



**UNIVERSITAT POLITÈCNICA DE CATALUNYA  
BARCELONATECH**

**Escola Superior d'Enginyeries Industrial,  
Aeroespacial i Audiovisual de Terrassa**

ESEIAAT - UPC

# **Study for the computational resolution of conservation equations of mass, momentum and energy. Possible application to different aeronautical and industrial engineering problems: Case 1B**

---

Attachment A - Results

**Author:** Laura Pla Olea

**Director:** Carlos David Perez Segarra

**Co-Director:** Asensio Oliva Llena

**Degree:** Grau en Enginyeria en Tecnologies Aeroespacials

**Delivery date:** 10-06-2017

# Contents

<b>List of Tables</b>	<b>ii</b>
<b>List of Figures</b>	<b>iii</b>
<b>1 Smith-Hutton problem</b>	<b>1</b>
1.1 $\rho/\Gamma = 10$ . . . . .	1
1.2 $\rho/\Gamma = 10^3$ . . . . .	3
1.3 $\rho/\Gamma = 10^6$ . . . . .	6
<b>2 Driven cavity problem</b>	<b>8</b>
<b>3 Bibliography</b>	<b>18</b>

# List of Tables

# List of Figures

1.1	Representation of the whole domain for $\rho/\Gamma = 10$ (CDS) . . . . .	1
1.2	Representation of the whole domain for $\rho/\Gamma = 10$ (UDS) . . . . .	2
1.3	Representation of the whole domain for $\rho/\Gamma = 10$ (HDS) . . . . .	2
1.4	Representation of the whole domain for $\rho/\Gamma = 10$ (EDS) . . . . .	3
1.5	Representation of the whole domain for $\rho/\Gamma = 10$ (PLDS) . . . . .	3
1.6	Representation of the whole domain for $\rho/\Gamma = 10^3$ (UDS) . . . . .	4
1.7	Representation of the whole domain for $\rho/\Gamma = 10^3$ (HDS) . . . . .	4
1.8	Representation of the whole domain for $\rho/\Gamma = 10^3$ (EDS) . . . . .	5
1.9	Representation of the whole domain for $\rho/\Gamma = 10^3$ (PLDS) . . . . .	5
1.10	Representation of the whole domain for $\rho/\Gamma = 10^6$ (UDS) . . . . .	6
1.11	Representation of the whole domain for $\rho/\Gamma = 10^6$ (HDS) . . . . .	6
1.12	Representation of the whole domain for $\rho/\Gamma = 10^6$ (EDS) . . . . .	7
1.13	Representation of the whole domain for $\rho/\Gamma = 10^6$ (PLDS) . . . . .	7
2.1	Comparison between the reference solution and the calculated one of the horizontal velocity along the vertical line in the geometric center of the cavity	9
2.2	Comparison between the reference solution and the calculated one of the vertical velocity along the horizontal line in the geometric center of the cavity	11
2.3	Horizontal velocity inside the cavity . . . . .	13
2.4	Vertical velocity inside the cavity . . . . .	15
2.5	Streamlines of the flow inside the cavity . . . . .	17

# 1 | Smith-Hutton problem

In the following sections there are represented the results of the Smith-Hutton problem for all the resolution schemes that have been coded.

## 1.1 $\rho/\Gamma = 10$

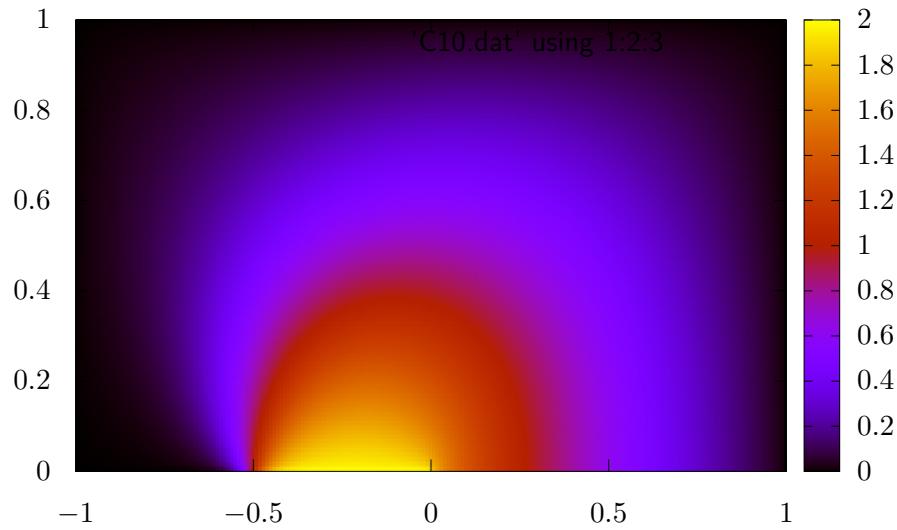


Figure 1.1: Representation of the whole domain for  $\rho/\Gamma = 10$  (CDS)

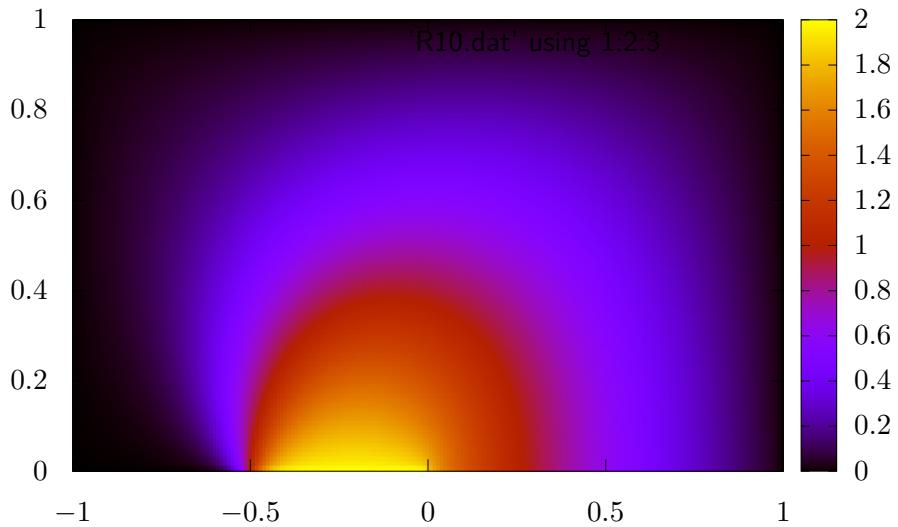


Figure 1.2: Representation of the whole domain for  $\rho/\Gamma = 10$  (UDS)

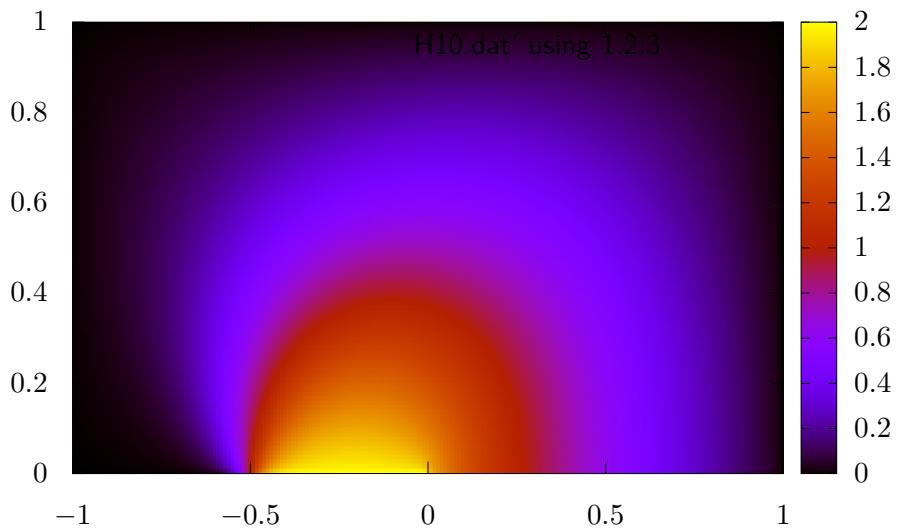


Figure 1.3: Representation of the whole domain for  $\rho/\Gamma = 10$  (HDS)

$$\rho/\Gamma = 10^3$$

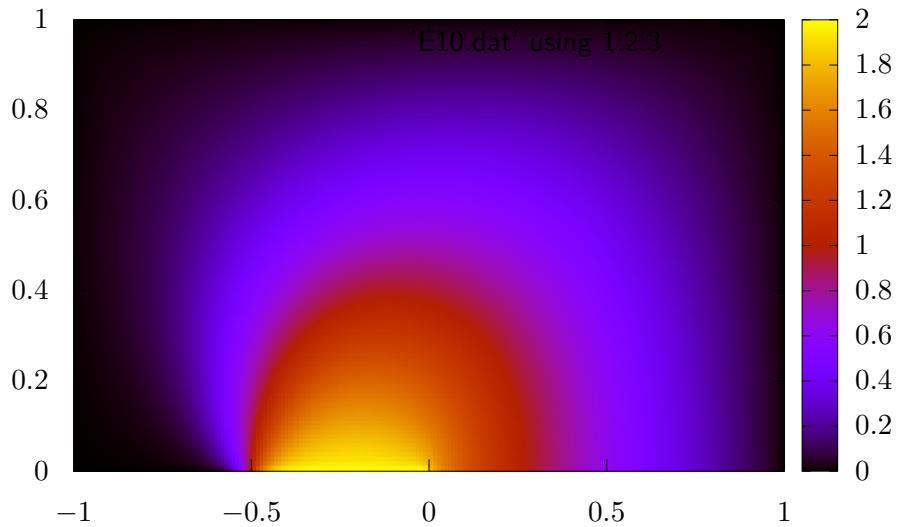


Figure 1.4: Representation of the whole domain for  $\rho/\Gamma = 10$  (EDS)

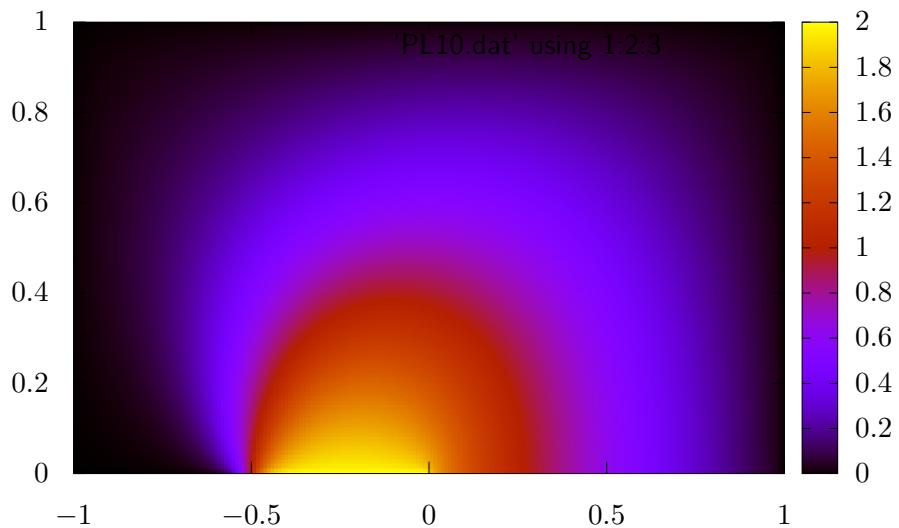


Figure 1.5: Representation of the whole domain for  $\rho/\Gamma = 10$  (PLDS)

## 1.2 $\rho/\Gamma = 10^3$

In this section there is not a solution for the central differencing scheme because it diverges.

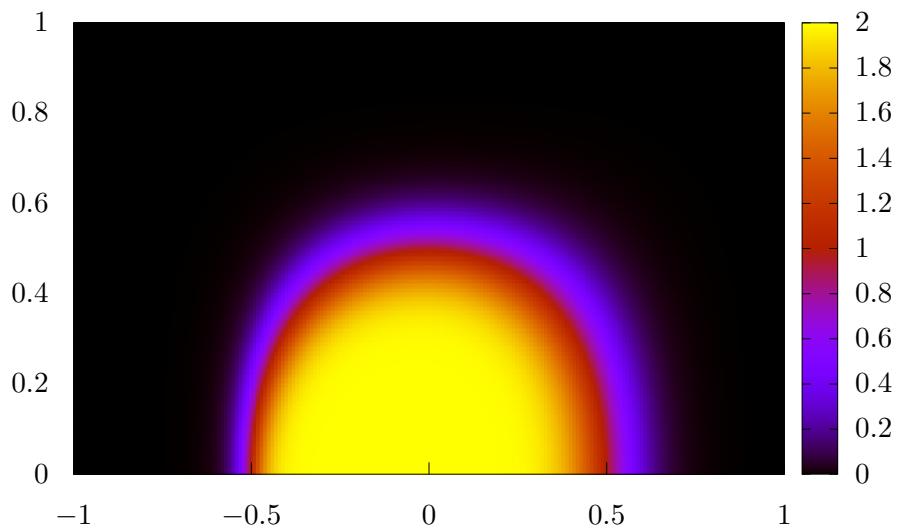


Figure 1.6: Representation of the whole domain for  $\rho/\Gamma = 10^3$  (UDS)

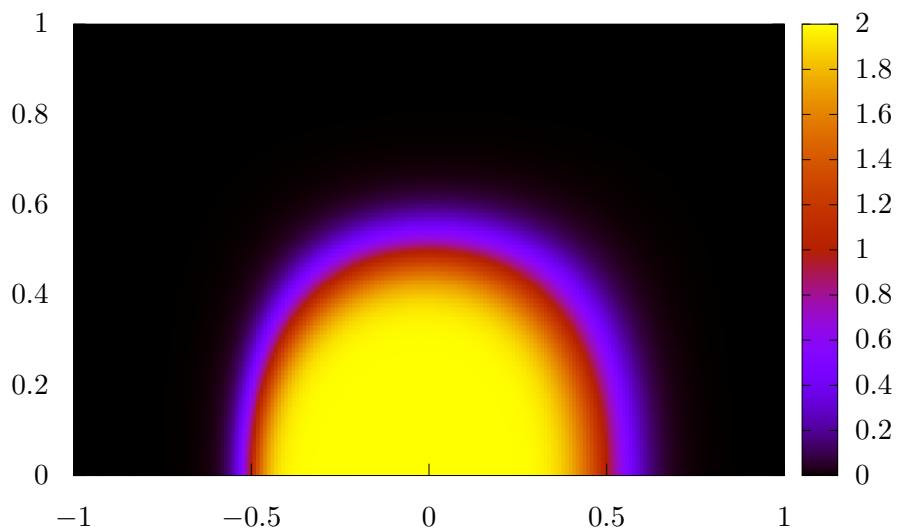


Figure 1.7: Representation of the whole domain for  $\rho/\Gamma = 10^3$  (HDS)

$$\rho/\Gamma = 10^3$$

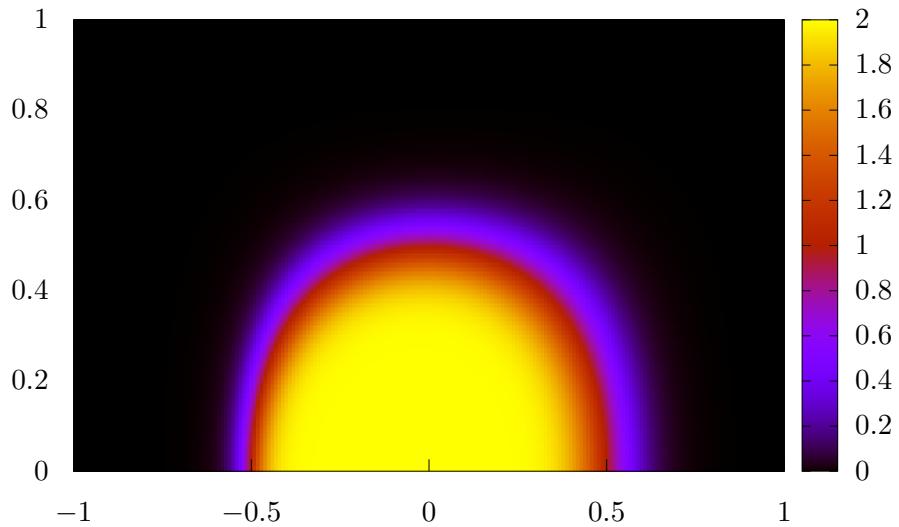


Figure 1.8: Representation of the whole domain for  $\rho/\Gamma = 10^3$  (EDS)

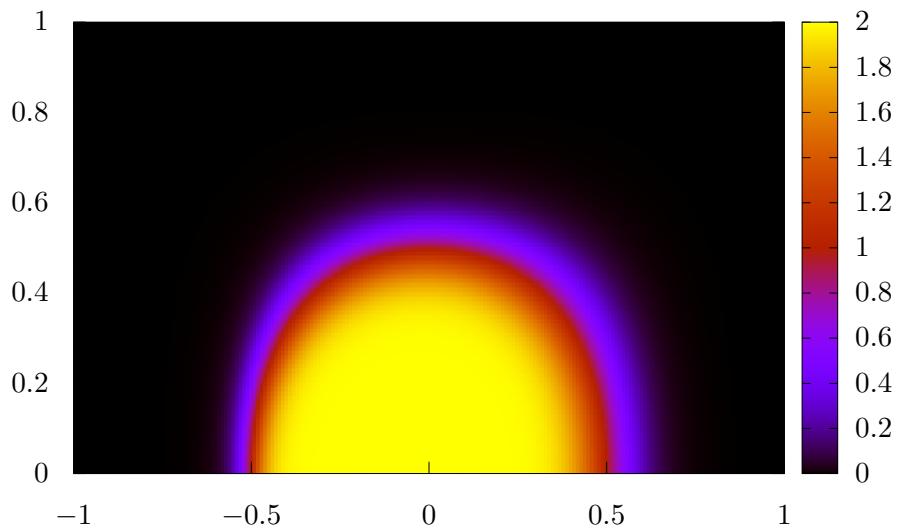


Figure 1.9: Representation of the whole domain for  $\rho/\Gamma = 10^3$  (PLDS)

$$\rho/\Gamma = 10^6$$

### 1.3 $\rho/\Gamma = 10^6$

Like in the previous section, in this case there is no results for the central differencing scheme because of its divergence.

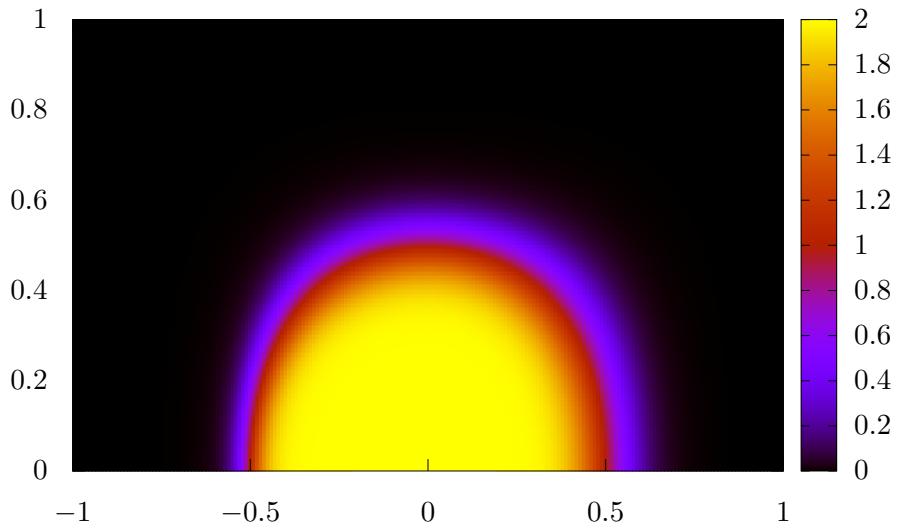


Figure 1.10: Representation of the whole domain for  $\rho/\Gamma = 10^6$  (UDS)

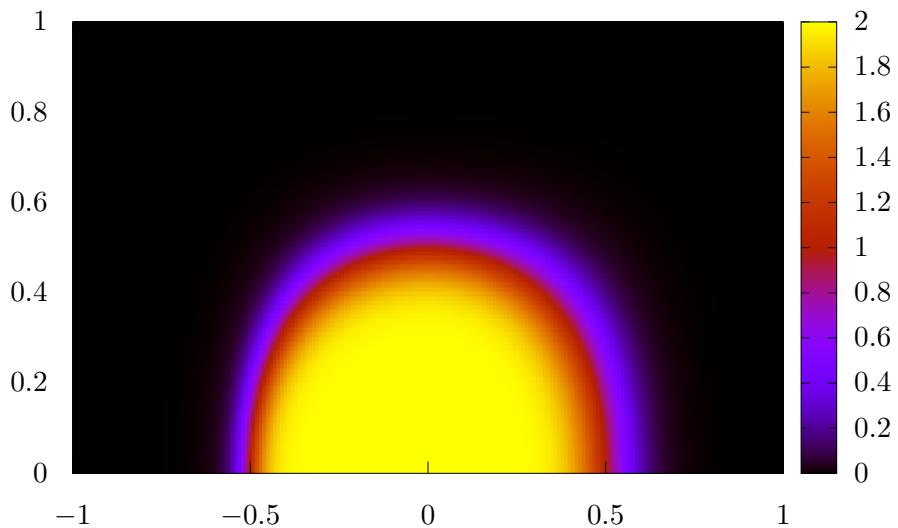


Figure 1.11: Representation of the whole domain for  $\rho/\Gamma = 10^6$  (HDS)

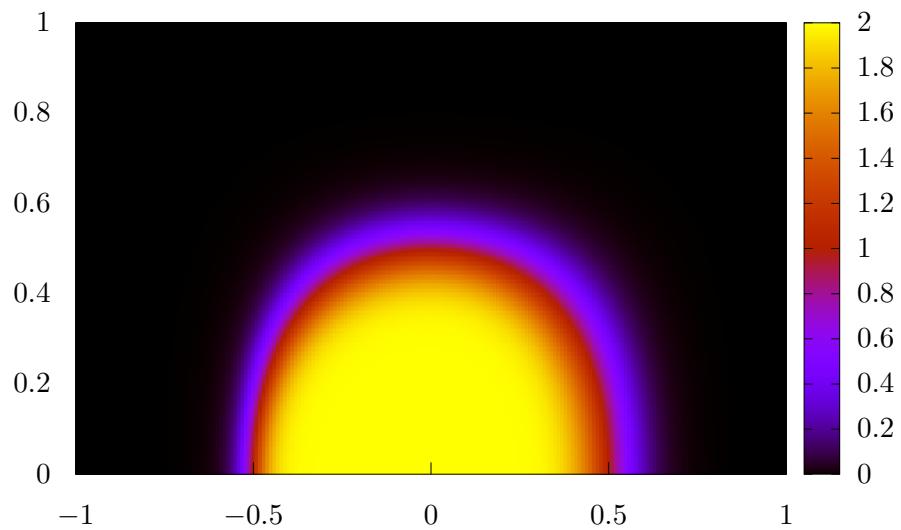


Figure 1.12: Representation of the whole domain for  $\rho/\Gamma = 10^6$  (EDS)

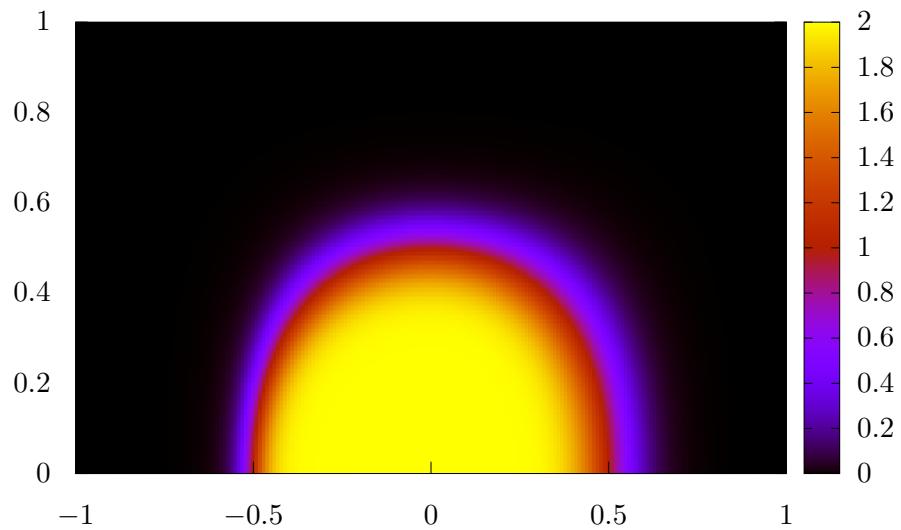
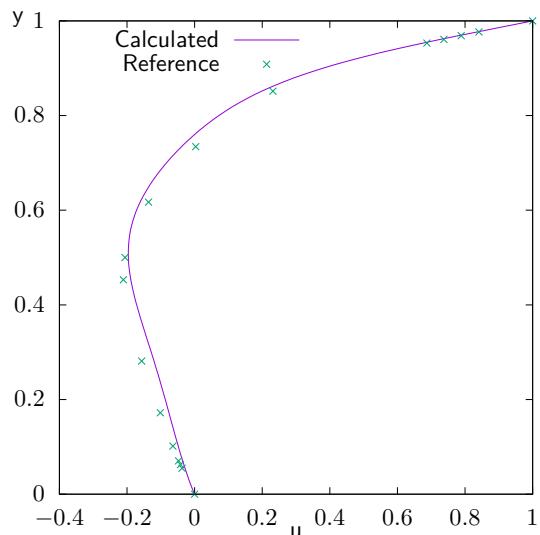
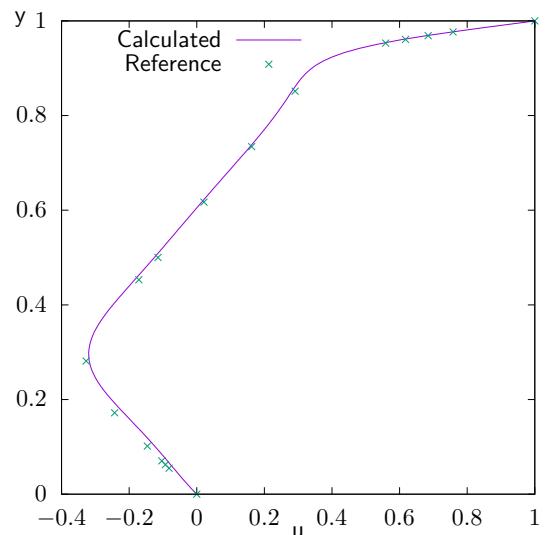
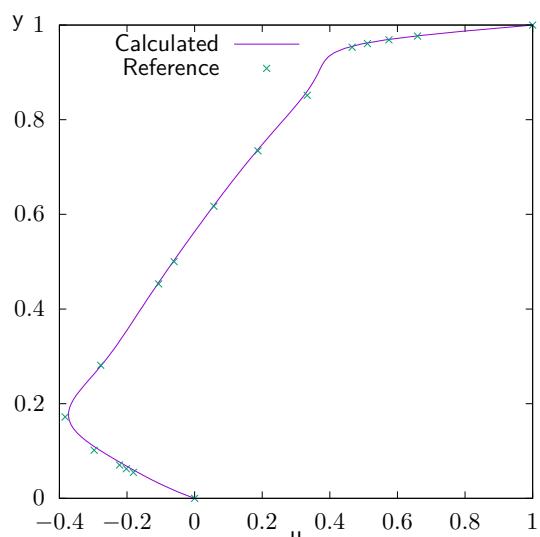
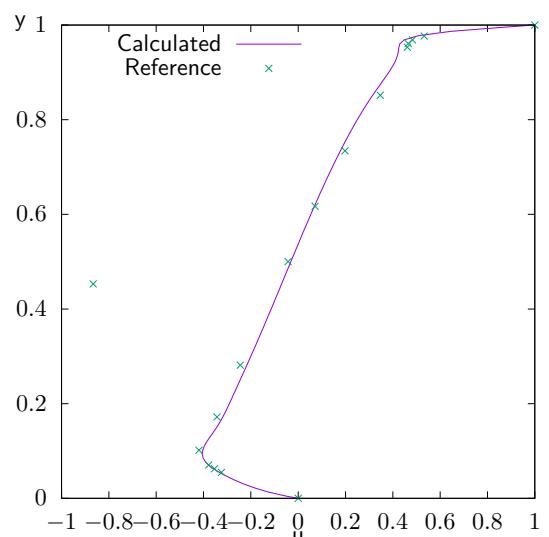


Figure 1.13: Representation of the whole domain for  $\rho/\Gamma = 10^6$  (PLDS)

## 2 | Driven cavity problem

(a)  $Re = 100$ (b)  $Re = 400$ (c)  $Re = 1000$ (d)  $Re = 3200$

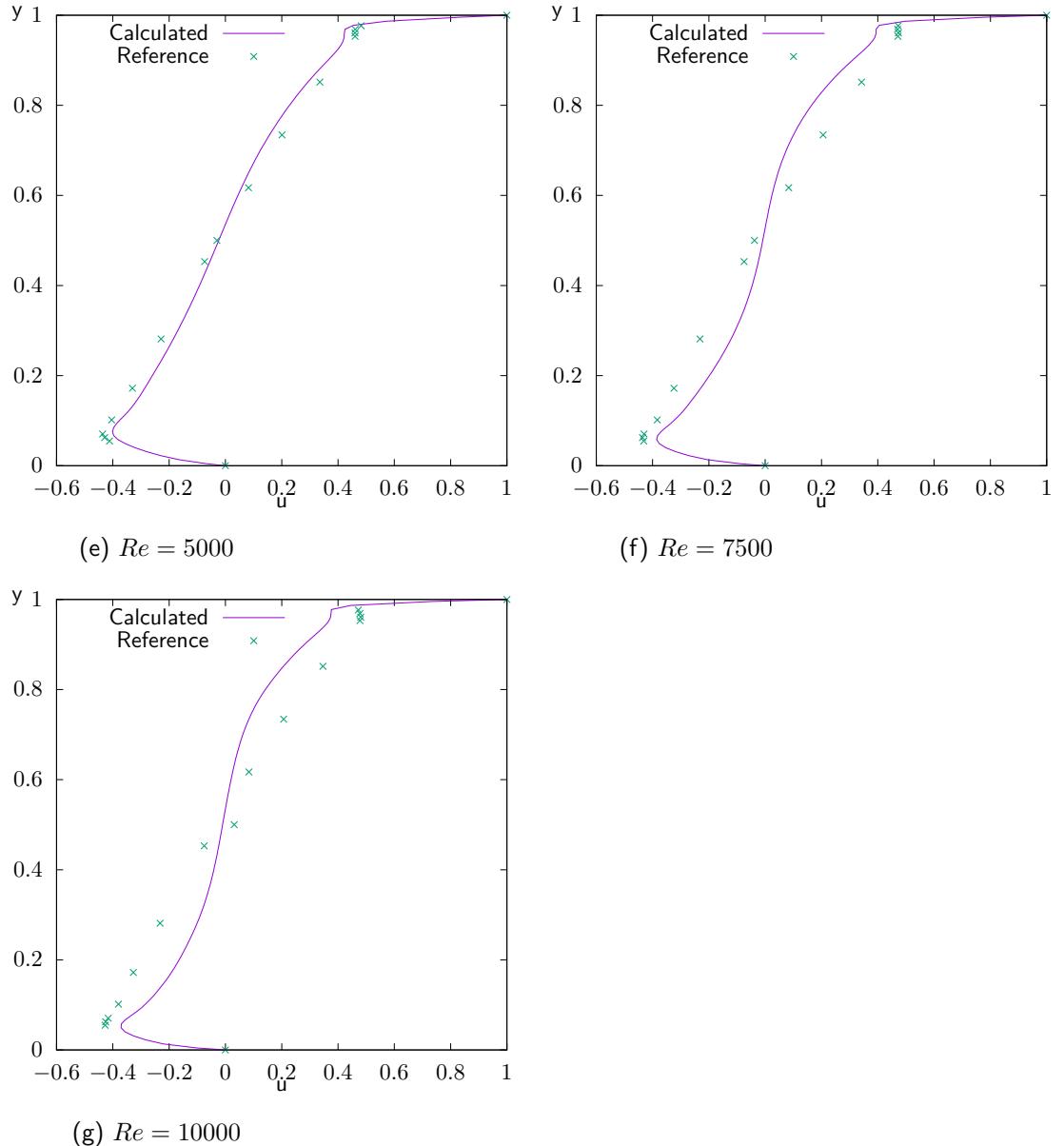
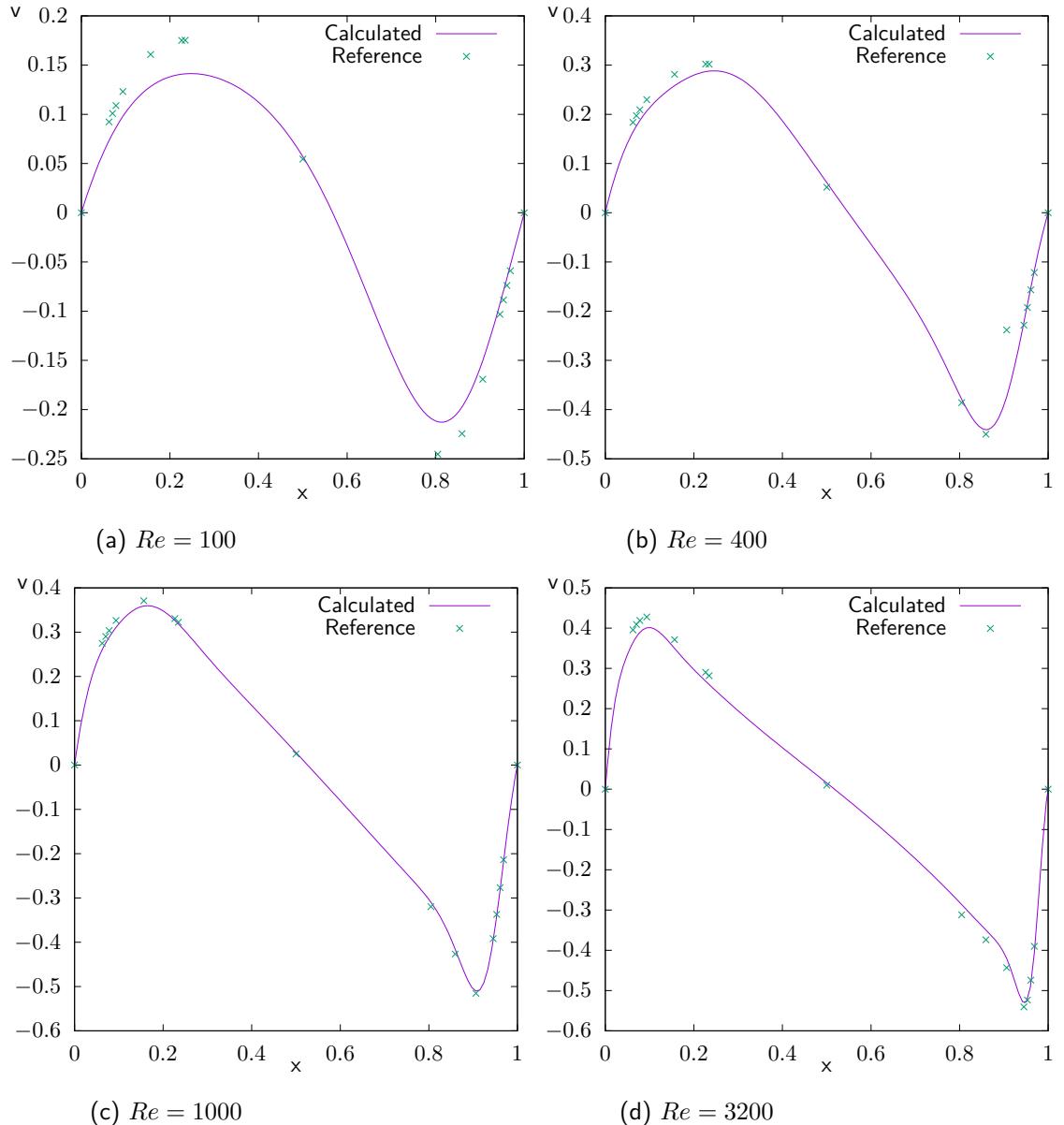


Figure 2.1: Comparison between the reference solution and the calculated one of the horizontal velocity along the vertical line in the geometric centre of the cavity [1]



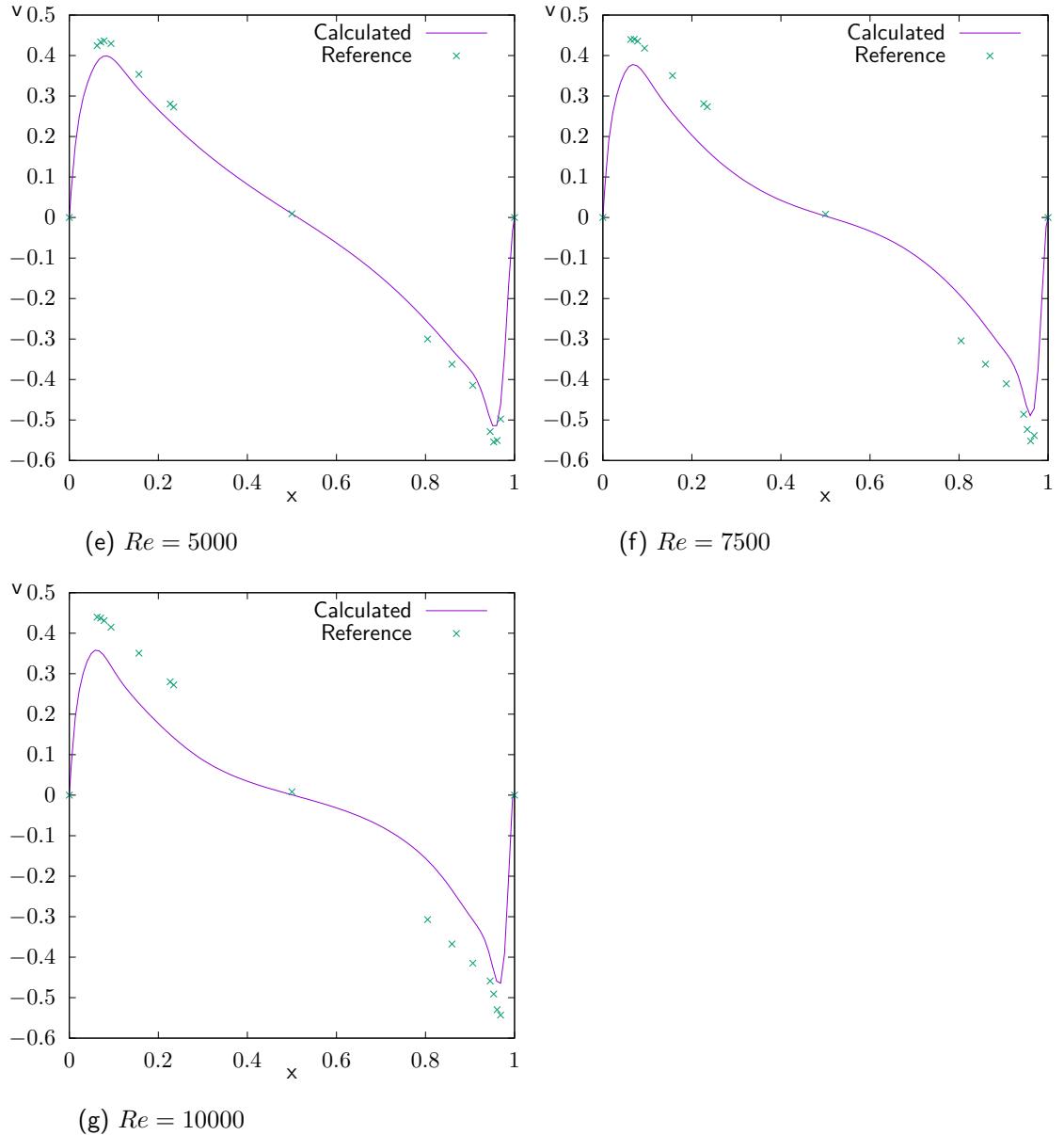
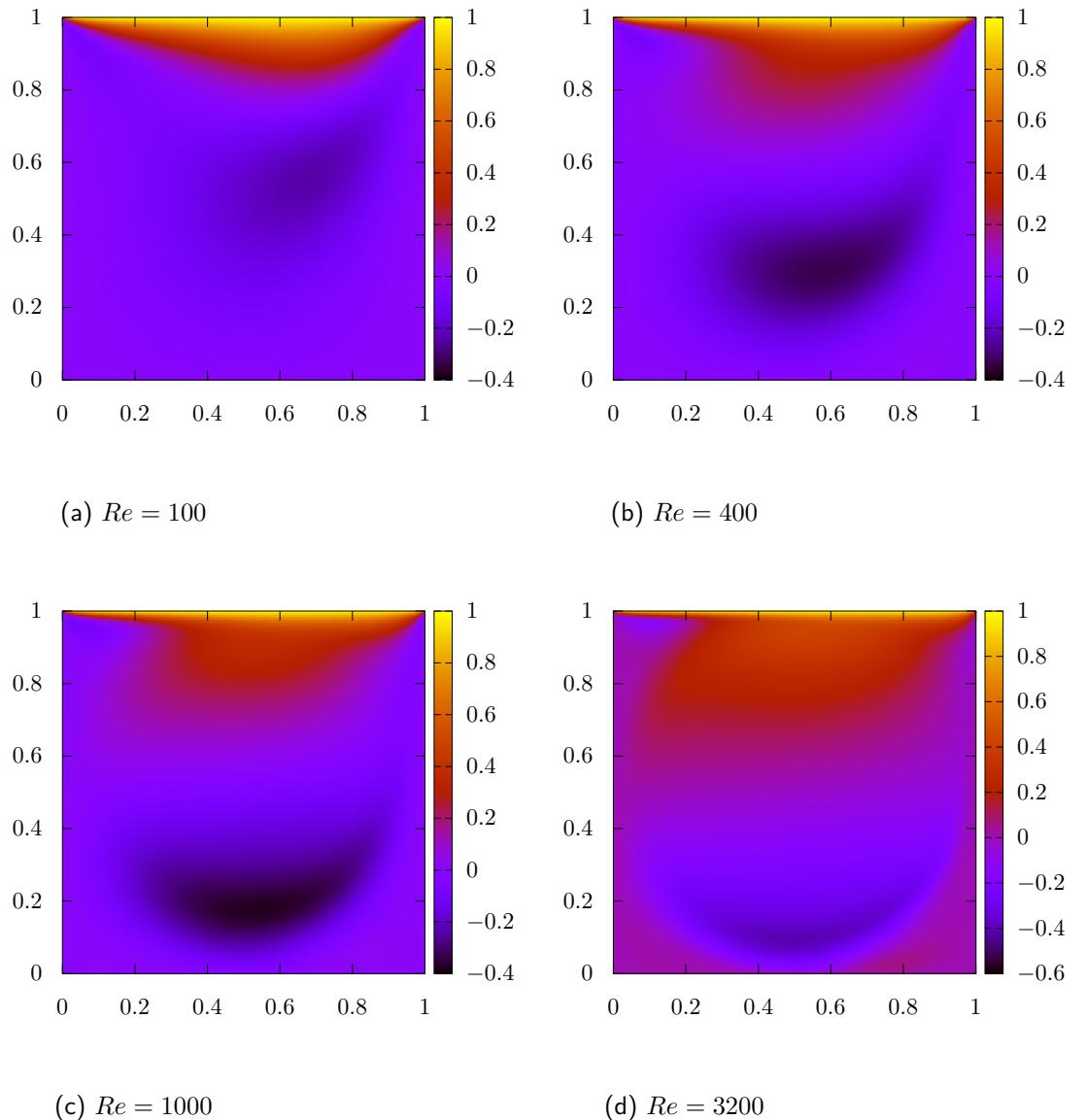


Figure 2.2: Comparison between the reference solution and the calculated one of the vertical velocity along the horizontal line in the geometric centre of the cavity [1]



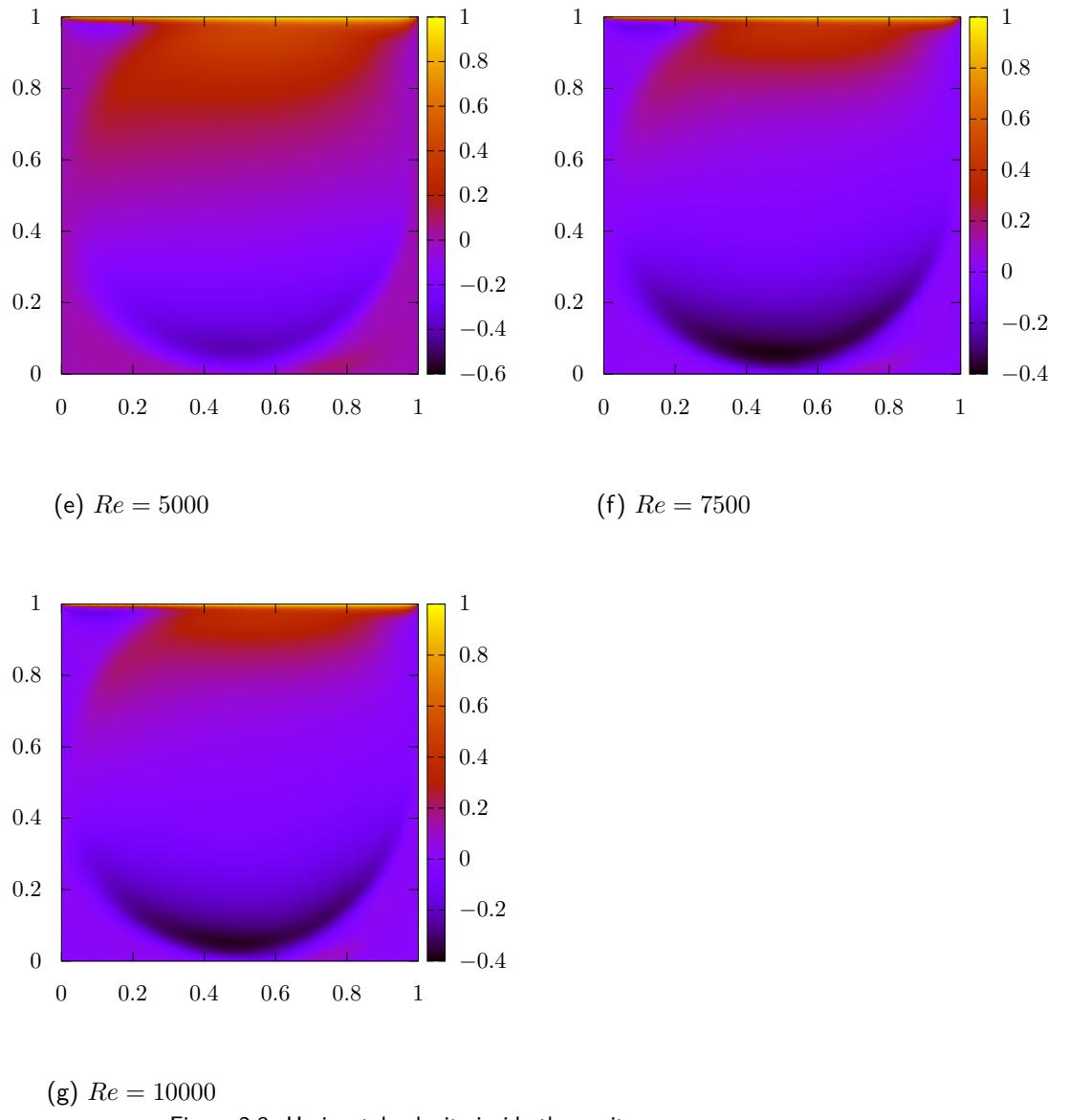
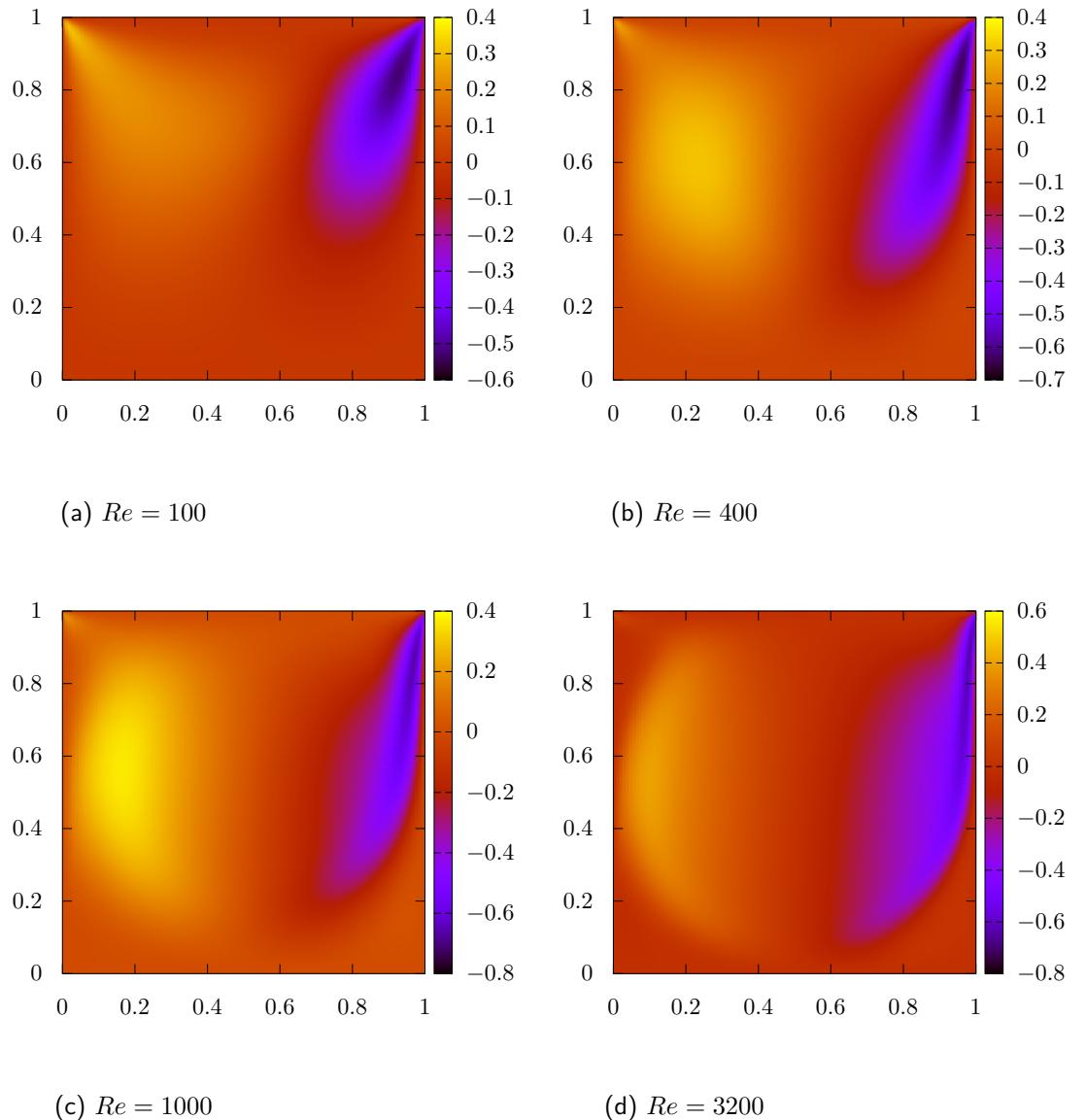


Figure 2.3: Horizontal velocity inside the cavity



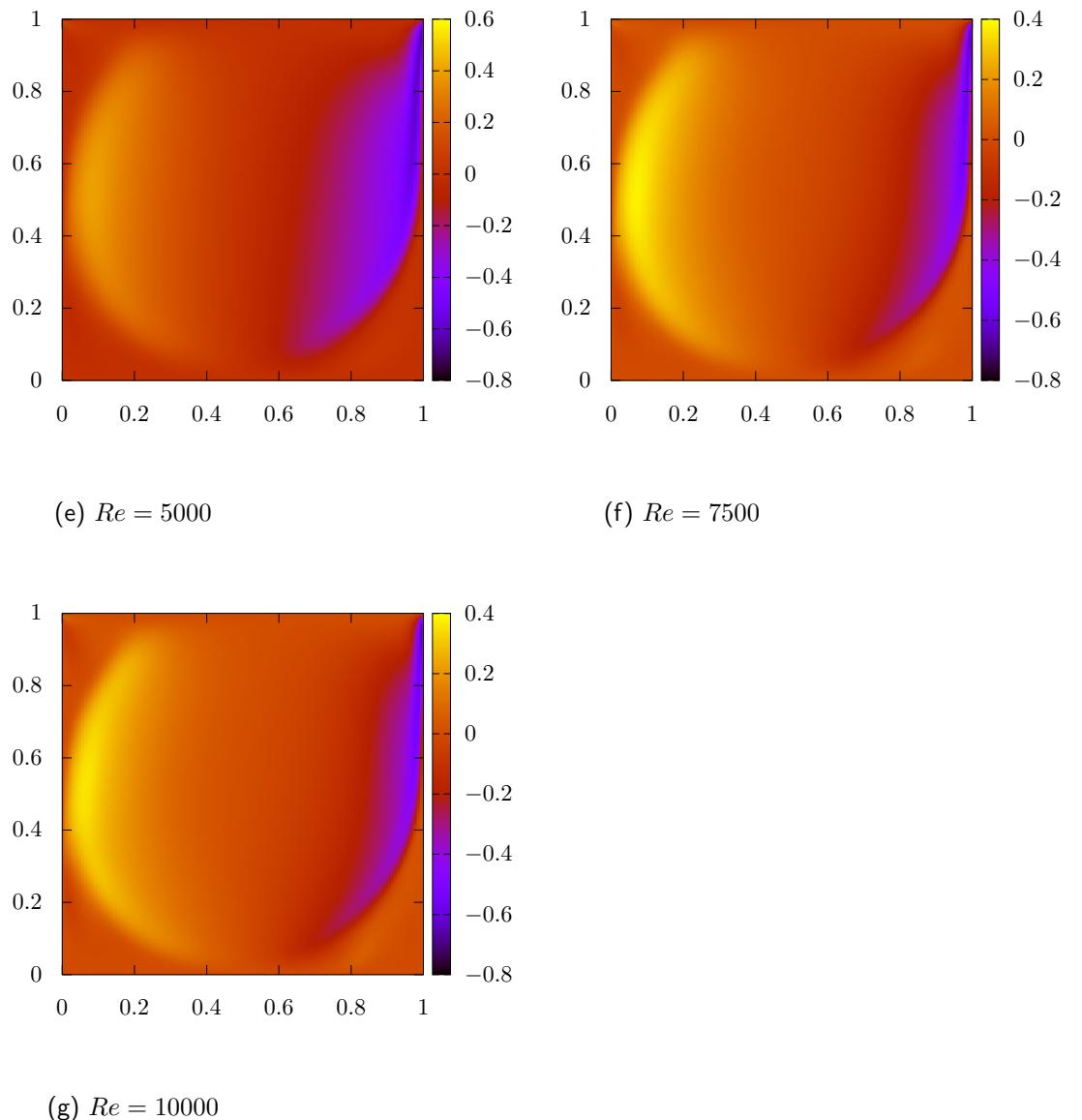
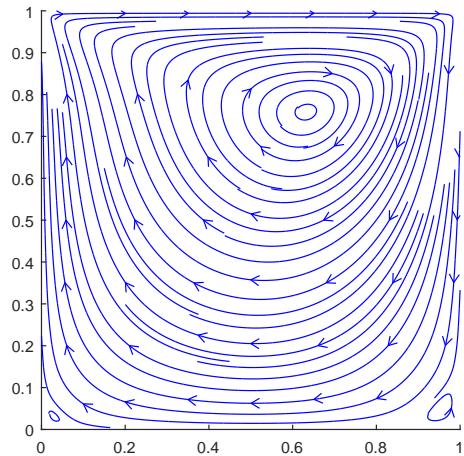
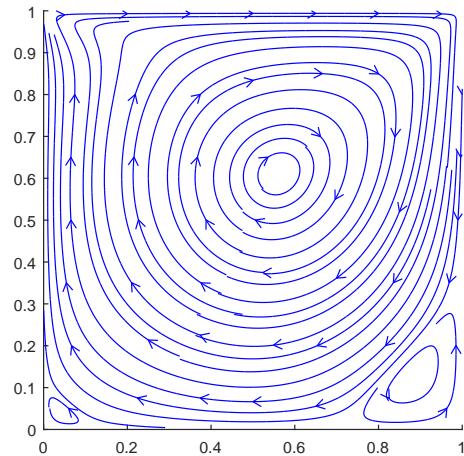


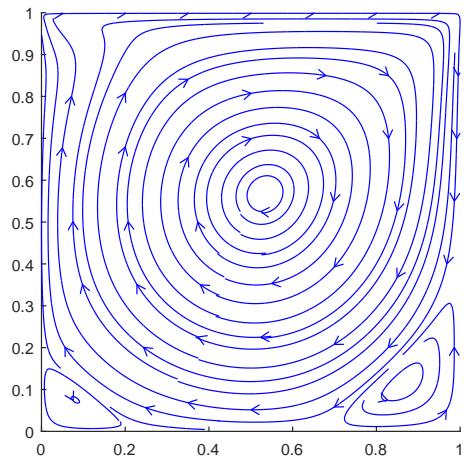
Figure 2.4: Vertical velocity inside the cavity



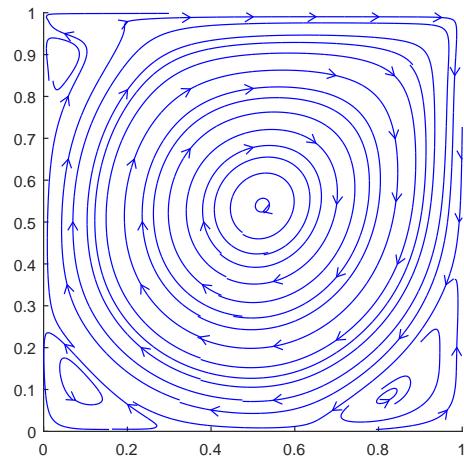
(a)  $Re = 100$



(b)  $Re = 400$



(c)  $Re = 1000$



(d)  $Re = 3200$

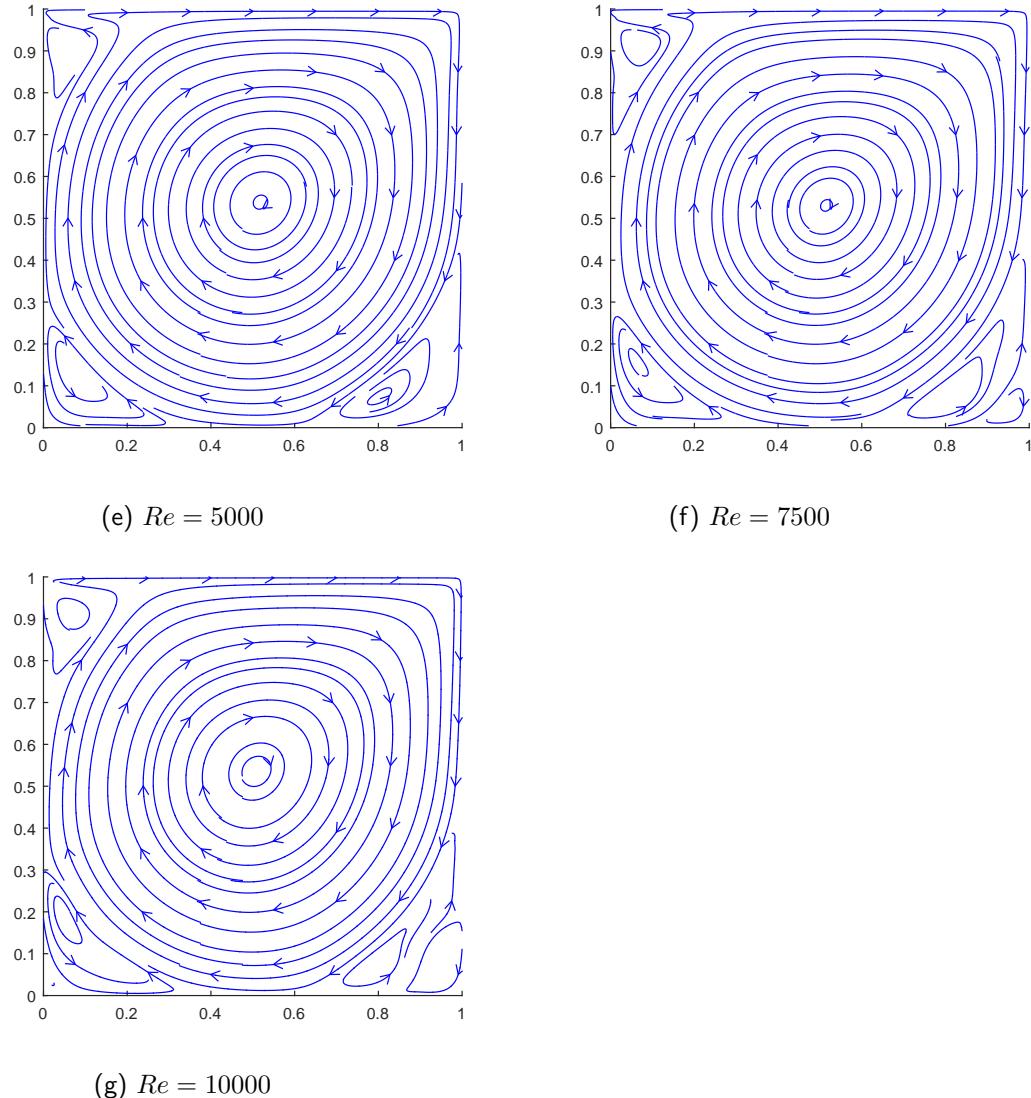


Figure 2.5: Streamlines of the flow inside the cavity

# 3 | Bibliography

- [1] U. Ghia, K. N. Ghia, and C. T. Shin. High-Re solutions for incompressible flow using the Navier-Stokes equations and a multigrid method. *Journal of Computational Physics*, 48:387–411, 1982.