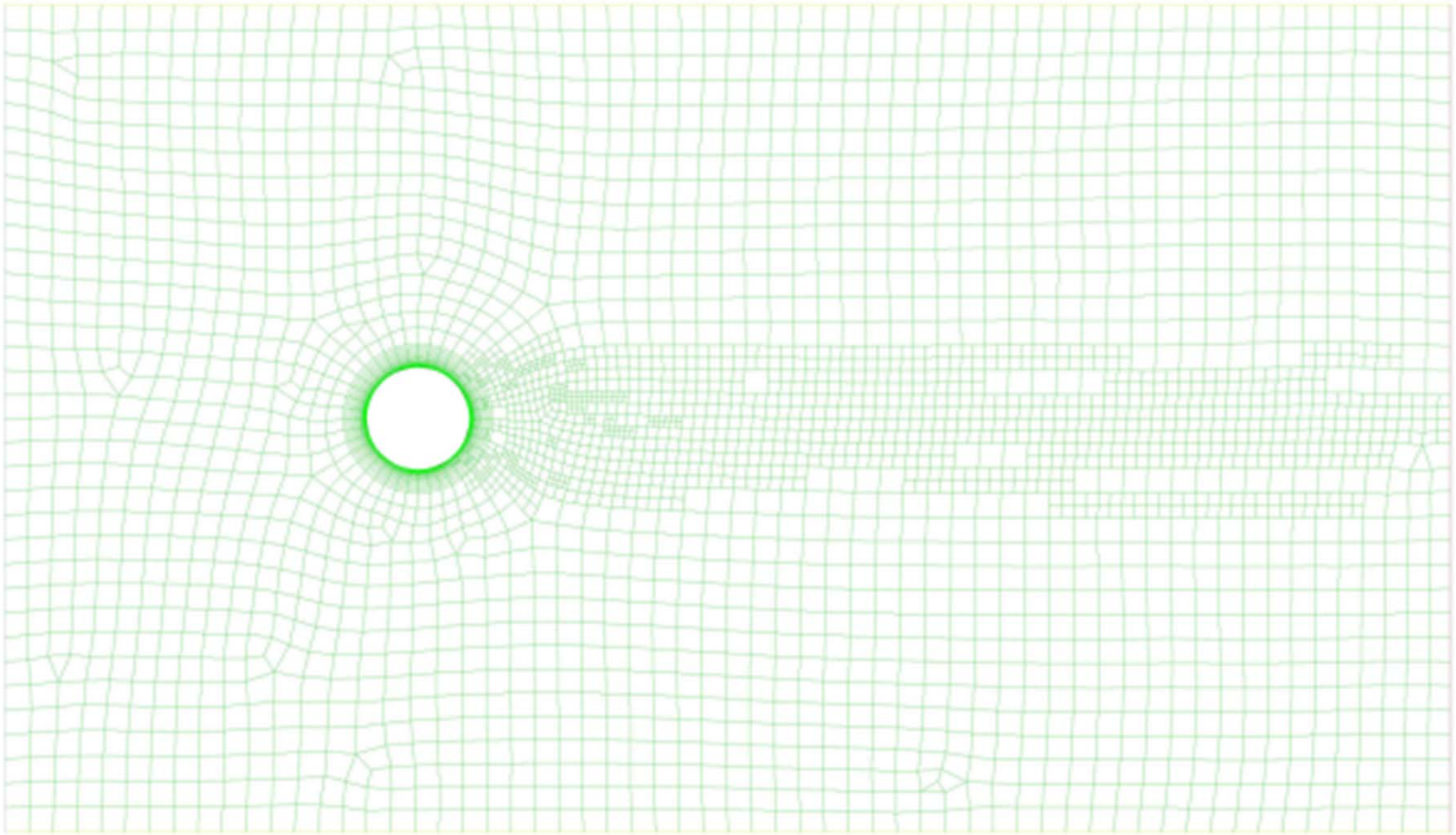


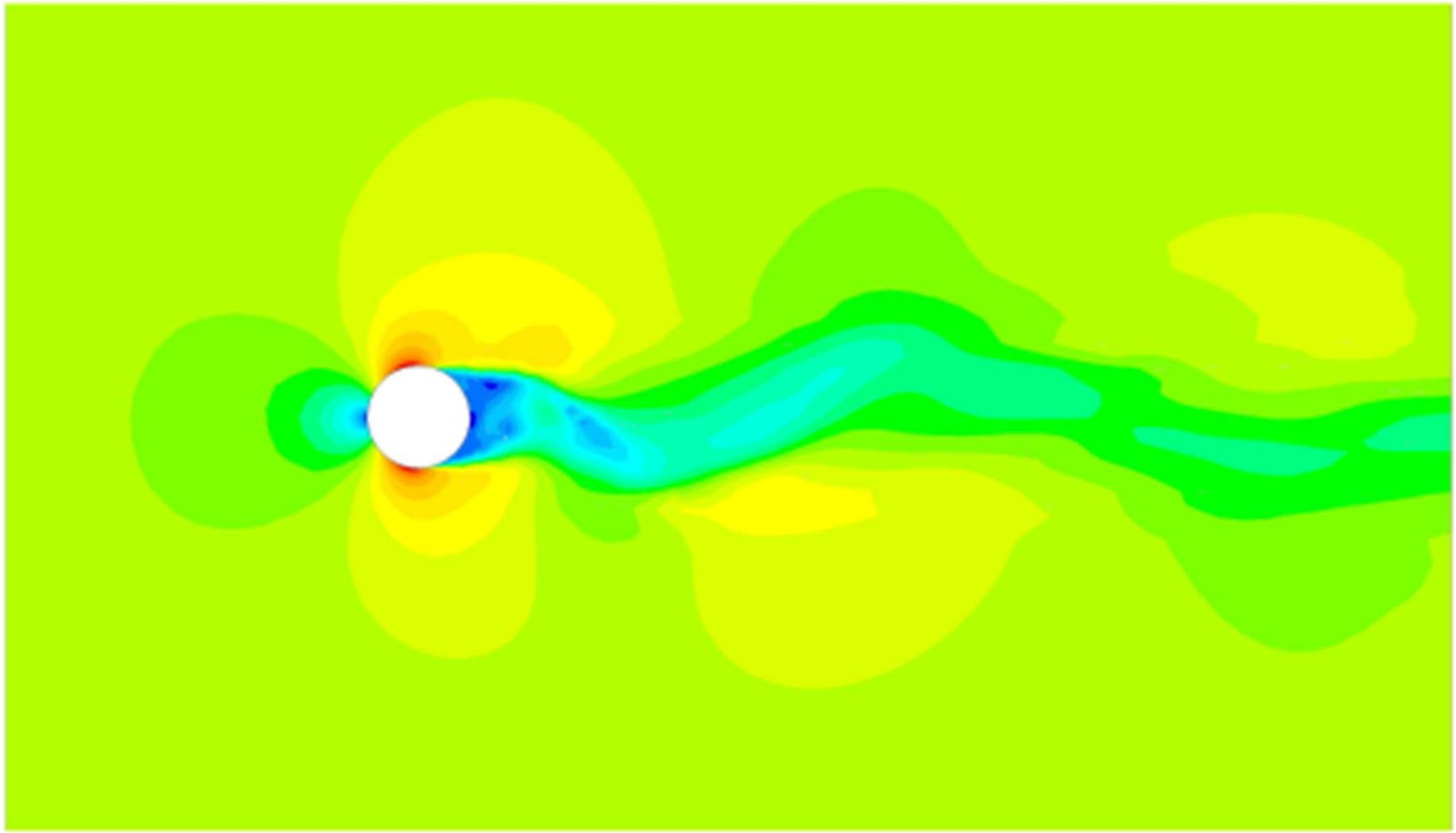


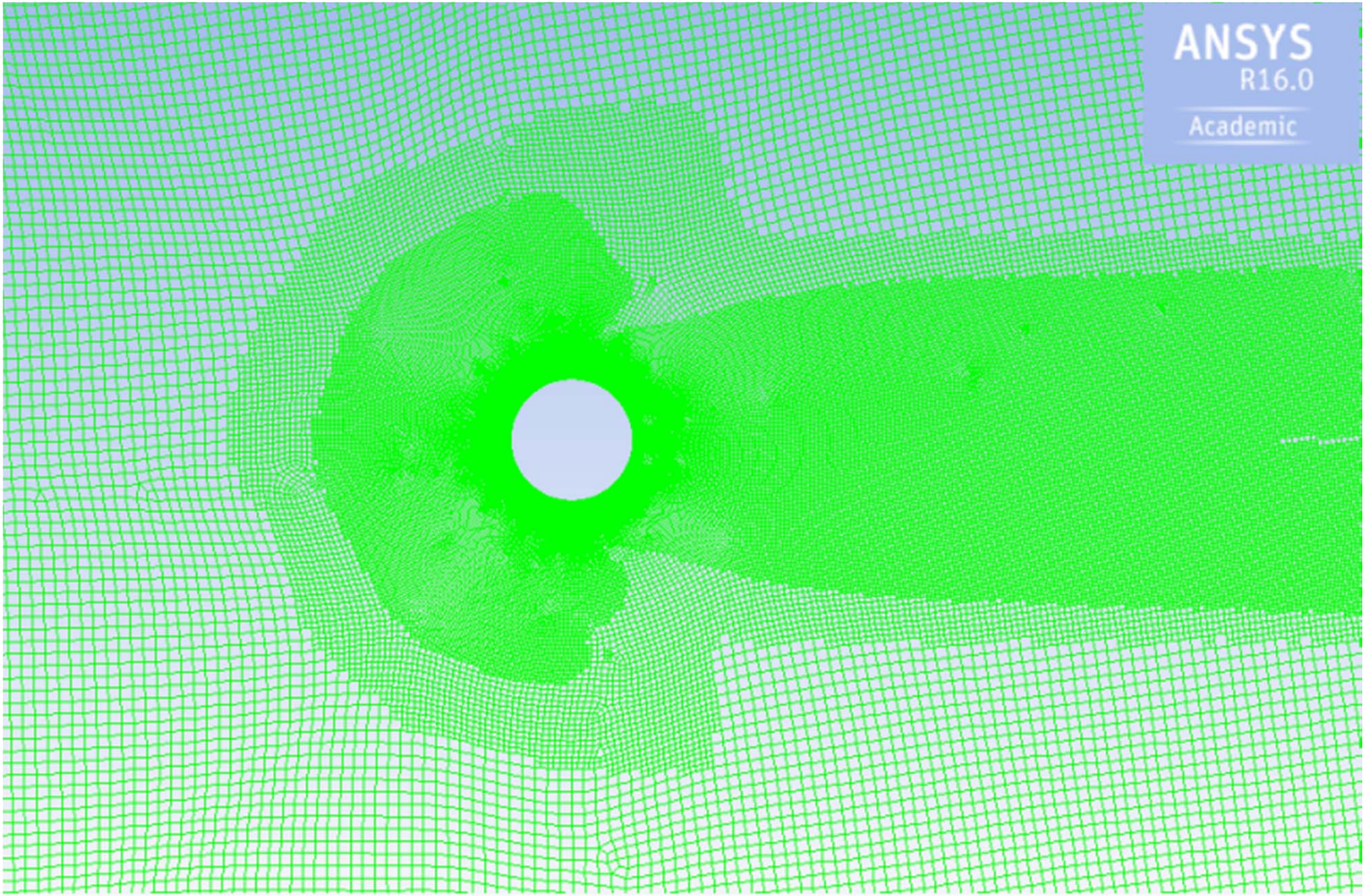


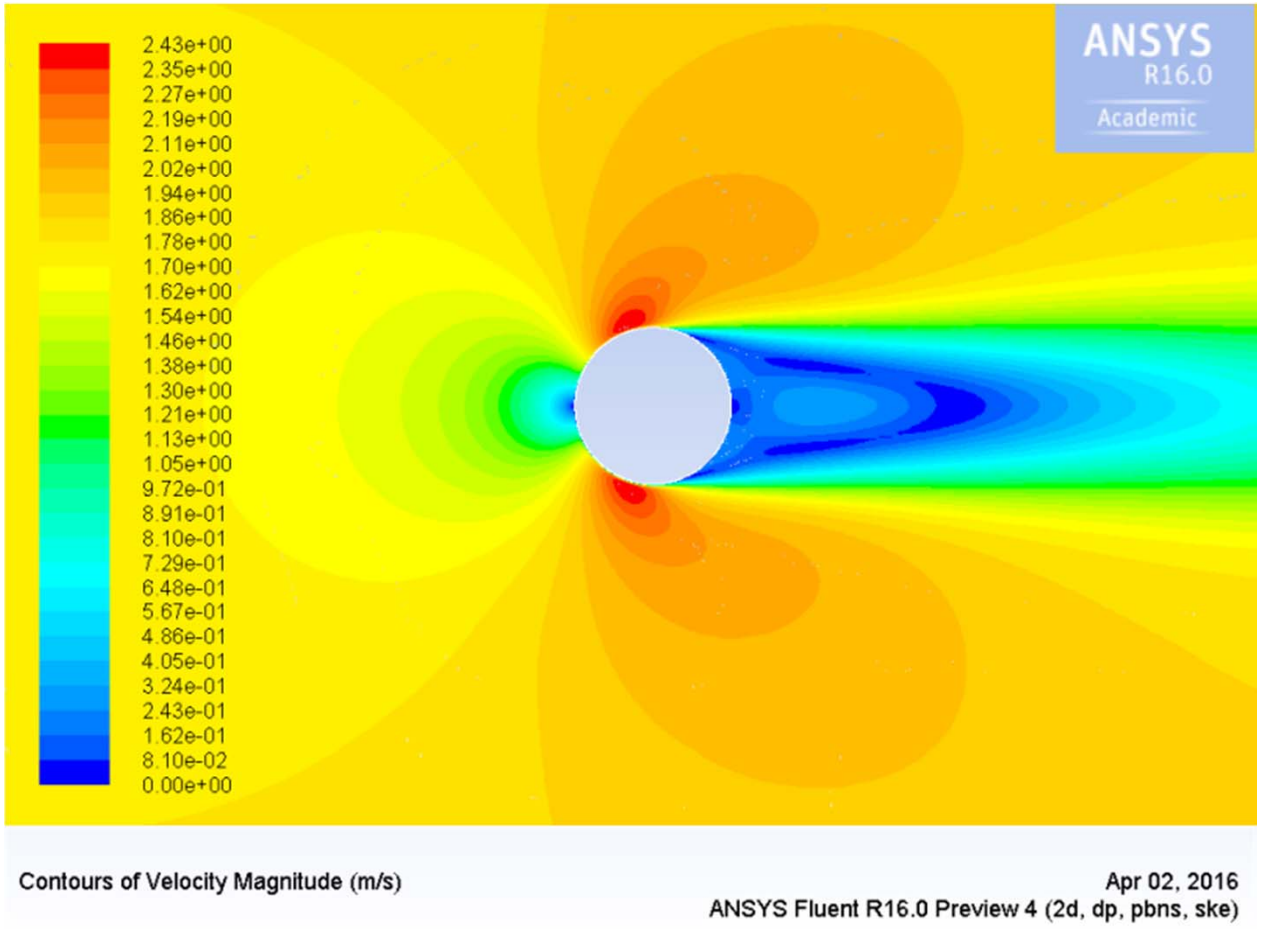


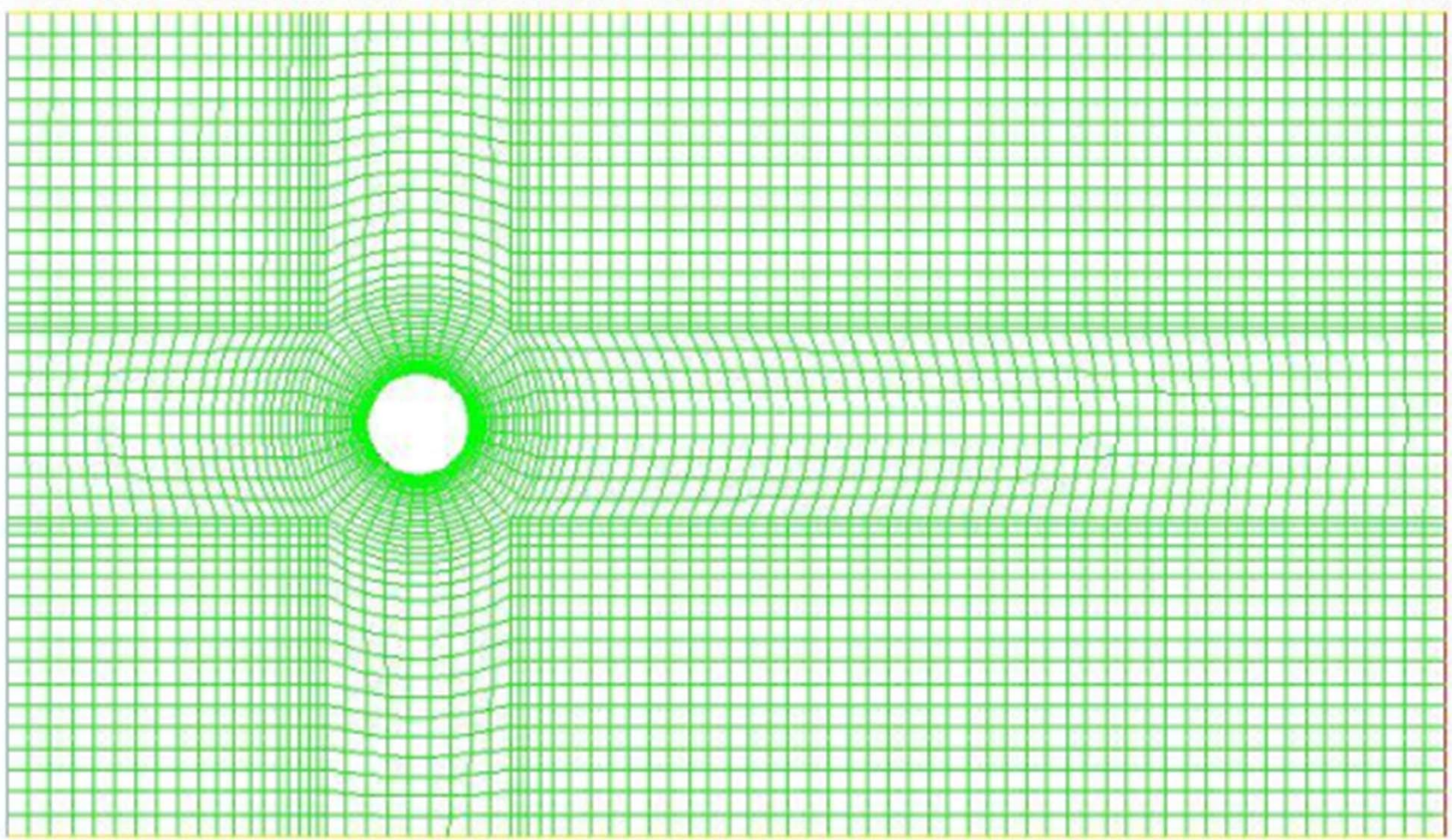


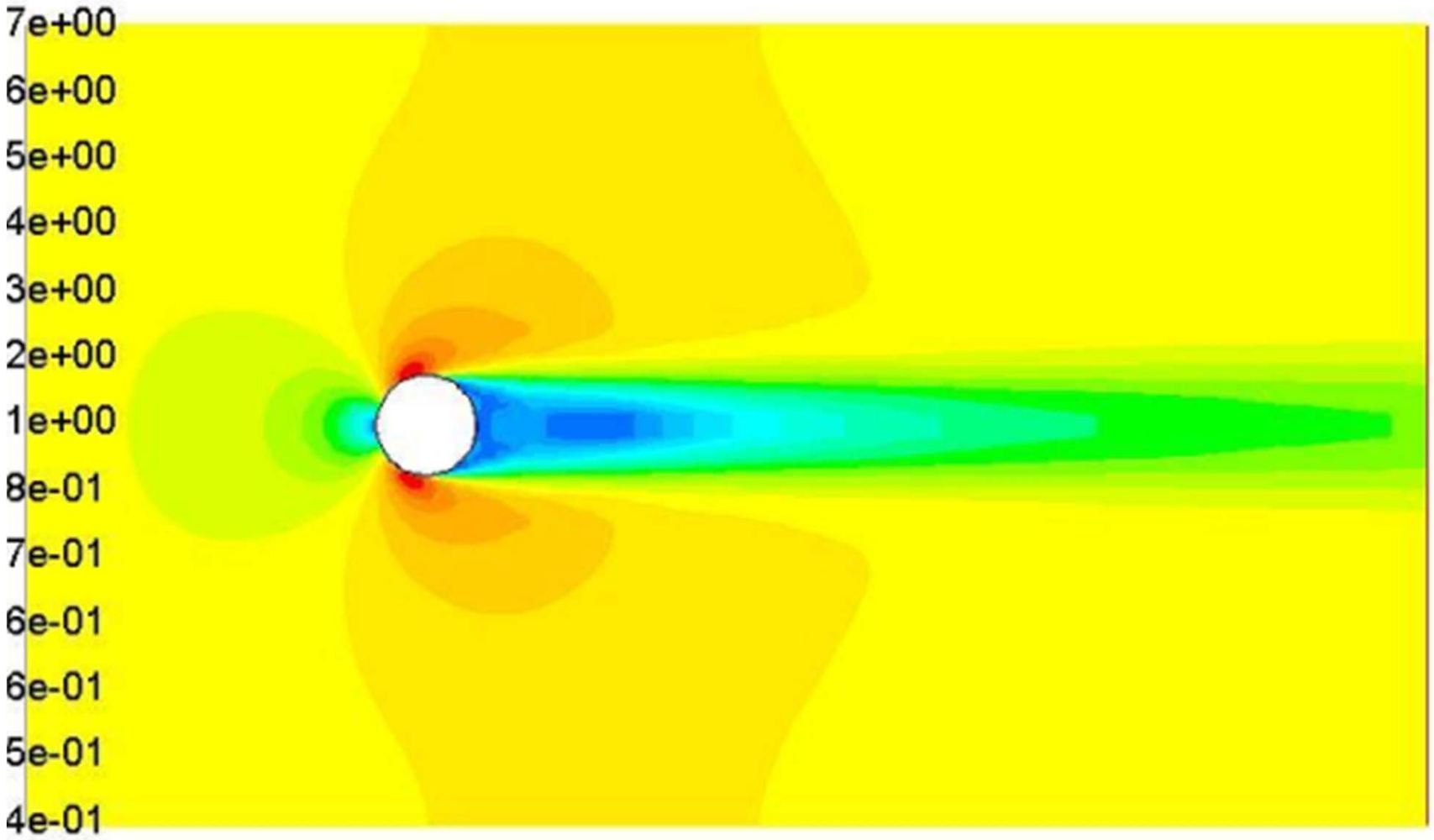





ANSYS
R16.0
Academic


2.43e+00
2.35e+00
2.27e+00
2.19e+00
2.11e+00
2.02e+00
1.94e+00
1.86e+00
1.78e+00
1.70e+00
1.62e+00
1.54e+00
1.46e+00
1.38e+00
1.30e+00
1.21e+00
1.13e+00
1.05e+00
9.72e-01
8.91e-01
8.10e-01
7.29e-01
6.48e-01
5.67e-01
4.86e-01
4.05e-01
3.24e-01
2.43e-01
1.62e-01
8.10e-02
0.00e+00
ANSYS
R16.0
Academic
Contours of Velocity Magnitude (m/s)
Apr 02, 2016
ANSYS Fluent R16.0 Preview 4 (2d, dp, pbns, ske)




7e+00
6e+00
5e+00
4e+00
3e+00
2e+00
1e+00
8e-01
7e-01
6e-01
6e-01
5e-01
4e-01