Turbulent drag reduction over an oscillating wall

by

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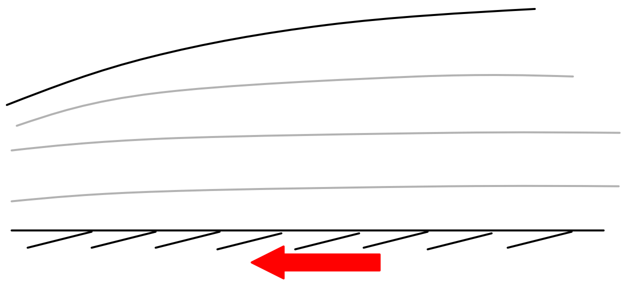
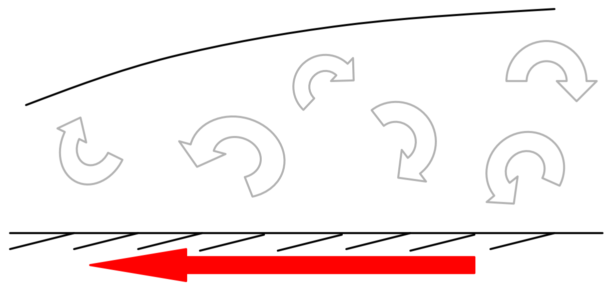
Problem:



Laminar boundary layer



Turbulent boundary layer

$$\tau_{\mathbf{lam}} \ll \tau_{\mathbf{turb}}$$

Techniques **to reduce turbulence**

Reduce wall friction drag

Drag reduction techniques

Passive: **- Geometrical modifications**
- Injection of solutions into the flow

-Riblets - (Low Re)	5-10 %
-LEBU -	5 %
-Polymers - (High Re)	80 %

Active: **- Energy is introduced into the system**

-Local instantaneous suction-blowing 20 - 25%

Choi, Moin, Kim JFM 1994 vol. 262.

-Oscillating wall **-**

anwise wall velocity:

$$W = W_m \sin\left(\frac{2\pi t}{T}\right)$$

Pur ose o resent research or

uantify the effects of wall oscillation on turbulent structure

etermine de endence of amount of drag reduction on T and m

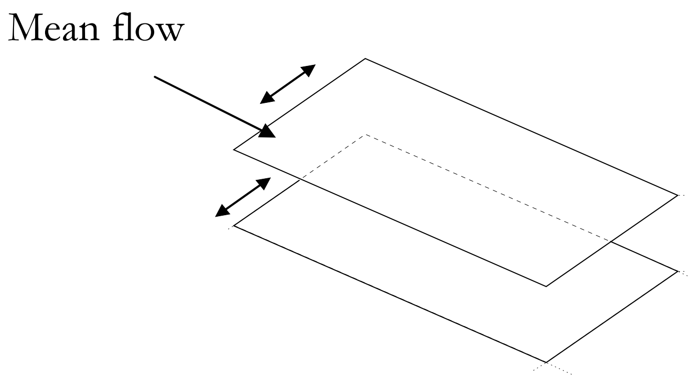
et energy savings

caling arameter

irect numerical simulation

D code and com uting system

- ncom ressible ull a ier- to es equations in cartesian coordinates
- Plane ressure-dri en turbulent channel low
- ertical elocity and ertical orticity ormulation ressure is absent
- ourier trans orms in homogeneous *x* and *z* directions
- ourth-order *compact* inite di erence schemes in *y*
- High accuracy ***±1% of wall friction.***



Low-cost arallel com uting
Low communication time

Physical roblem and discretization

- all boundary condition on -com onent

$$W = W_m \sin\left(\frac{2\pi t}{T}\right)$$

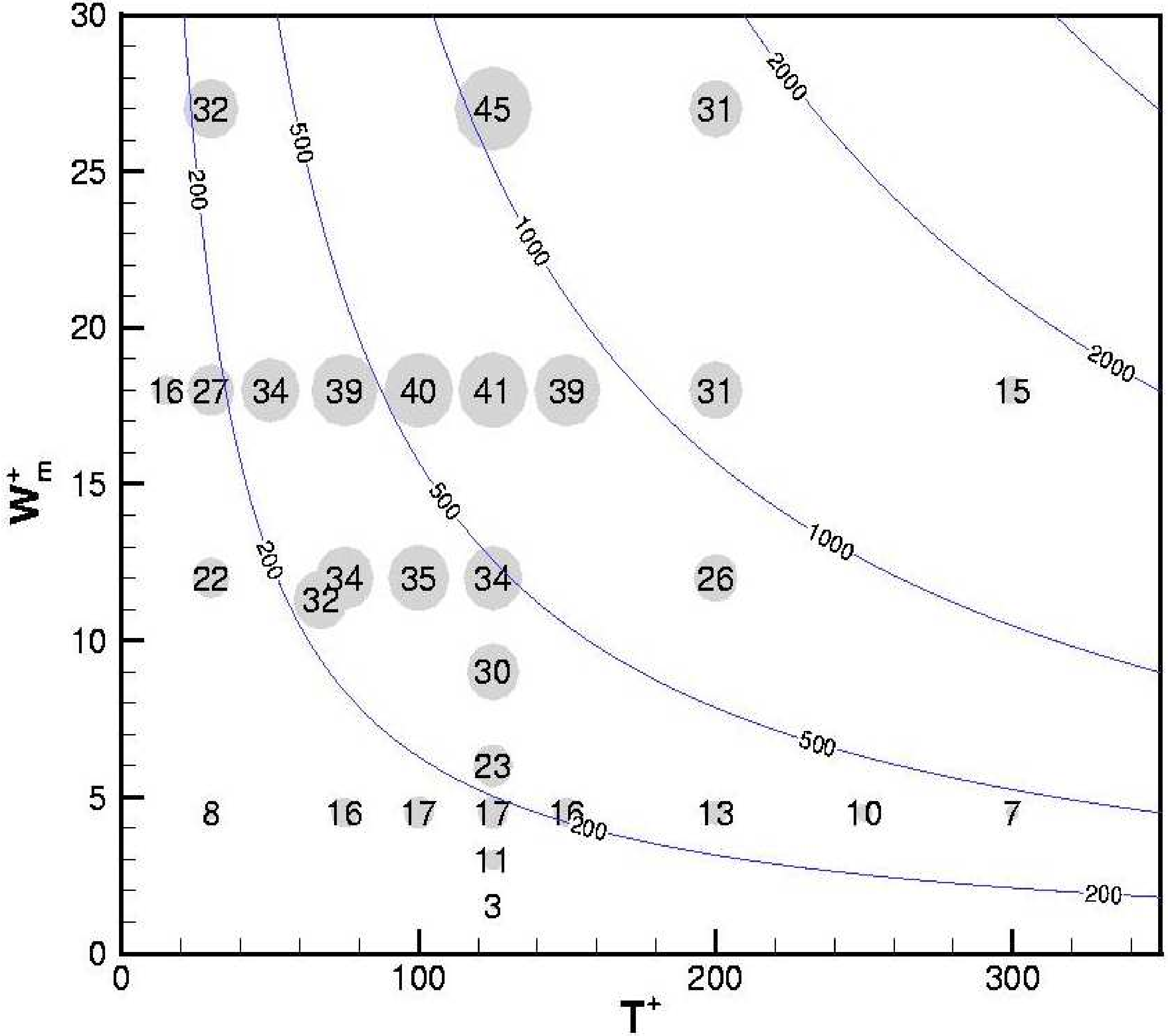
- Reynolds number o the low Re_τ 200

- x-discreti ation ourier modes Δx^+ 1 1
- z-discreti ation ourier modes Δz^+ 5
- y-discreti ation collocation oints Δy^+ 0 8 5

- L_x 21 h
- L_z 2 h

- Total integration time or run t^+ 8 00
- Time discreti ation Δt^+ 0 1

bsolute drag reduction



a imum R:

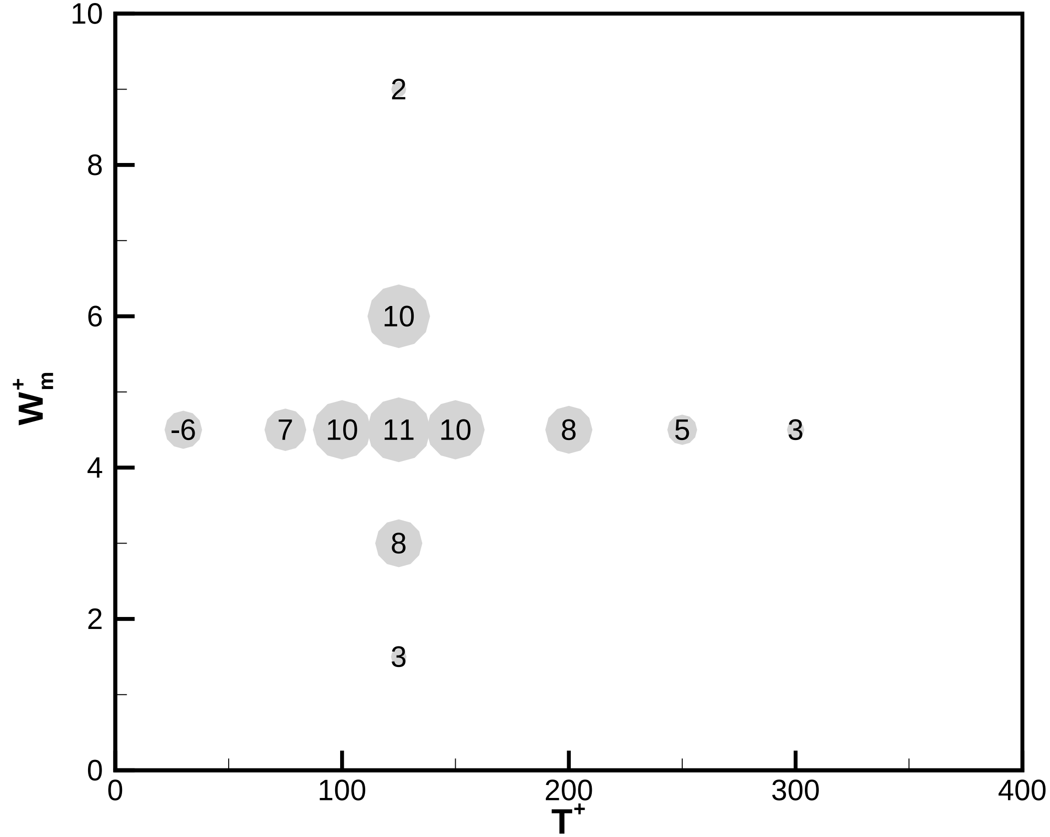
PTI T :
T

scaling with

har contrast
with e eriments

Good agreement
with numerical wor s

et energy sa ings



- rucial **ET** energy sa ing considering P ER T E THE LL
- Balance between P and P ne er studied in detail be ore

- **ET** energy sa ing is ossible result o RE T im ortance a imum gain + 5 and T^+ 125
- ain is ossible or **T** and or **m**
- **A RA I T E E ERE**

caling arameter

- m ortance to determine a scaling arameter **f** **m** **T**
- ost o e erimentalists ERR E U L thin is the ey
- e ha e shown R de ends on both and T

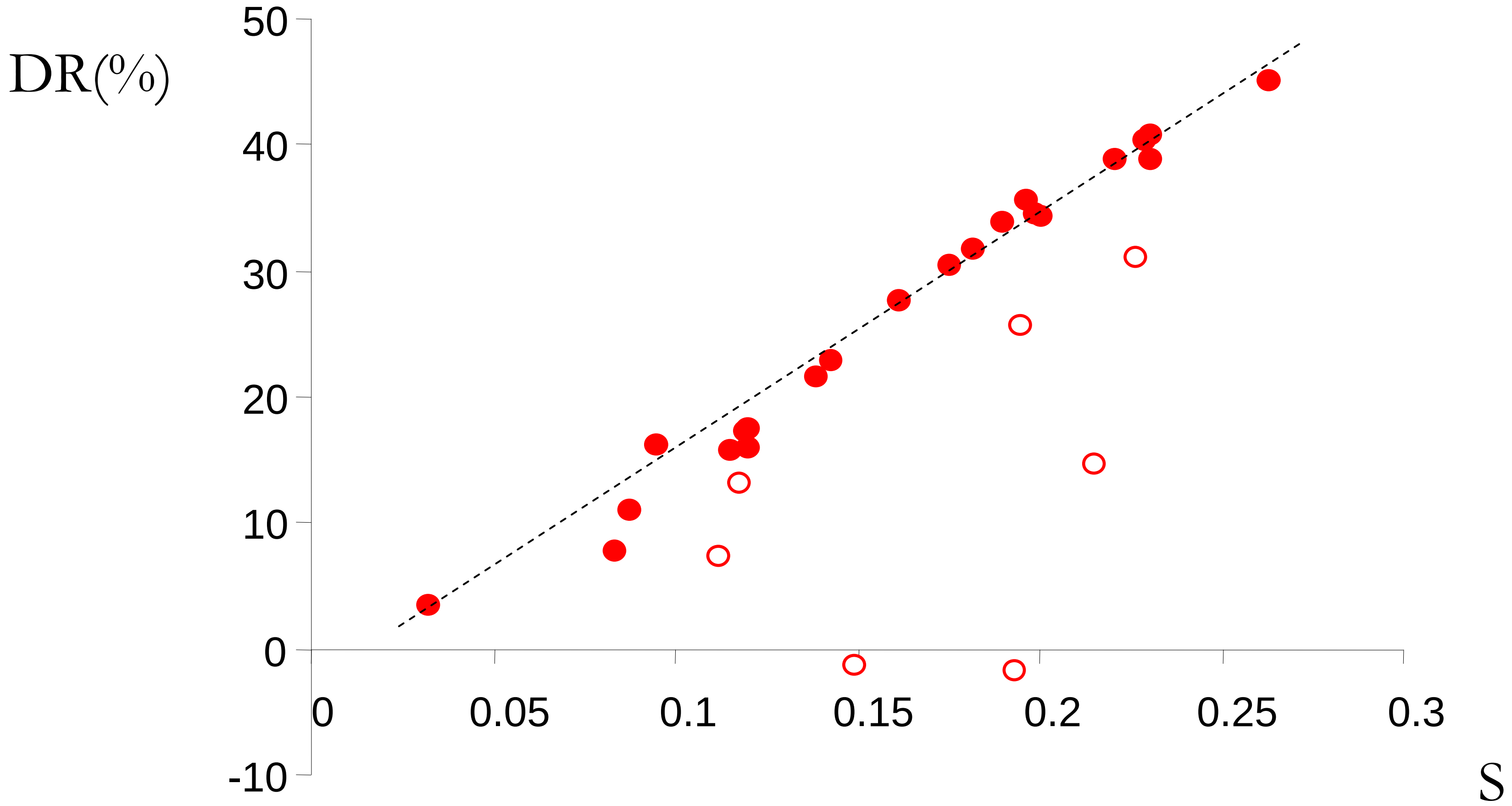
DR y$_{CR}$ STOKES

y is a critical height where turbulent structures are affected

A is acceleration of to es layer

$$S_{DR} = \ln(W_m{}^+)\sqrt{\frac{2\pi}{T^+}}e^{-y_{CR}{}^+\sqrt{\frac{\pi}{T^+}}}$$

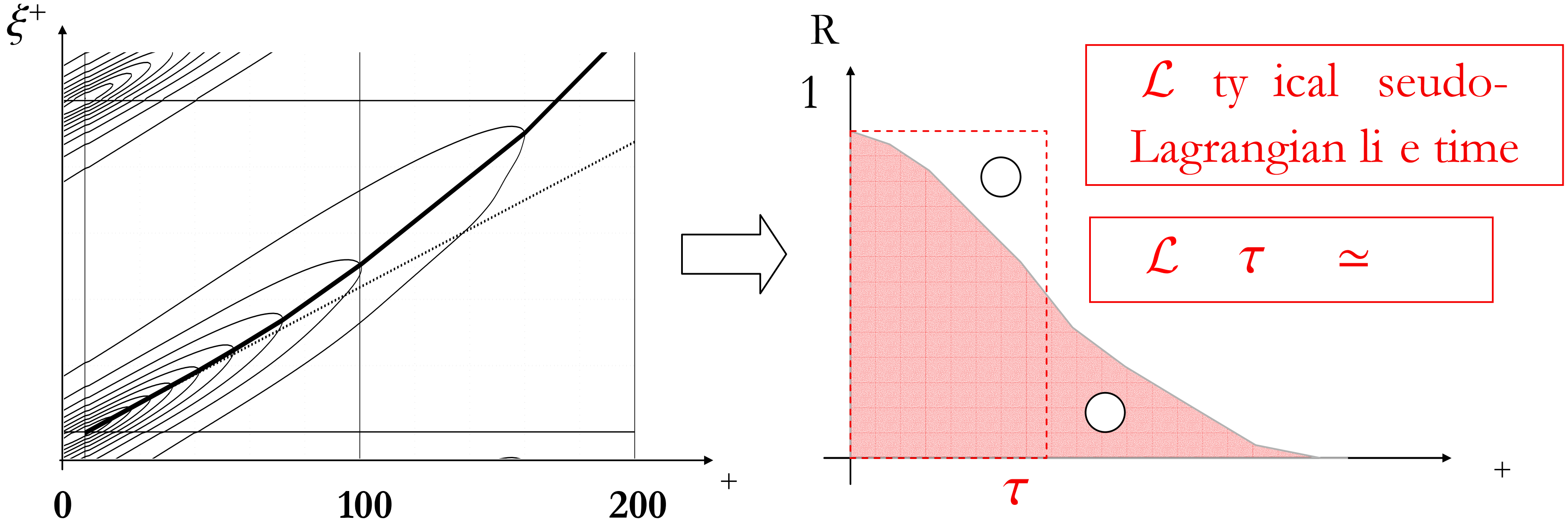
caling arameter



- **E cellent agreement** or T^+ 150 correlation coe icient ≃ 1

- **ad agreement** or T^+ 150

hy is the correlation dro ing or +



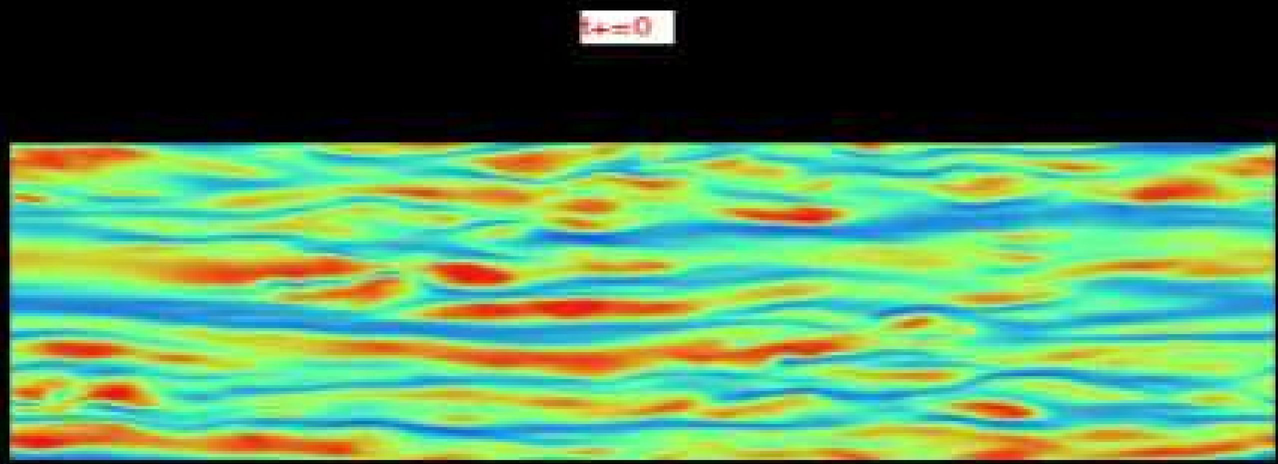
Re uadrio Luchini y c o ugust 200 ol 15 n 8

T ℒ Turbulence structures ha e enough time to de elo their dynamics and re-establish natural turbulence cycle hence natural drag

T ℒ nteraction is not strong enough correlation is high but R is low

T ≃ ℒ Perfect matching high correlation and high R

O O O + m



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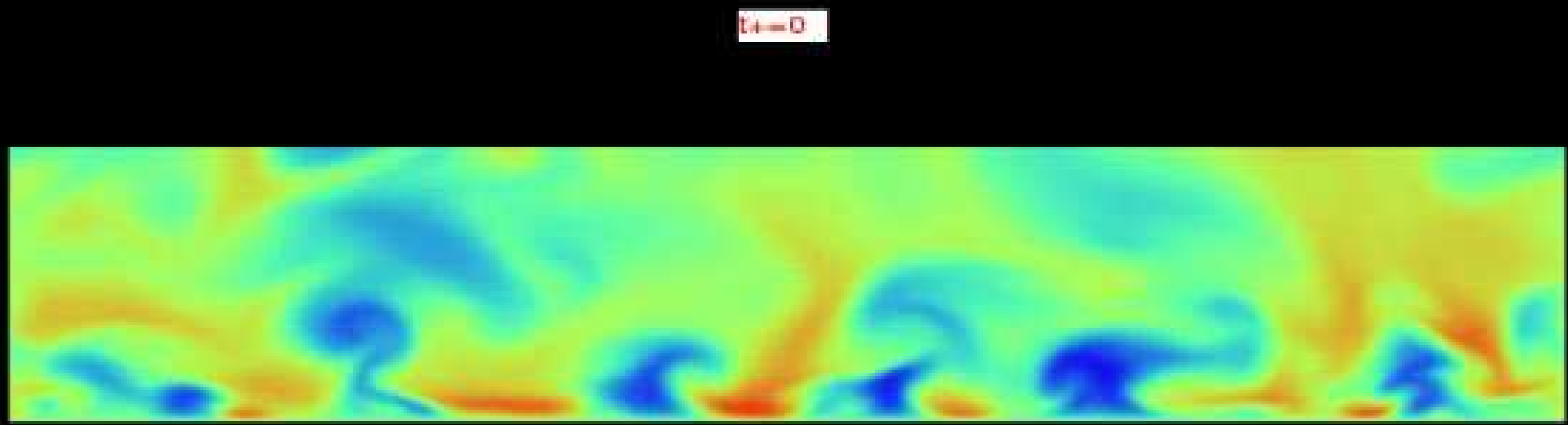

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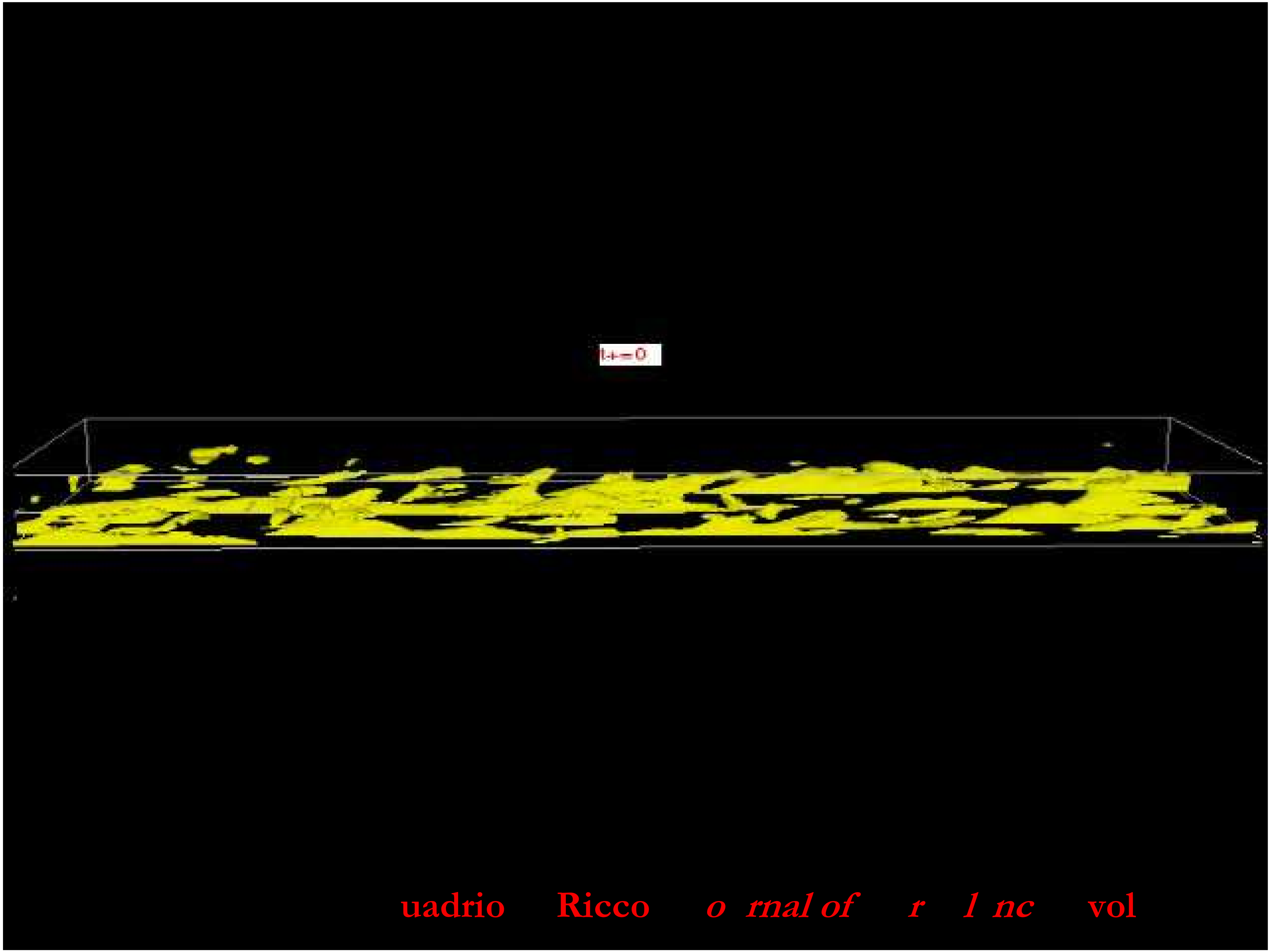
uadrio Ricco o rnal of r l nc vol

onclusions

-Precise determination o drag reduction de endence on oscillation
  arameters $^+$ and T^+
- **ET** energy sa ing is P   BLE
- caling arameter has been ound
- umerical isuali ations o turbulent ield rom start-u   o oscillation

uture   or

- nnular geometry
-Reynolds number e ect on drag reduction ro erties
-   timi ation o oscillating motion