TÜBİTAK

İSTANBUL TEKNİK ÜNİVERSİTESİ 1773

EURO²

Introduction to Computational Fluid Dynamics

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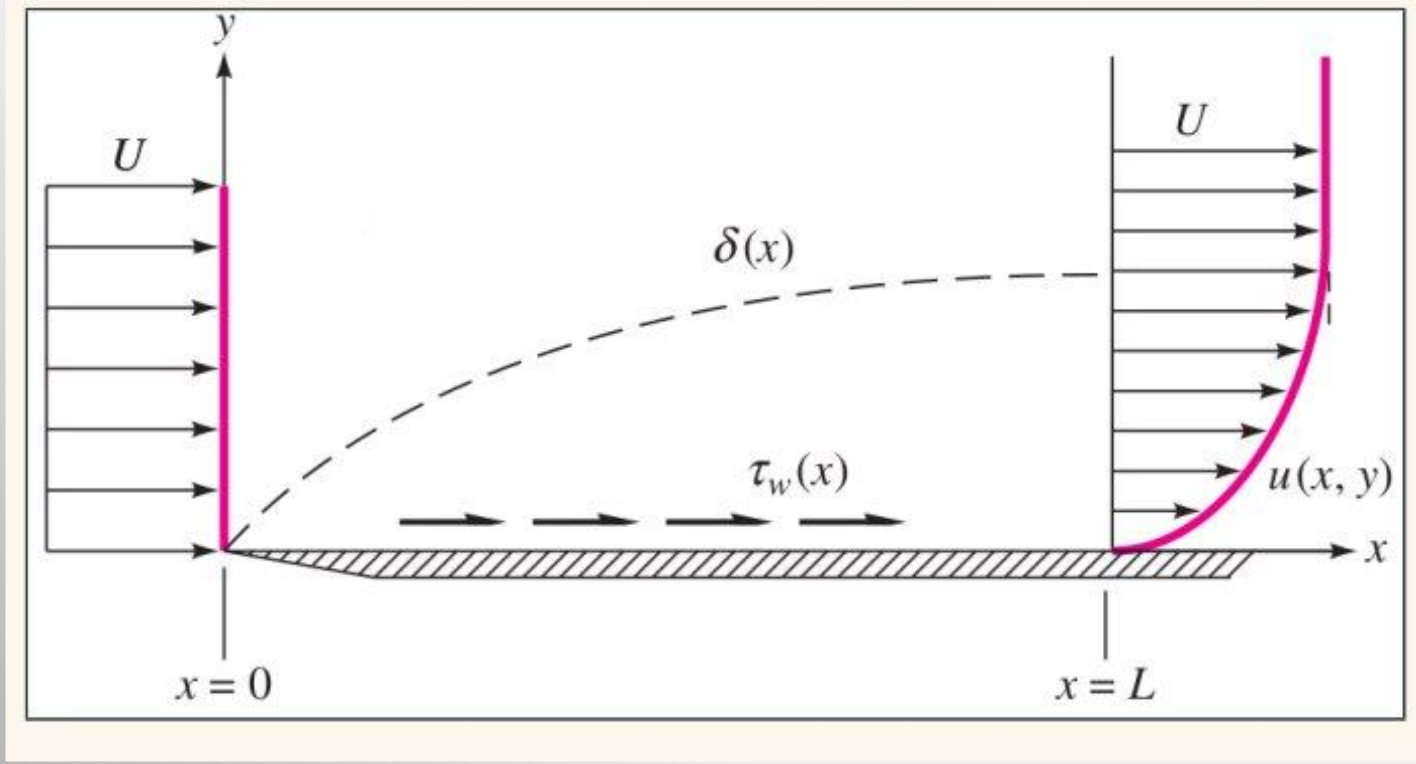
CFD of a turbulent boundary layer experiment

Turbulent boundary layer over a flat plate



$$U(y) = 0.99 \times U_\infty$$

$$\delta^* = \int_0^\delta (1 - \frac{U}{U_\delta}) dy$$

$$\tau_{wall} = \mu (\frac{\partial U}{\partial y})_{y=0}$$

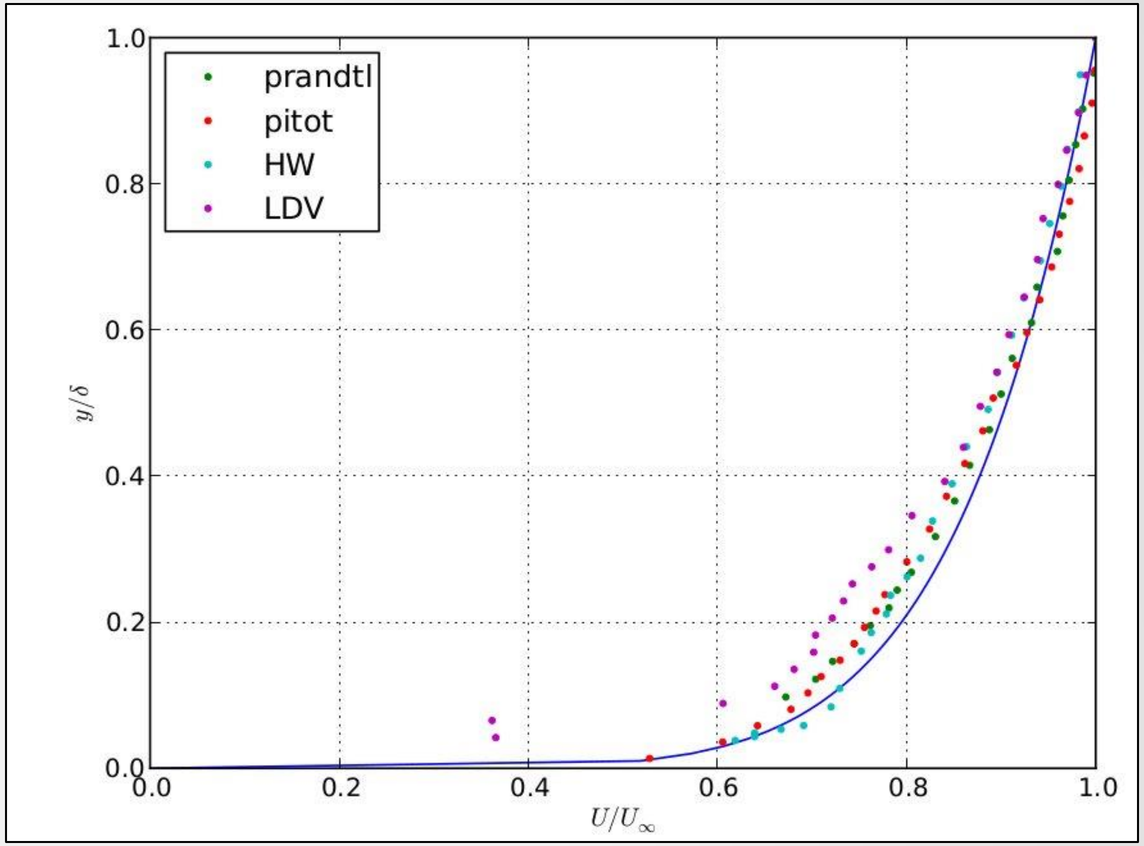
$$C_f = 2(\frac{u_\tau}{\rho})^2$$

CFD of a turbulent boundary layer experiment

The simulation of flow over a flat plate experiment in a mini wind tunnel.

Free stream velocity: 10 meter/second
The tunnel length: 1 meter
The tunnel height: 0.2 meter
The tunnel width: 0.2 meter

The data are collectetd using
several techniques.



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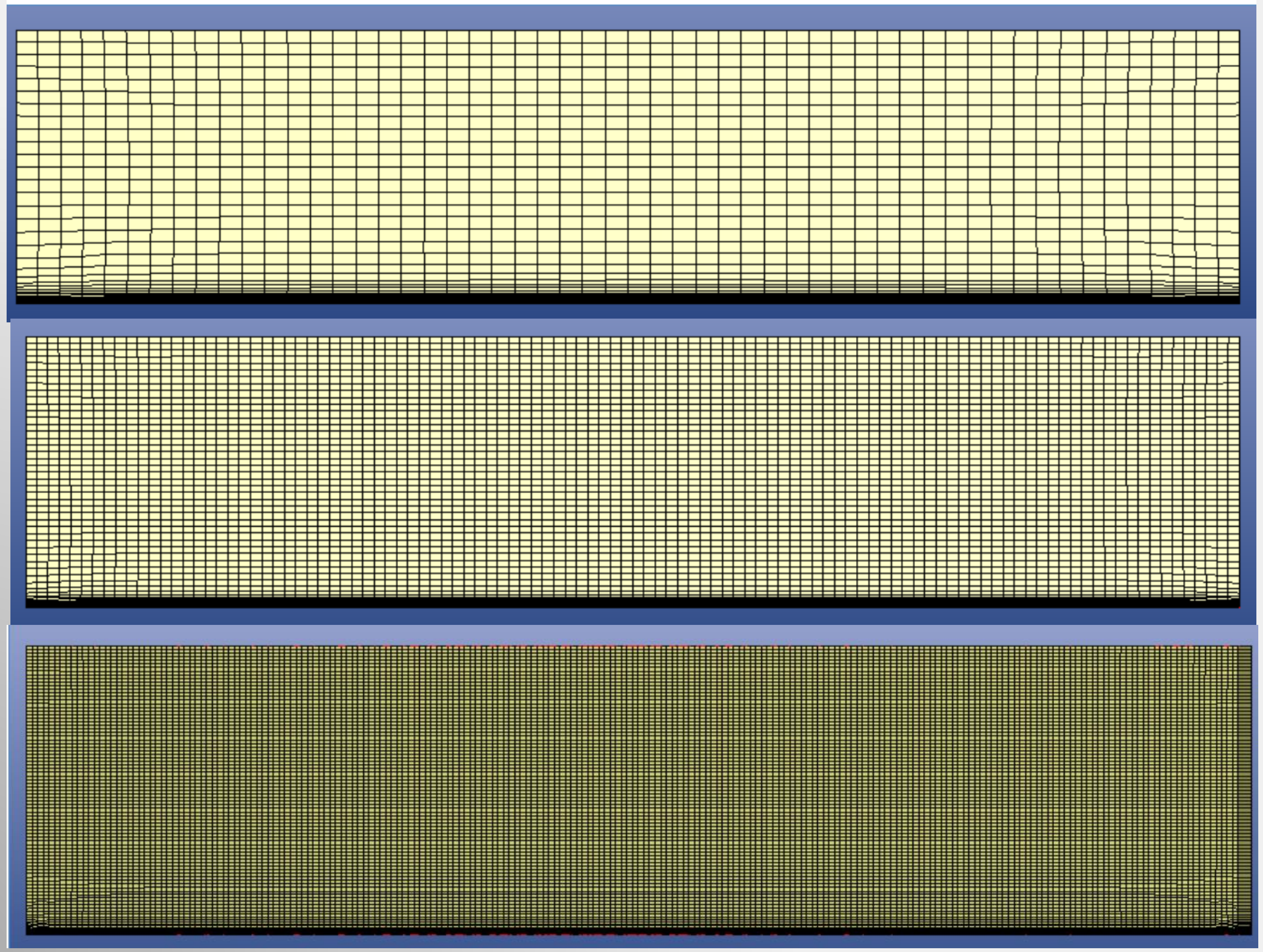
	$U_\infty(m/s)$	C_f	$\delta(mm)$	$\delta^*(mm)$	$\theta(mm)$	H
Theor.	10.00	0.00427	18.7	2.61	2.03	1.28
Prandtl	9.87	0.00411	21.1	1.99	1.64	1.22
Pitot	9.95	0.00385	23.4	2.88	2.22	1.29
HW	10.34	0.00408	19.6	2.37	1.92	1.23
LDV	10.01	0.00324	21.4	3.15	2.27	1.39

Grid Generation



	X	Y	Total
Grid 1	54	21	1134
Grid 2	108	41	4428
Grid 3	216	80	17280

There is not a single way of generating different grids!

It is much more complicated when the domain is not simple like this.

Turbulence modelling

Three turbulence models are employed.

Spalart-allmaras

- 1-equation model
- It requires less sources
- It is designed specifically for aerospace applications

K-epsilon Low Re Yang-Shih

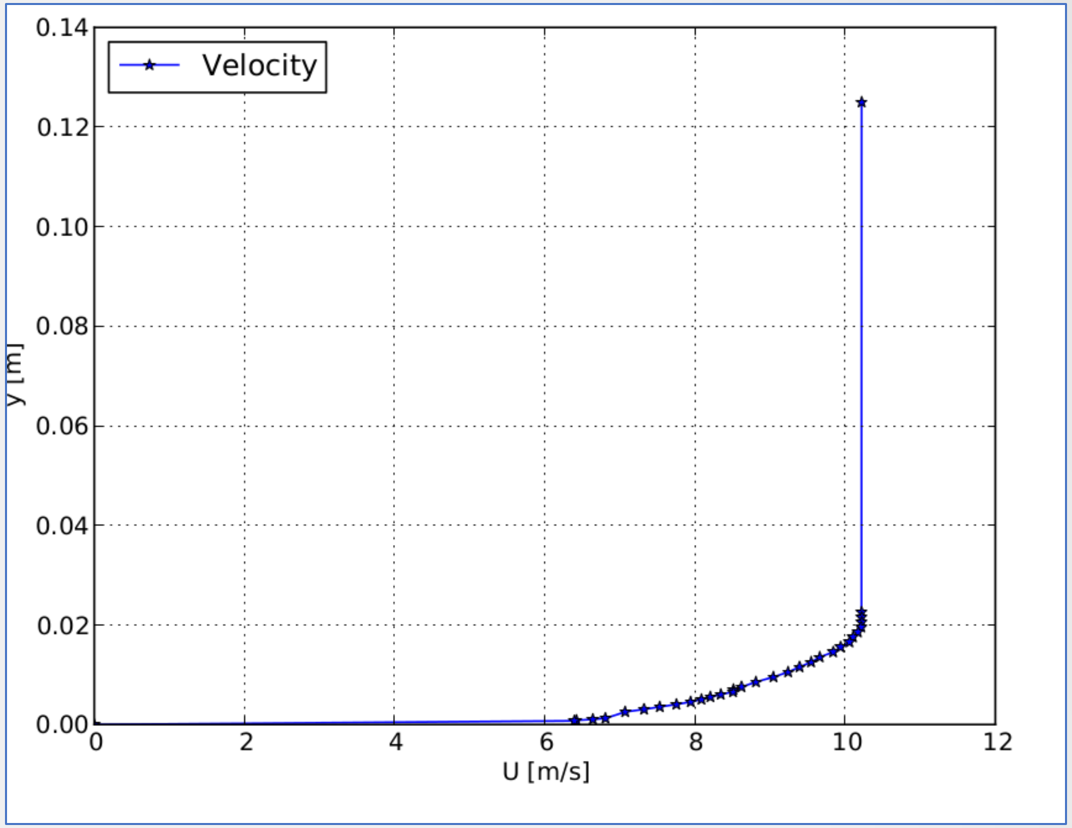
- 2-equation model
- Designed for wall-bounded flows
- Modeled eddy viscosity through velocity and time scale

K-omega SST

- 2-equation model
- Good for wall-bounded flows
- A blend for k-epsilon and k-omega

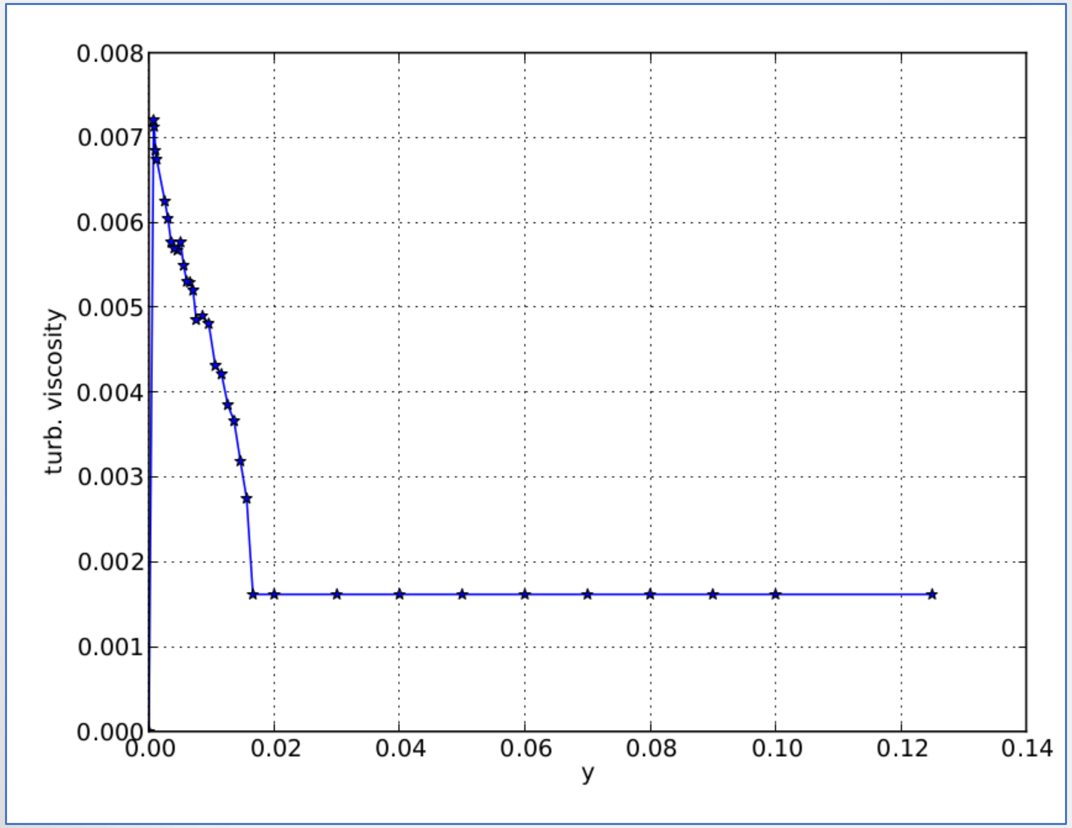
Boundary conditions

Inlet velocity is taken from the experimental results



Boundary conditions

Inlet turbulent viscosity for Spalart-Allmaras



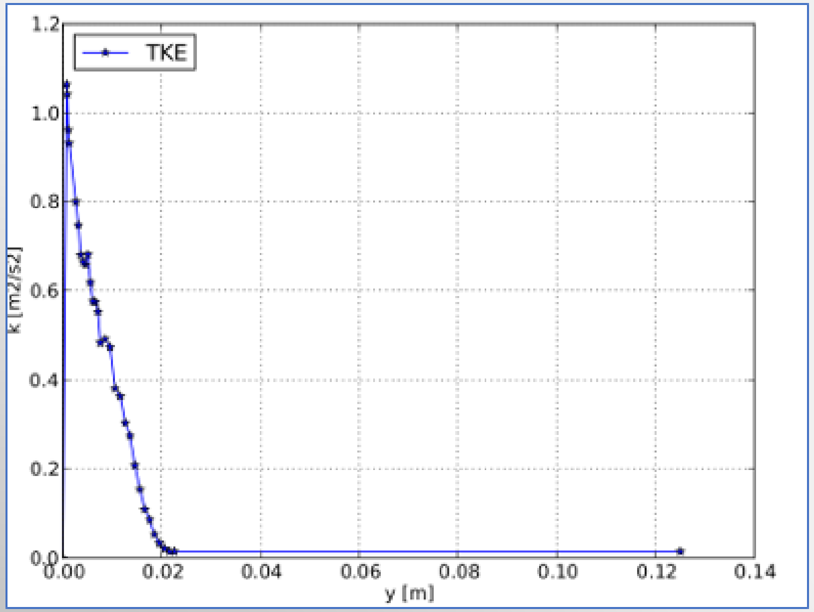
$$\widetilde{\nu} = \sqrt{1.5}(\bar{u}lL)$$

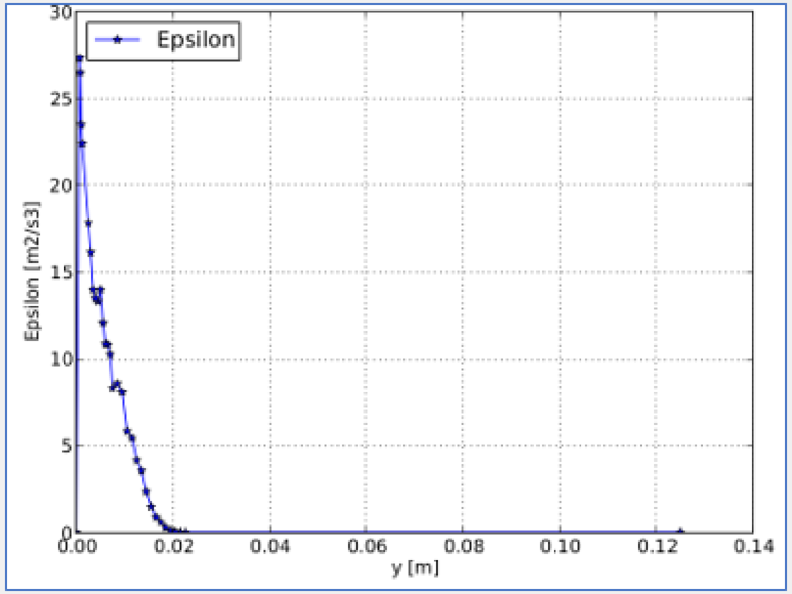
$$X = \frac{\widetilde{\nu}}{\nu}$$

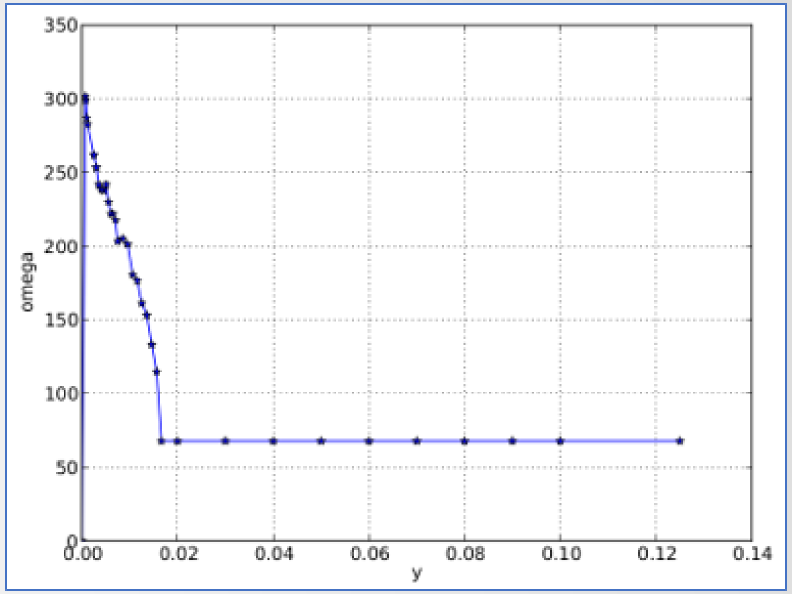
$$f_{v1} = \frac{X^3}{X^3 + C_{v1}^3}$$

$$\nu_T = \widetilde{\nu} f_{v1}$$

Boundary conditions







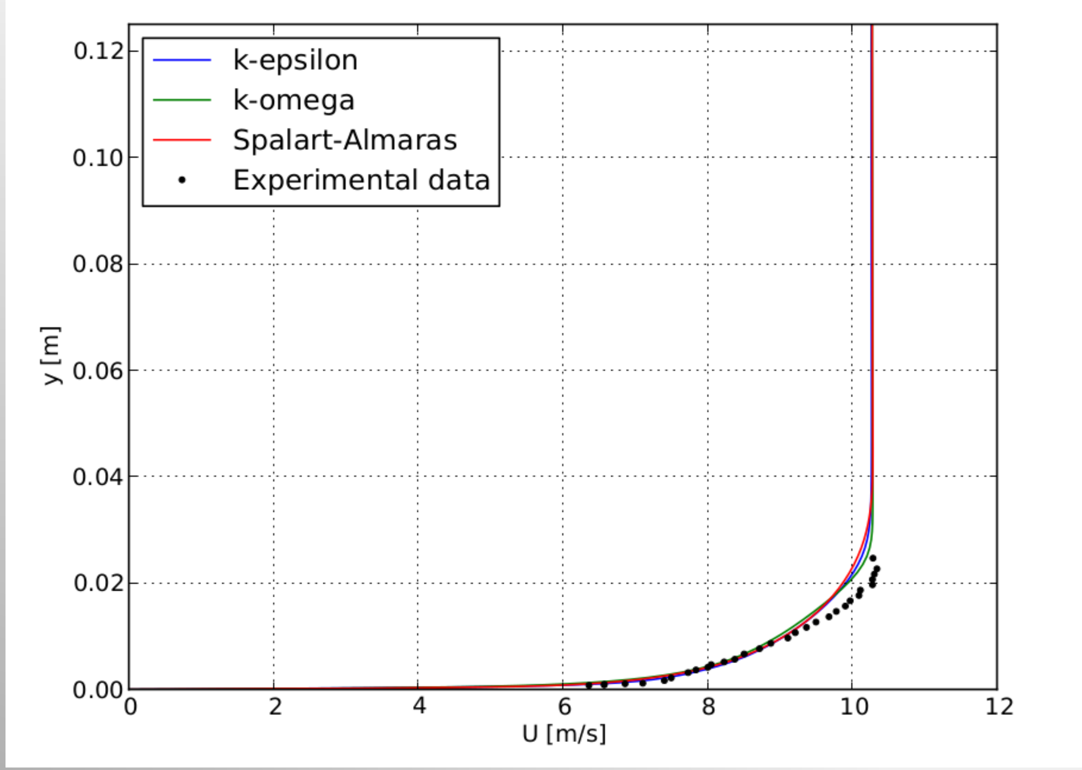
$$k = \frac{3}{2}(\bar{u})^2$$

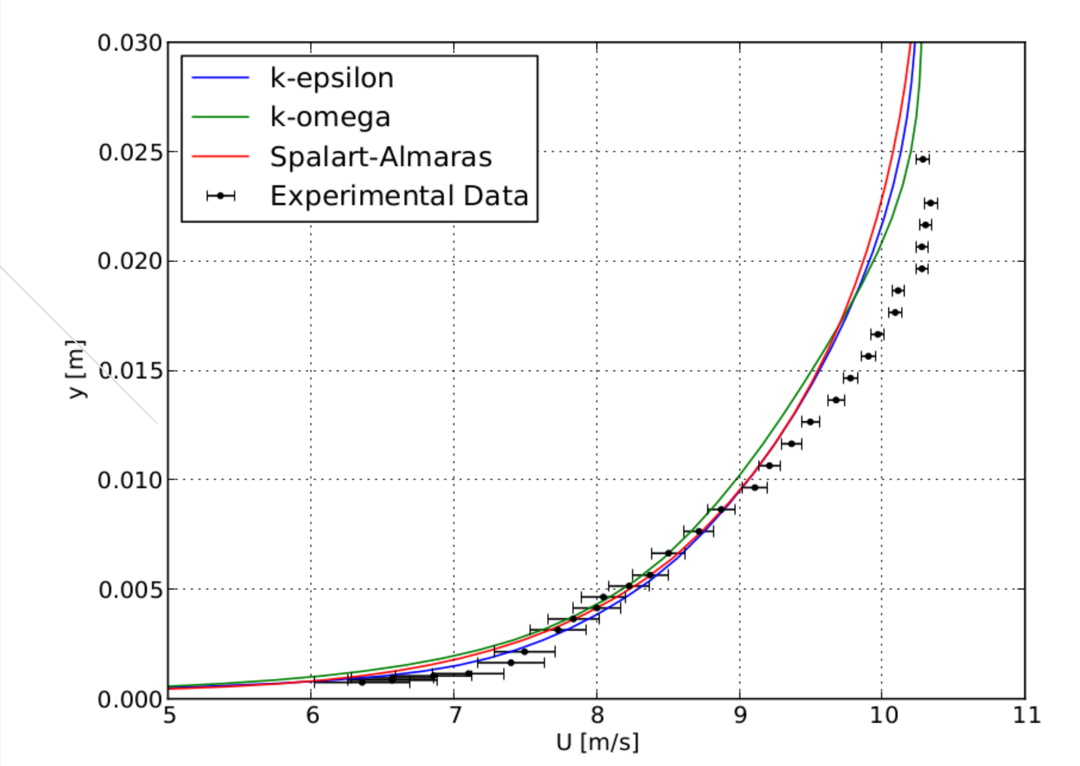
$$\epsilon = C_\mu^{0.75}\frac{k^{1.5}}{L}$$

$$\omega = C_\mu^{-0.25}\frac{\sqrt{k}}{l}$$

Boundary conditions

Results for different turbulence models





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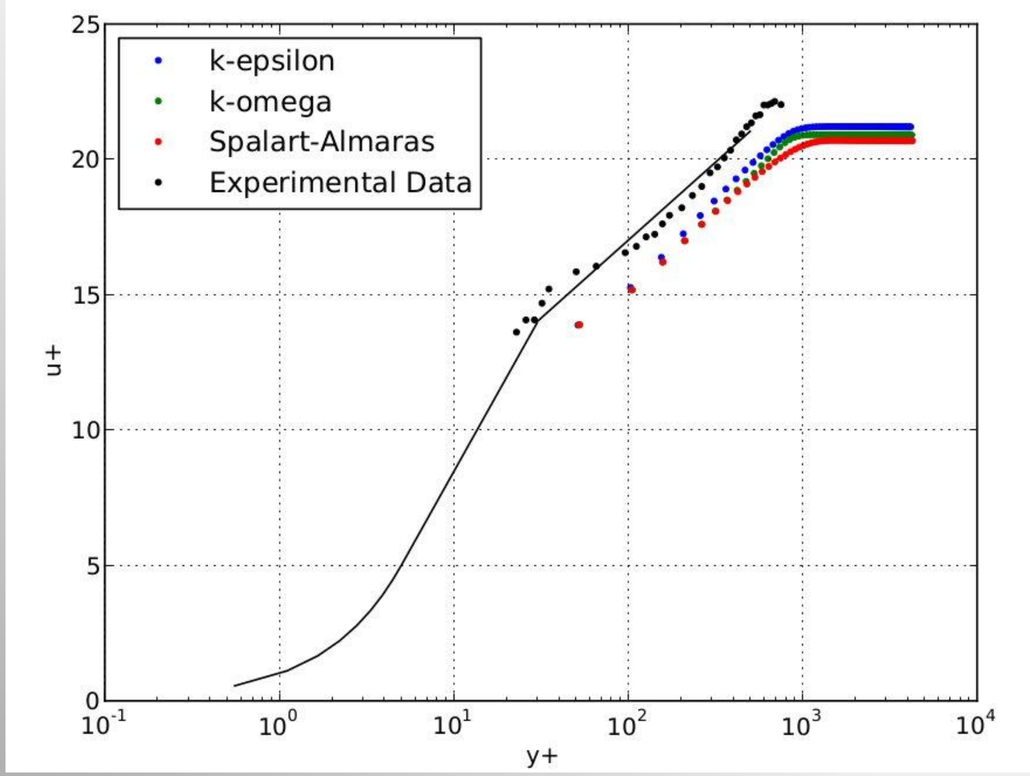
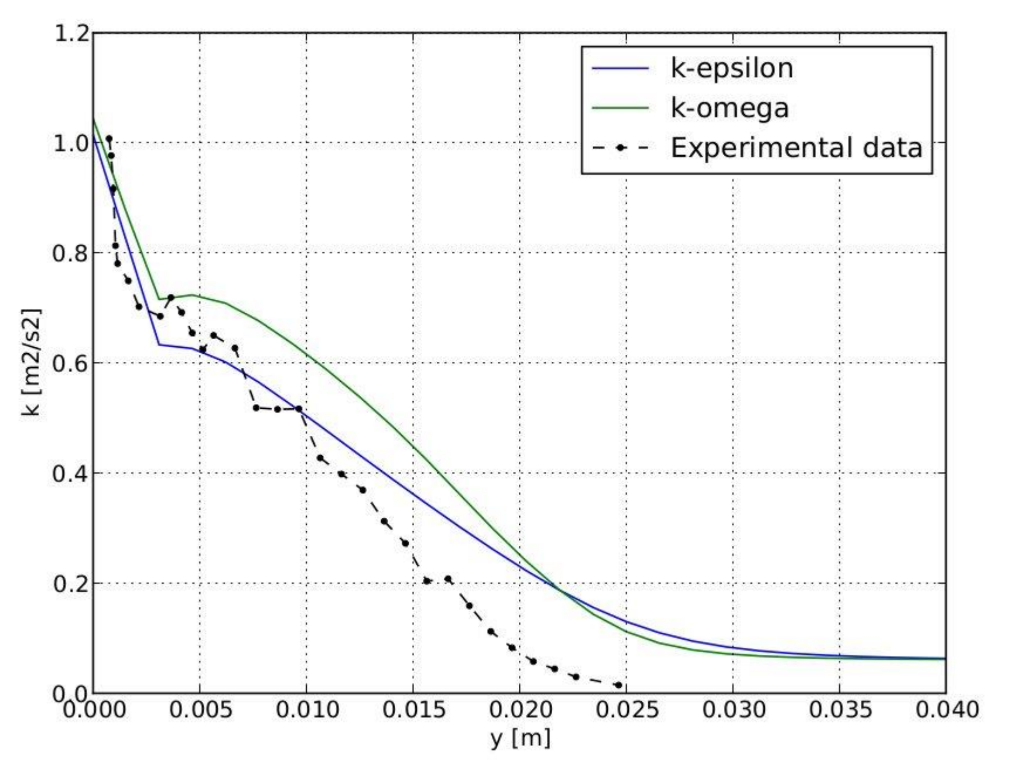
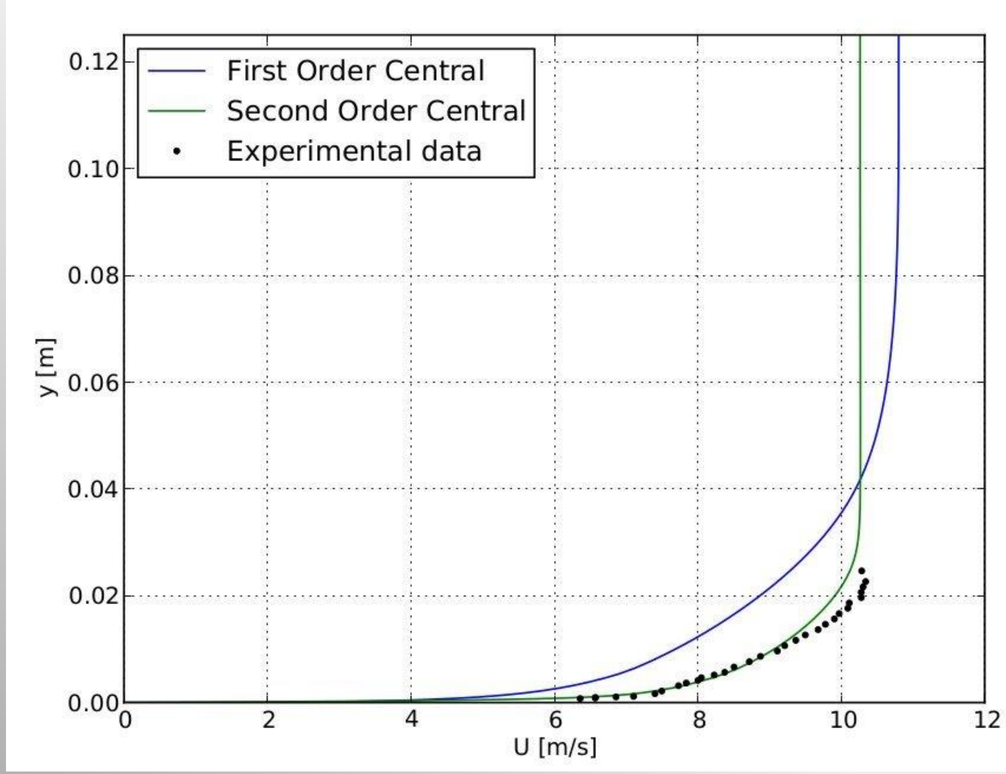
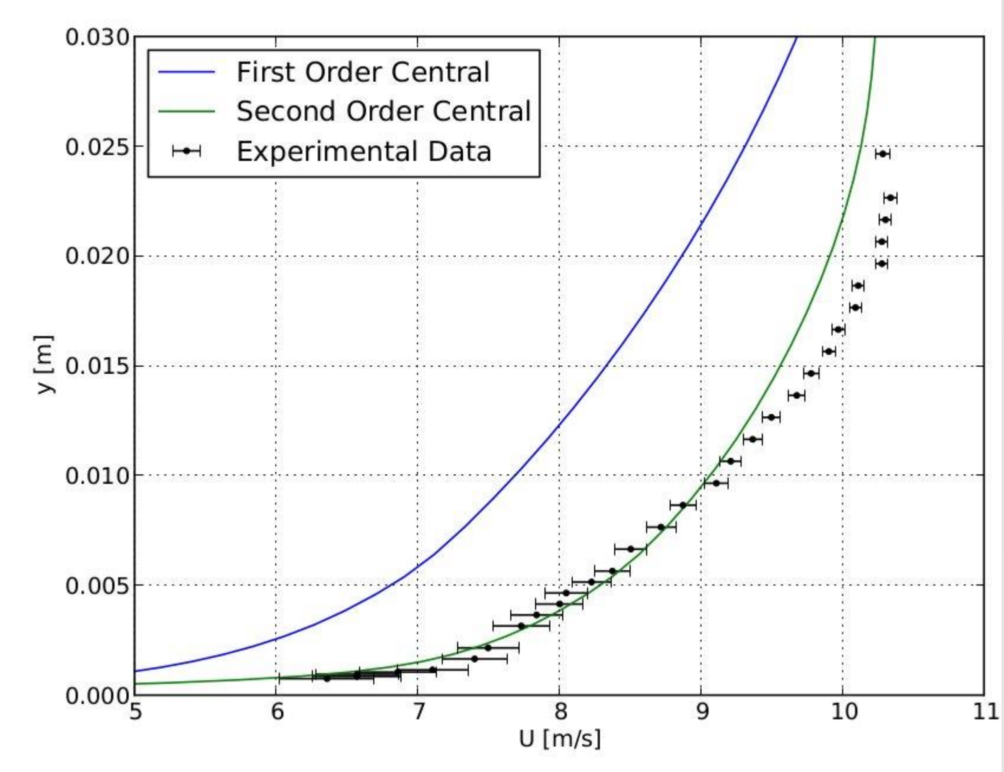




Boundary conditions

Results for different numerical schemes





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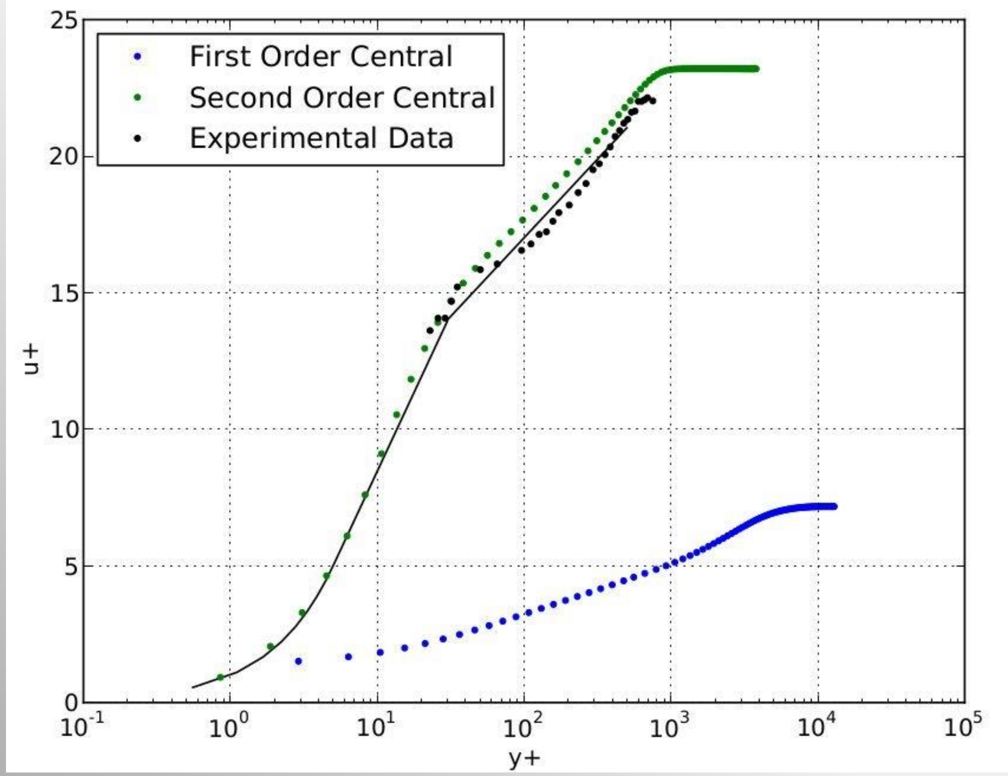
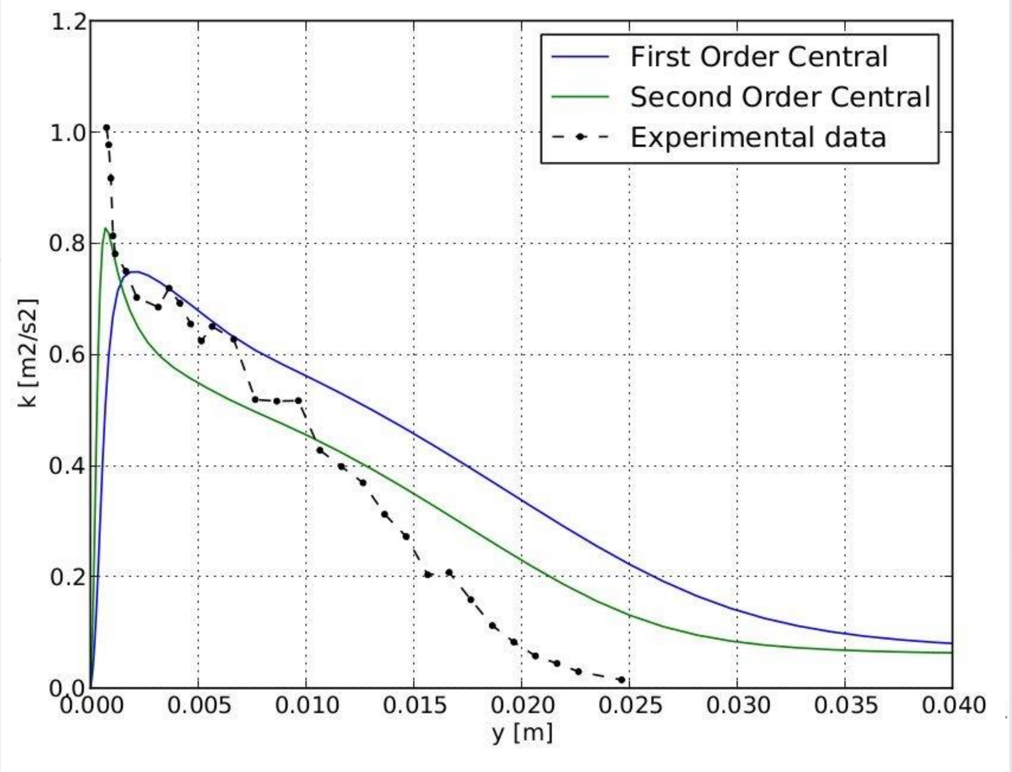
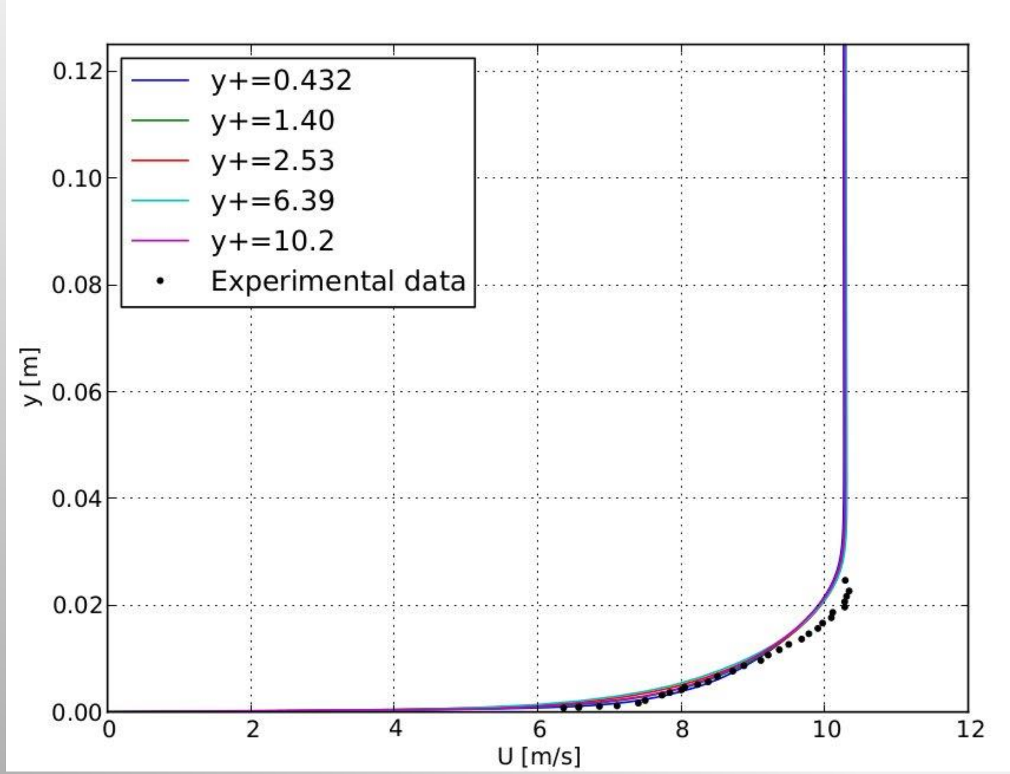
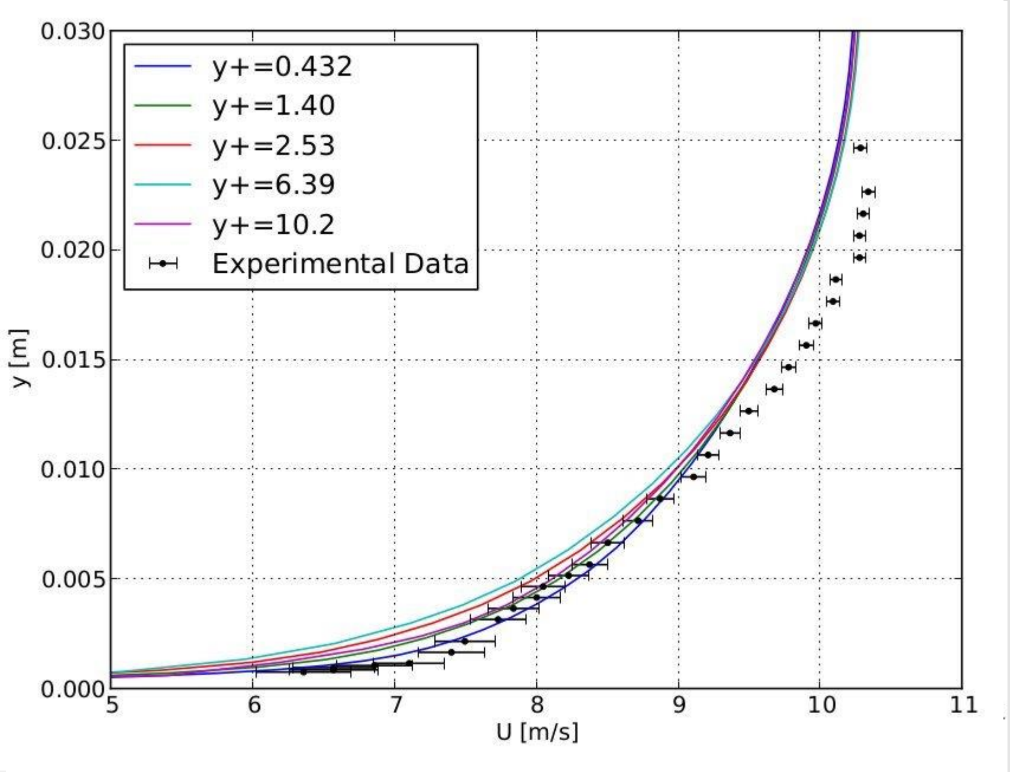




Results for different wall treatments





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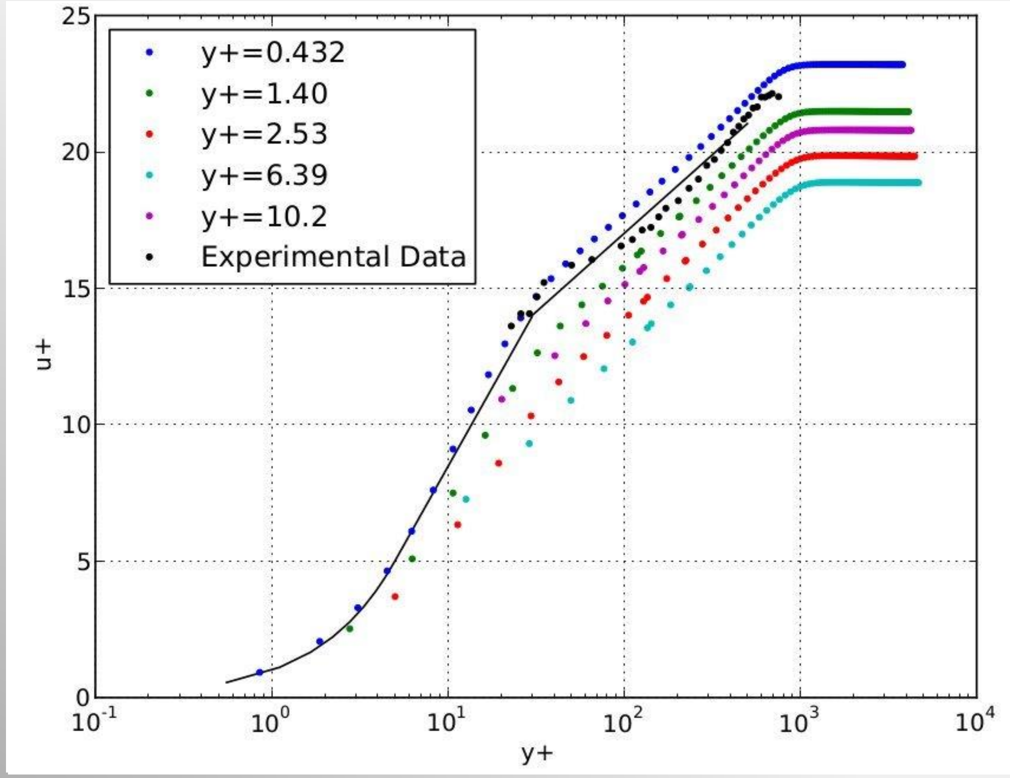

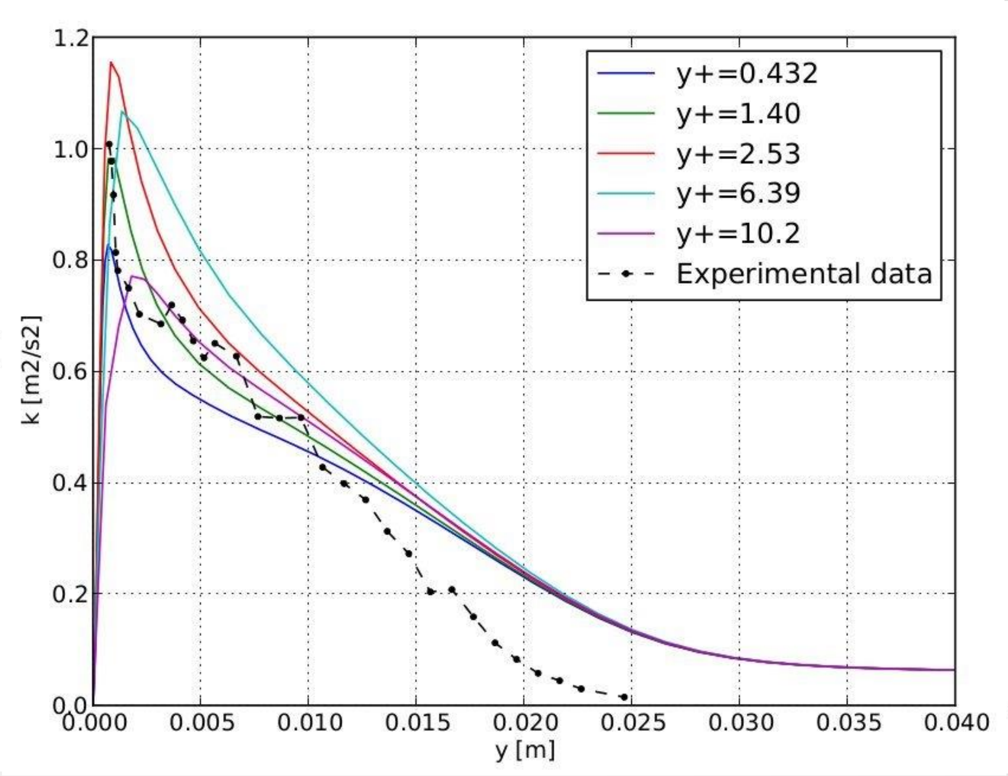

Thanks

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