Time-resolved evolution of the wall-bounded vorticity cascade

Adrián Lozano-Durán & Javier Jiménez

Computational Fluid Dynamics Lab, Universidad Politécnica de Madrid, Spain

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**Numerical Experiments & Vortex Clusters**

<table>
<thead>
<tr>
<th>$\text{Re}_\tau$</th>
<th>$L_x/h$</th>
<th>$L_z/h$</th>
<th>$N_F$</th>
<th>$T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>950</td>
<td>$\pi$</td>
<td>$\pi/2$</td>
<td>$10^4$</td>
<td>10</td>
</tr>
</tbody>
</table>

**Numerical Experiments**
DNS in Channel

**Vortex Clusters**

\[ D(x) > \alpha D'(y) \]

sponge of strings
Tracking Method

1) Look for cluster intersections

2) Sort clusters in branches

An example

Volume

time

Branch

Branch
Lifetimes & Wall-normal Displacement

\[ T \propto V^{1/3} \]

Volume\(^+\)

\[ y_{\text{end}}^+ \]

\[ y_{\text{origin}}^+ \]

\[ y_{\text{origin}} \rightarrow y_{\text{end}} \]
Smooth Growth & Decrease vs. Cascade

Smooth

Cascade

$V_{\text{max}}$

t

$V_{\text{max}}^+$

fraction

Cascade

Smooth

15$\eta$

$\sim 5\%$

$10^0$

$10^{-1}$

$10^{-2}$

$10^4$

$10^6$

Growth

Decrease

mergers

splits

p.d.f.

t

lifetime

0

0.2

0.4

0.6

0.8

1

0

0.5

1

1.5
Volume Fractions during the Cascade

\[
\begin{align*}
V_{\text{min}} / V_{\text{max}} & \\
\text{splits} & \\
\text{mergers} & \\
\text{viscous interactions} & \\
\text{random interactions} & \\
d \sim 7\eta & \\
V_{\text{max}} & \\
V_{\text{min}} & 
\end{align*}
\]
Conclusions

1. We can track in time 3D coherent structures.
2. Their lifetimes are proportional to the cube root of the maximum volume attained by them.
3. Their probability of moving away from the wall is only slightly higher than that of moving towards it and independent of their inception.
4. Vortex clusters grow and decay mostly by mergers (inverse cascade) and splits (direct cascade) if their size is above $15\eta$.
5. Both mergers and splits look quite similar except for some differences near the viscous scale.
6. Splits happen at all times.
7. Mergers happen most probably at the beginning of the life.