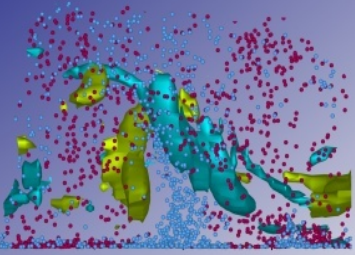
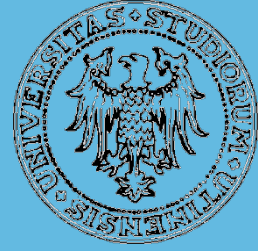


SIMULAZIONE NUMERICA DI UNO SHEAR-LAYER TURBOLENTO



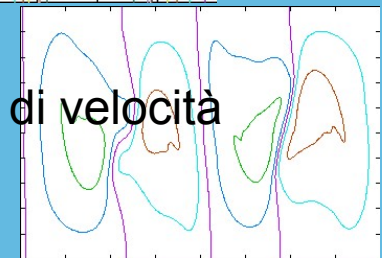
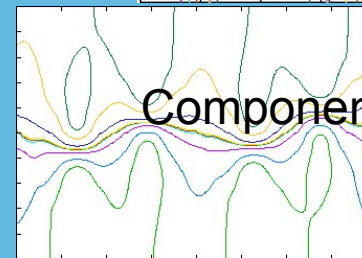
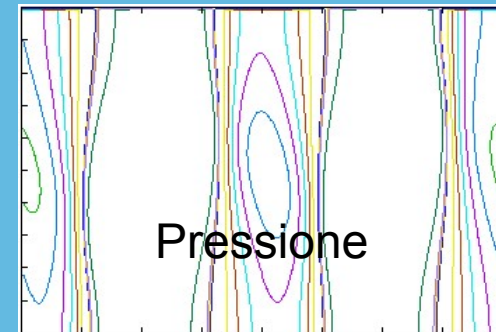
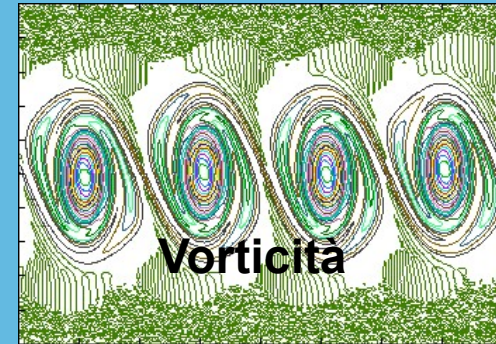


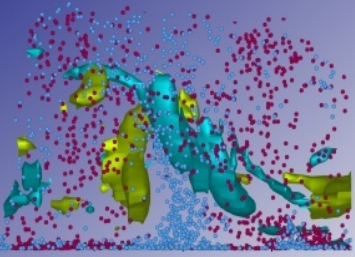
Introduzione



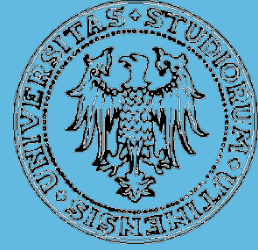
Shear-layer: zona di transizione localizzata fra due getti liberi fra i quali esiste una certa velocità relativa.

Studio parametrico della struttura turbolenta tramite un codice in *Fortran* in cui sono stati variati il **numero di Reynolds** e la **velocità indisturbata** del flusso.



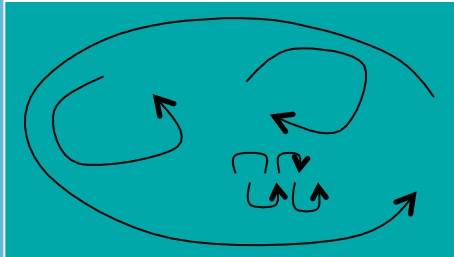


Tecniche numeriche di simulazione della turbolenza

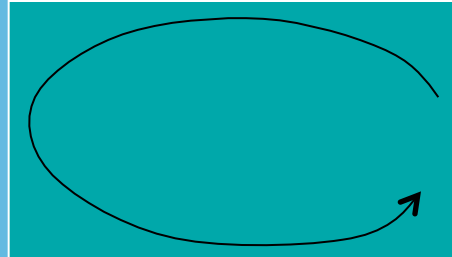


- RANS

Flusso reale

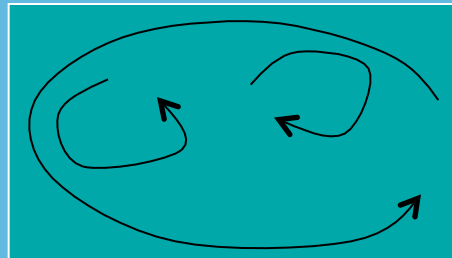
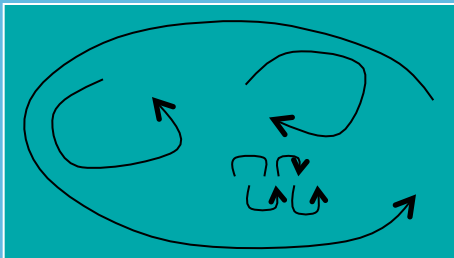


Flusso modellato



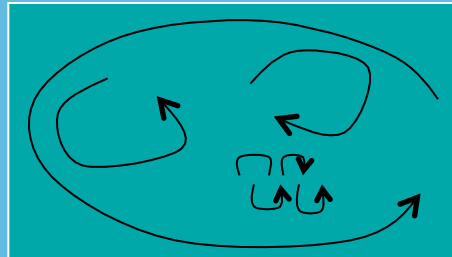
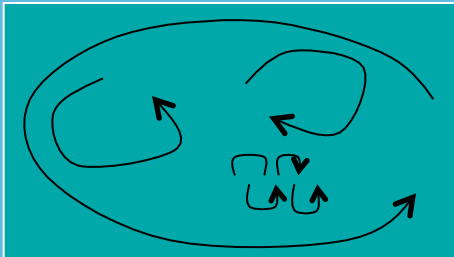
Risolve le strutture di scala maggiore (equazioni mediate nel tempo)

- LES



Risolve le strutture coerenti e modella quelle isotrope (equazioni mediate nello spazio)

- DNS

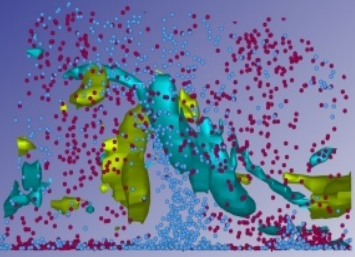


Risolve tutte le strutture senza introdurre modelli

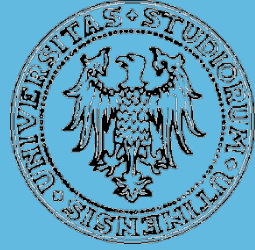
In questa analisi si è utilizzata LES perché:

- Si raggiungono numeri di **Reynolds** relativamente alti (100.000)

- Interesse per le **scale più grandi** del moto che nel caso dello shear-layer sono quelle più importanti perché controllano i meccanismi di trasferimento della massa e della quantità di moto.



Large Eddy Simulation



-Subgrid scale model

Punti griglia:

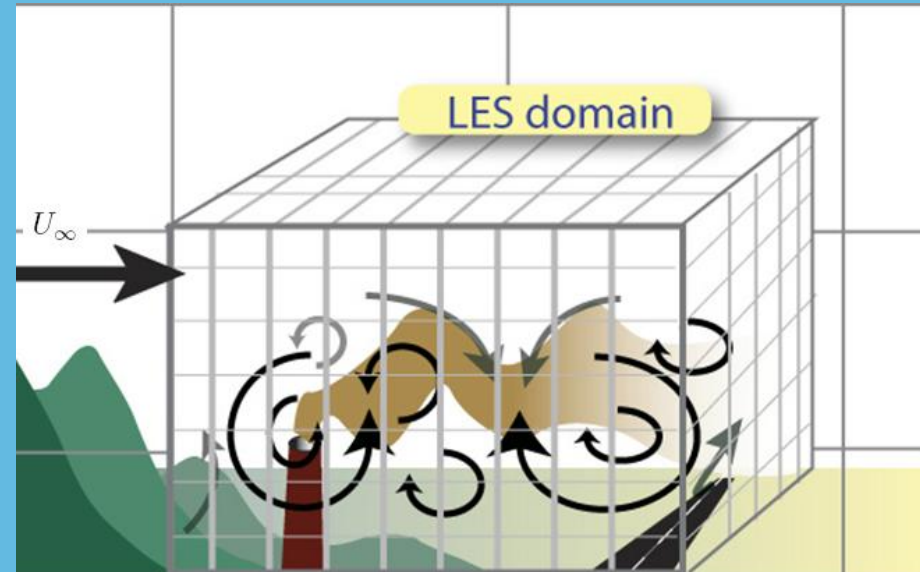
$$X_{\max} = 256$$

$$J_{\max} = 4$$

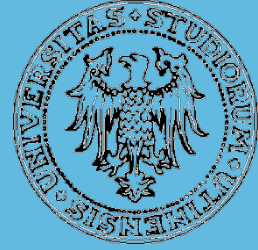
$$K_{\max} = 256$$

-Modelli di turbolenza di sottogriglia

Modello di Smagorinsky



Le equazioni del moto



Continuità:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

Conservazione quantità di moto:

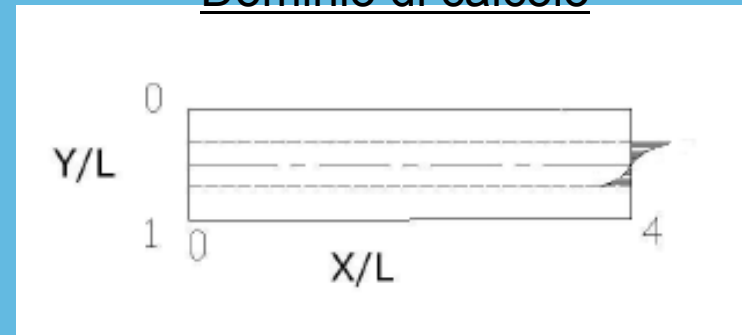
$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_j} u_i u_j = -\frac{1}{\rho} \frac{\partial p}{\partial x_i} + \nu \nabla^2 u_i$$

con $\nu = \nu_{molc} + \nu_t$

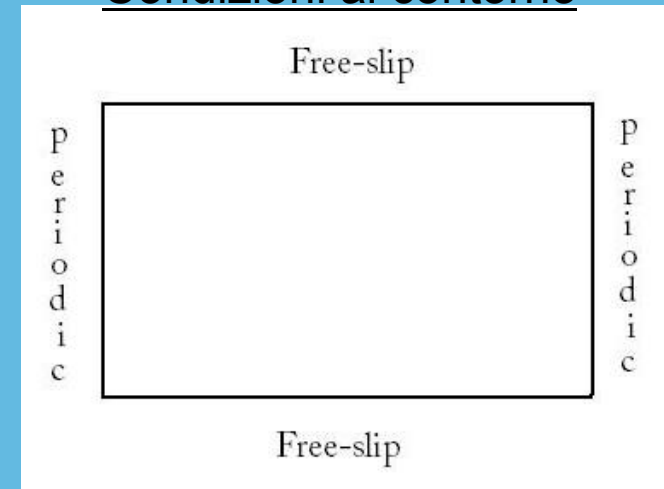
Viscosità turbolenta (Modello di Smagorinsky)

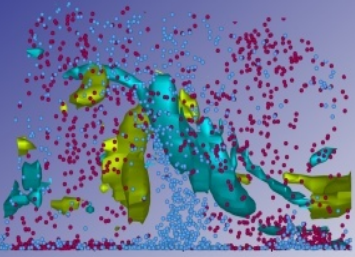
$$\nu_t = (C_s \Delta)^2 \sqrt{\frac{1}{2} S_{i,j} S_{i,j}}$$

Domaino di calcolo

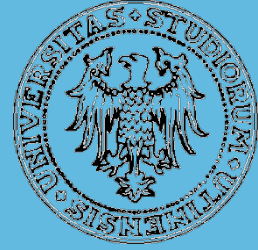


Condizioni al contorno

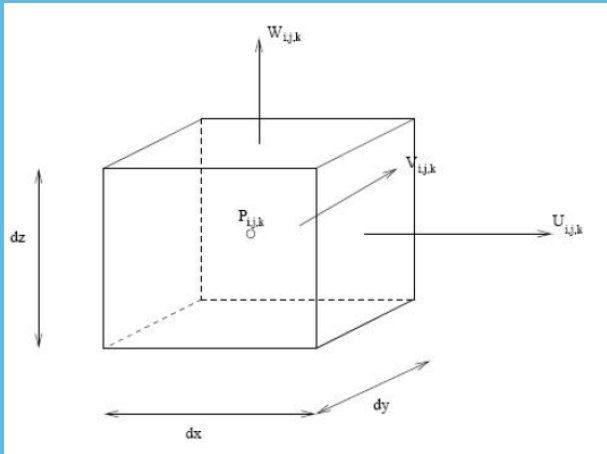




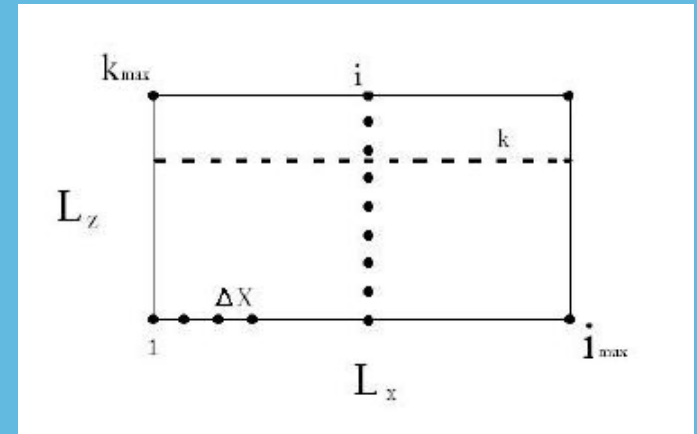
Discretizzazione



Cella della griglia di calcolo



Schema 2D della griglia



$$\Delta x = \frac{L_x}{i_{max}}$$

$$\Delta y = \frac{L_y}{j_{max}}$$

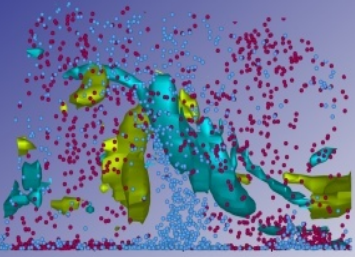
$$\Delta z = \frac{L_z}{k_{max}}$$

$$\nabla(u, v, w) = \frac{1}{dx}(U_{i,j,k} - U_{i-1,j,k}) + \frac{1}{dy}(U_{i,j,k} - U_{i,j-1,k}) + \frac{1}{dz}(U_{i,j,k} - U_{i,j,k-1})$$

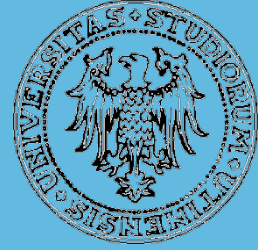


$$\frac{\partial p}{\partial x} = \frac{1}{dx}(P_{i+1,j,k} - P_{i,j,k})$$





Integrazione nel tempo



$$y^{n+1} - y^n = h(a f^n + b f^{n-1})$$

con $y' = f$

Algoritmo di
Adam-Bashfort

Essendo:

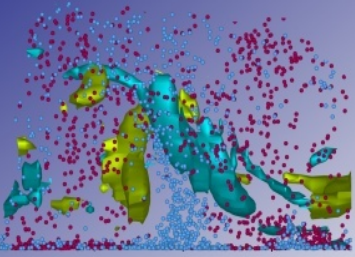
$$a + b = 1 \text{ e } b = -0.5$$

Per i termini di pressione:

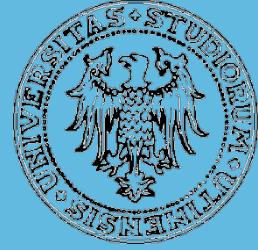
$$\Delta t \nabla^2 P^{n+1} = \text{div}(u^*)$$

Dalla cui discretizzazione si ottiene:

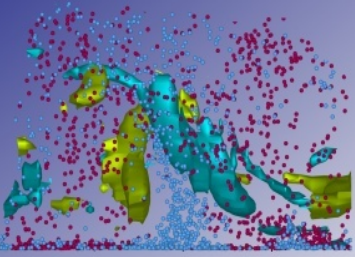
$$\frac{P_{i+1,j,k} - 2P_{i,j,k} + P_{i-1,j,k}}{dx^2} + \frac{P_{i,j+1,k} - 2P_{i,j,k} + P_{i,j-1,k}}{dy^2} + \frac{P_{i,j,k+1} - 2P_{i,j,k} + P_{i,j,k-1}}{dz^2} = \frac{1}{dt} \left(\frac{u_{i,j,k}^* - u_{i-1,j,k}^*}{dx} + \frac{v_{i,j,k}^* - v_{i,j-1,k}^*}{dy} + \frac{w_{i,j,k}^* - w_{i,j,k-1}^*}{dz} \right);$$



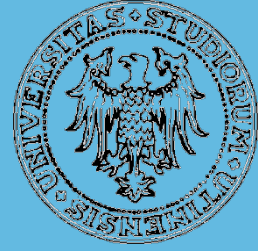
Parametri del Fluido



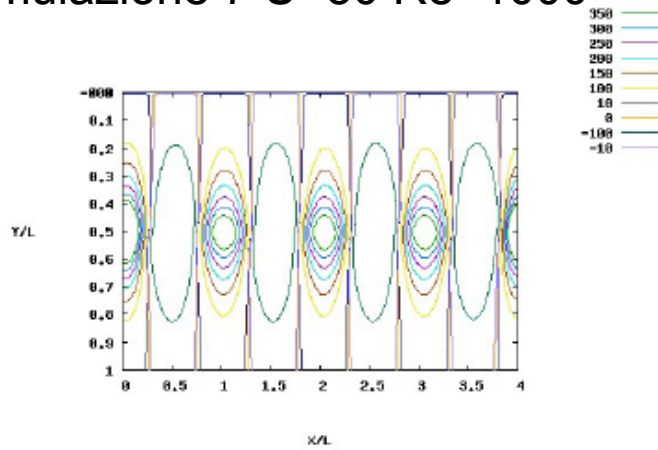
Simulazione	Velocità U_∞	Numero di Reynolds	Numero Time step	Total mill time
1	25	10	5000	0.1006210
2	25	100	5000	0.3002787
3	25	1000	3000	0.2022880
4	25	10000	3000	0.1454996
5	1	1000	3000	3.847478
6	5	1000	3000	0.9983597
7	50	1000	3000	0.1353284
8	125	1000	3000	$3.0382756 \cdot 10^{-2}$



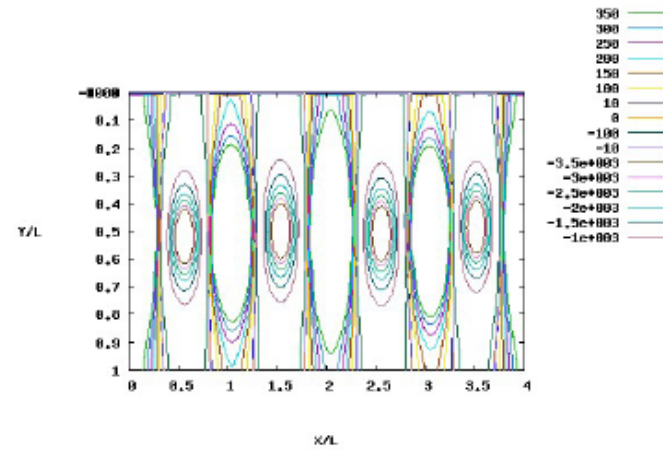
Andamento della pressione



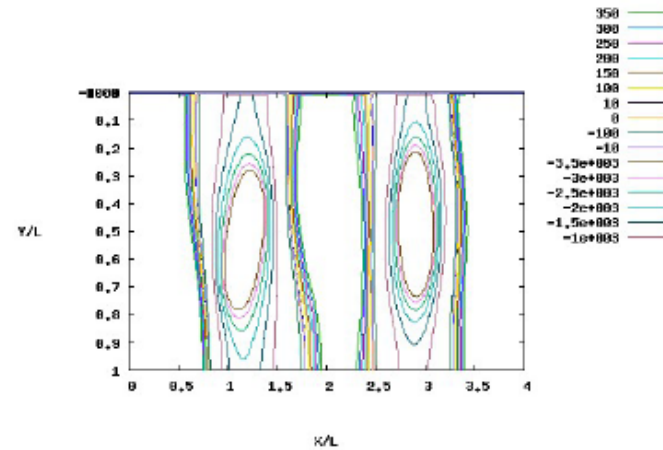
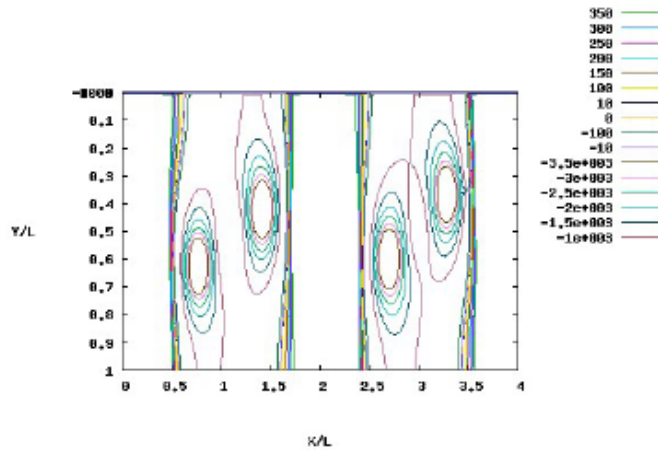
Simulazione 7 $U=50$ $Re=1000$

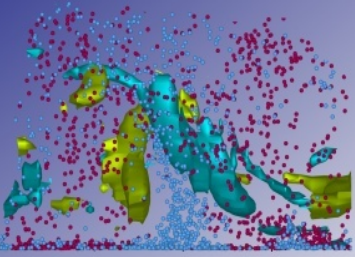


(a) 000083

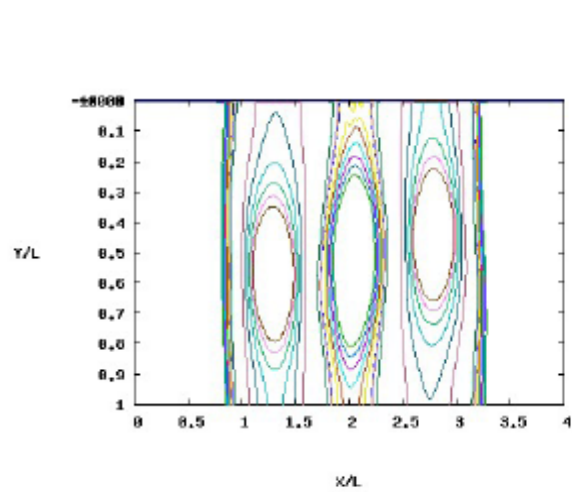
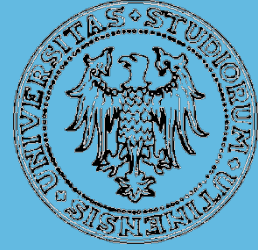


(b) 000915

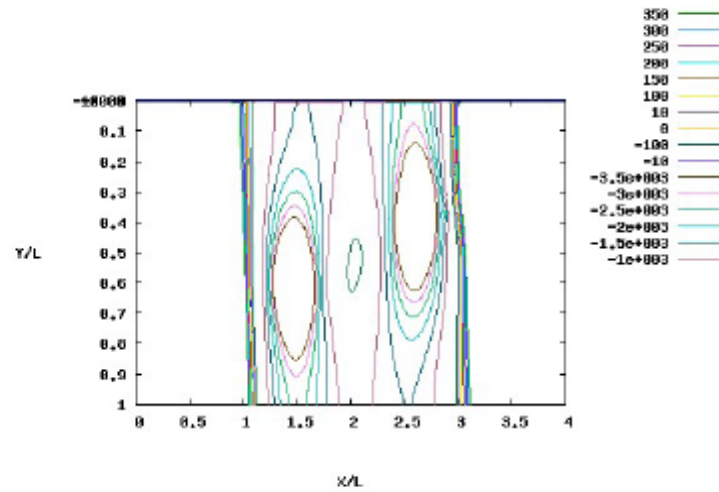




Andamento della pressione

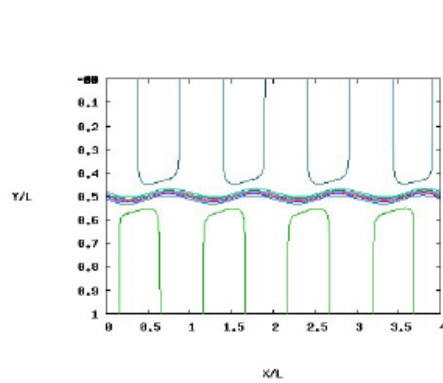
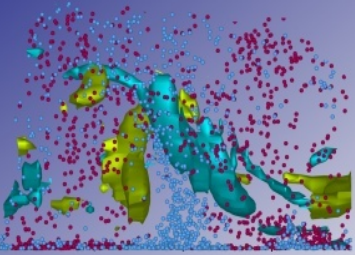
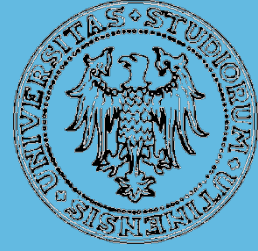


(e) 004131

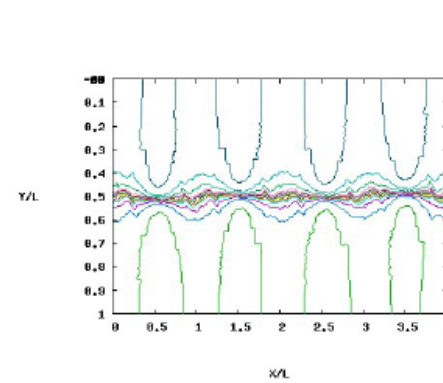


(f) 005000

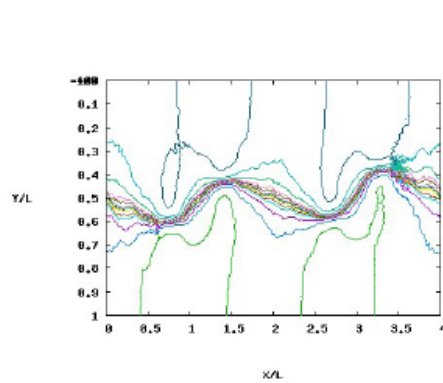
Componente orizzontale della velocità



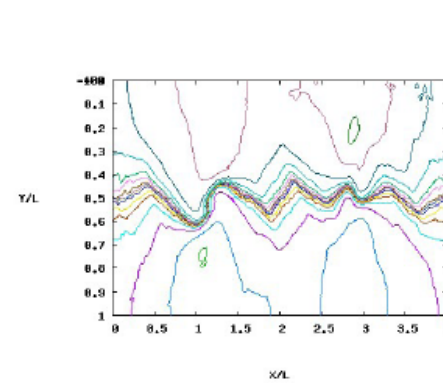
(a) 000083



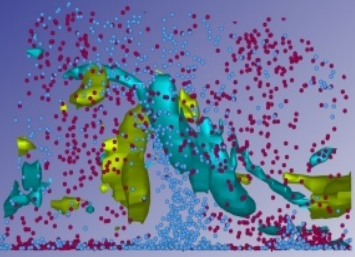
(b) 000915



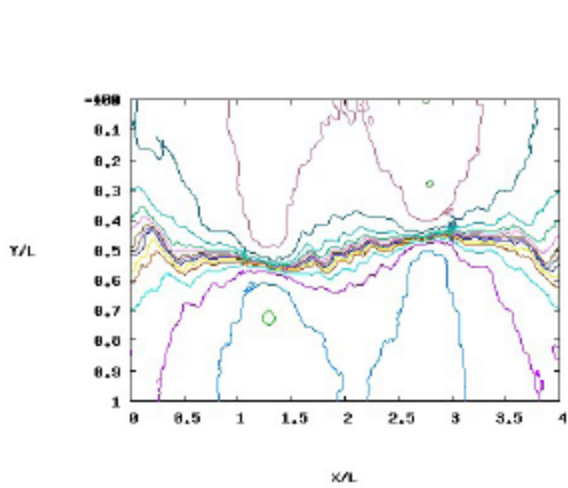
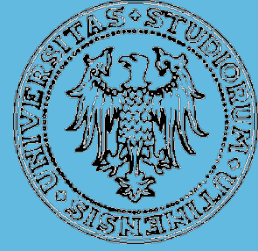
(c) 002103



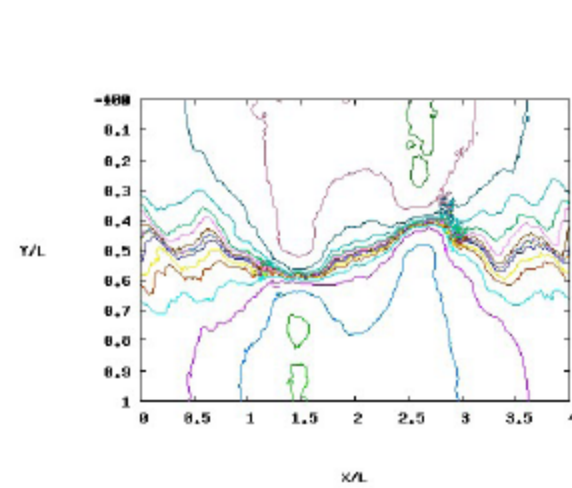
(d) 003297



Componente orizzontale della velocità

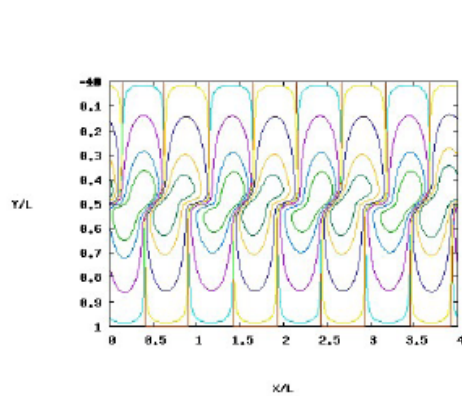
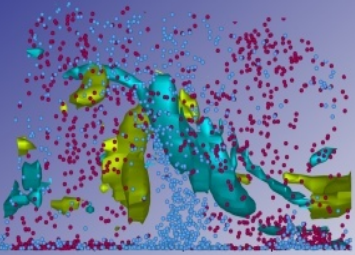
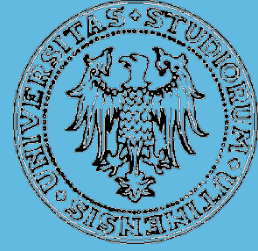


(e) 004131

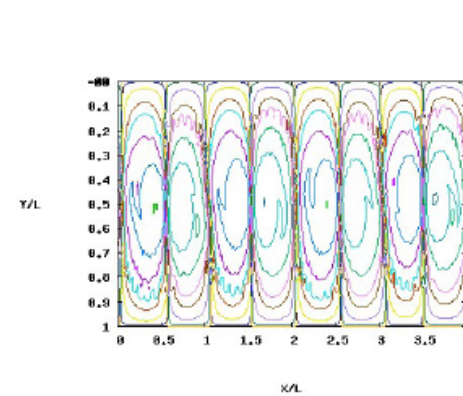


(f) 005000

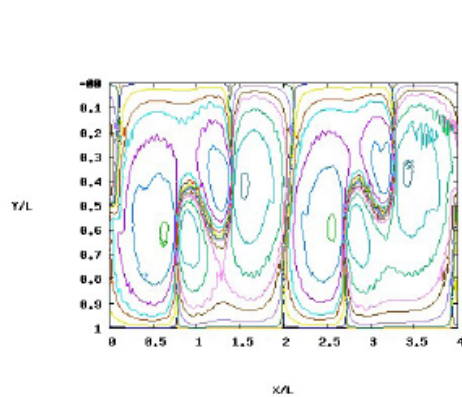
Componente verticale della velocità



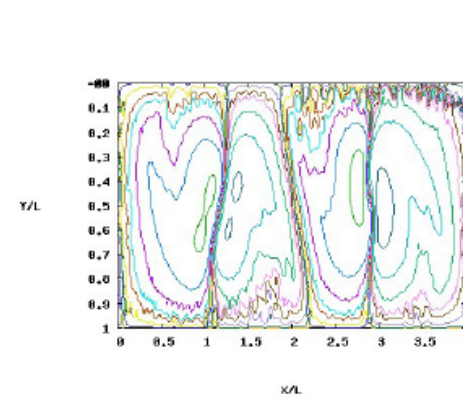
(a) 000083



(b) 000915

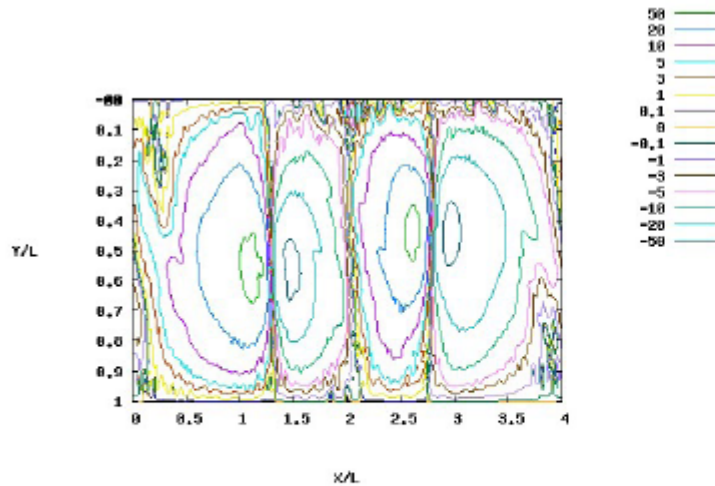
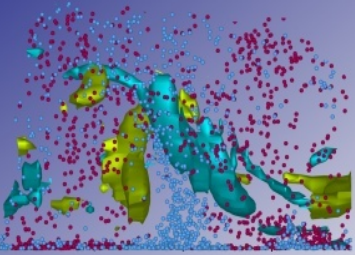
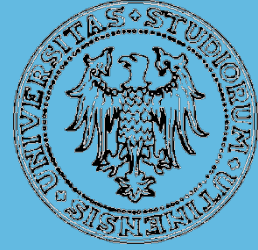


(c) 002103

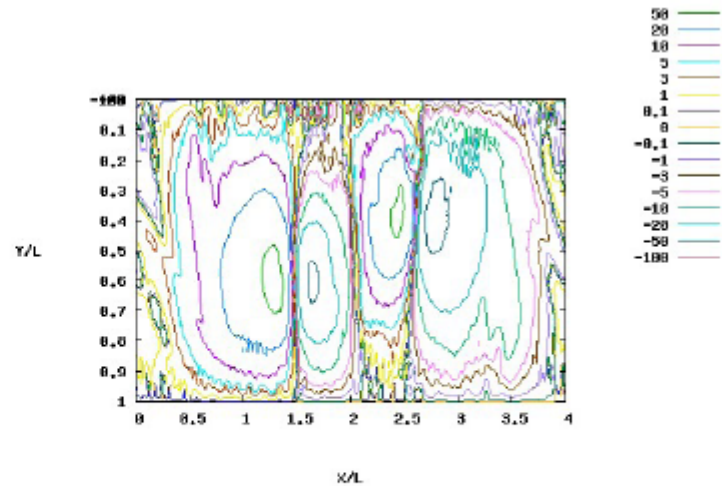


(d) 003297

Componente verticale della velocità



(e) 004131



(f) 005000