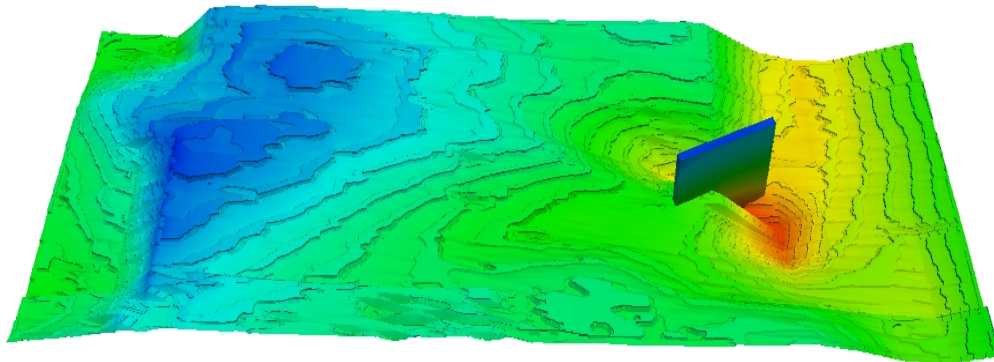


SUBMERGED VANES TURBULENCE

EXPERIMENTAL ANALYSIS

by

Khaled M. A. Hamad Mohamed



A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
PhD. In Civil Engineering

Supervised by:

Prof. Dr. Allen Bateman P.



GRUP D'INVESTIGACIO EN MODELITZACIO DE CONQUES I
TRANSPORT DE SEDIMENTS



Escola Tècnica Superior d'Enginyers
de Camins, Canals i Ports de Barcelona

UNIVERSITAT POLITÈCNICA DE CATALUNYA

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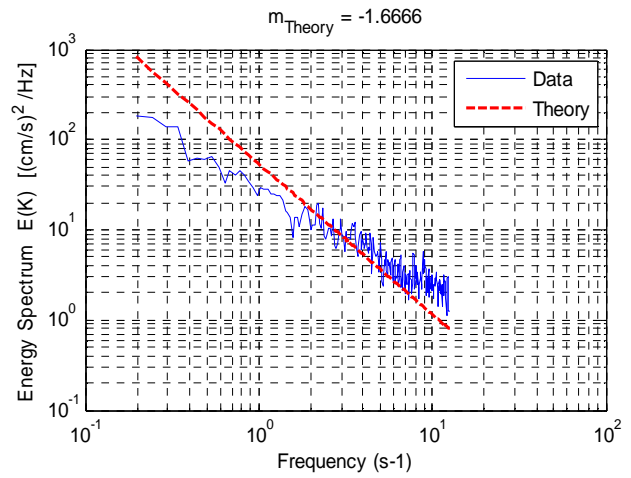
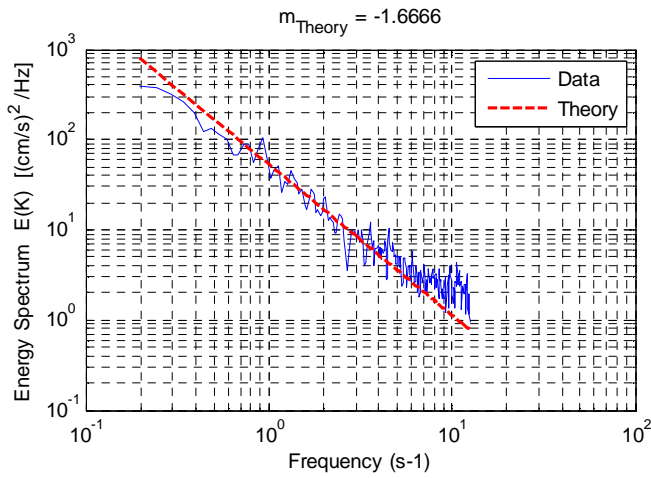
June 2015

APPENDIX D.

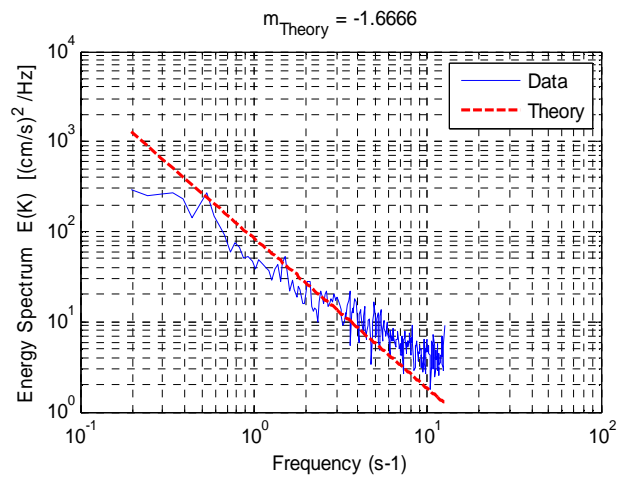
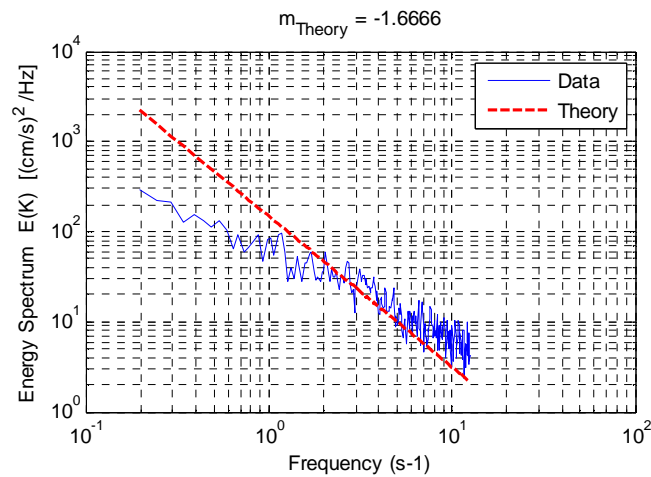
RESULTS – SUBMERGED VANES ADVANCED TURBULENCE

Appendix D Results – Submerged Vanes Advanced Turbulence

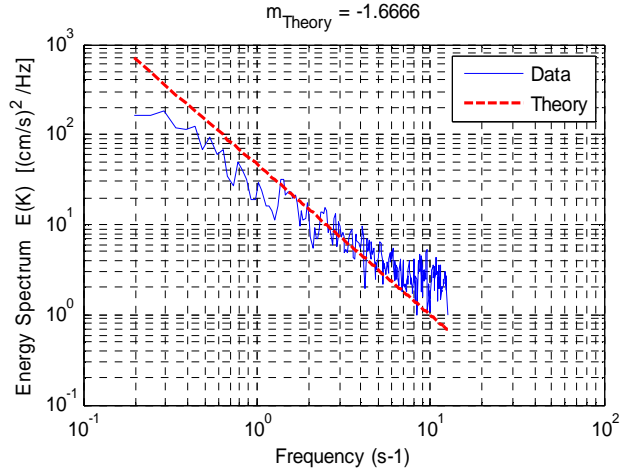
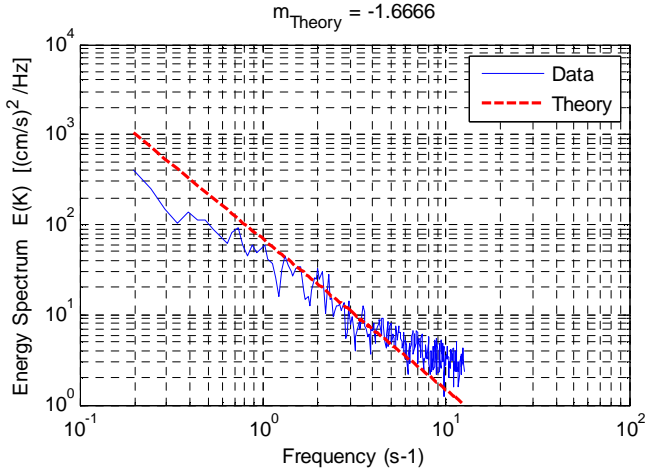
D.1 Kinetic Energy Spectrum



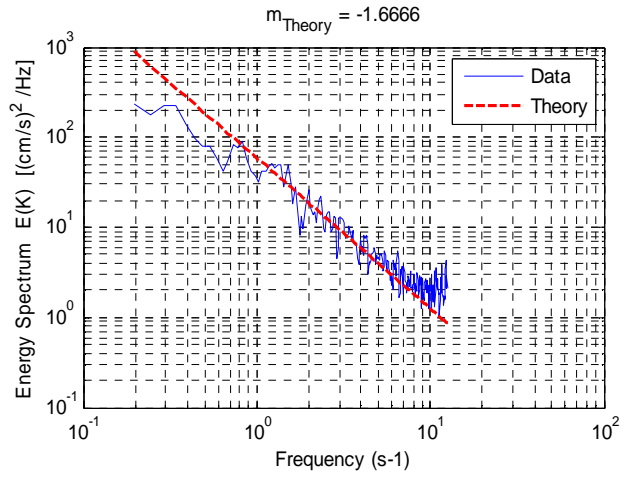
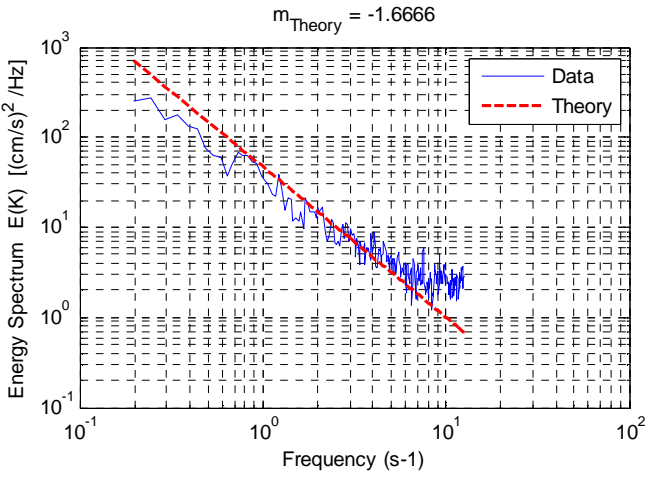
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = -25\text{-cm}$, $y = -25$, $z = 1\text{-cm}$ (left – Probe 0) and $x = 15\text{-cm}$, $y = -15$, $z = 1\text{-cm}$ (right – Probe 1).



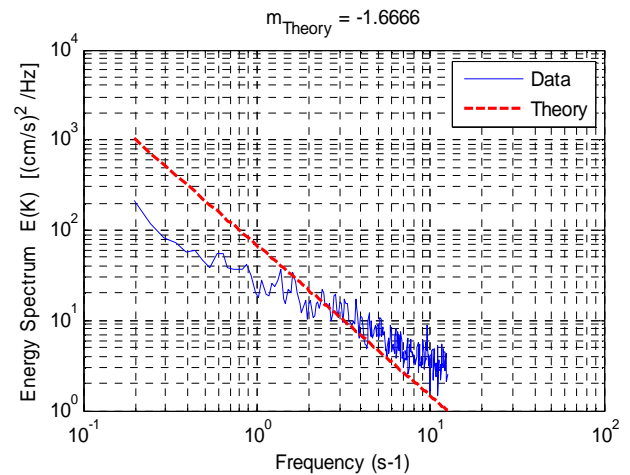
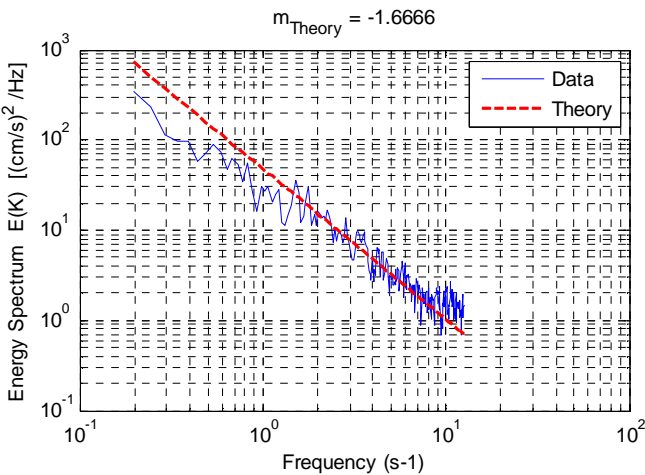
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 25\text{-cm}$, $y = -5$, $z = 1\text{-cm}$ (left – Probe 2) and $x = 35\text{-cm}$, $y = 0$, $z = 1\text{-cm}$ (right – Probe 3).



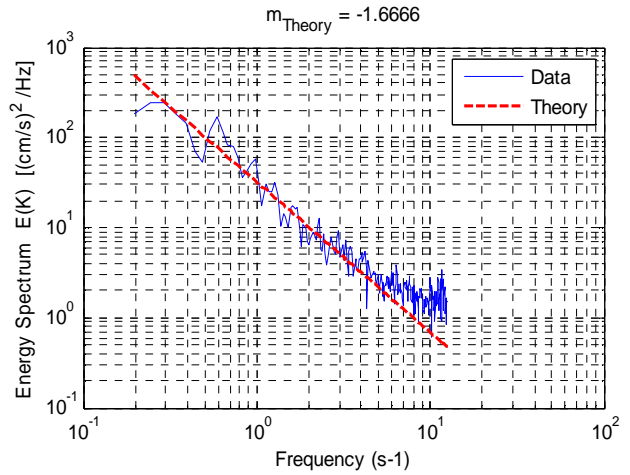
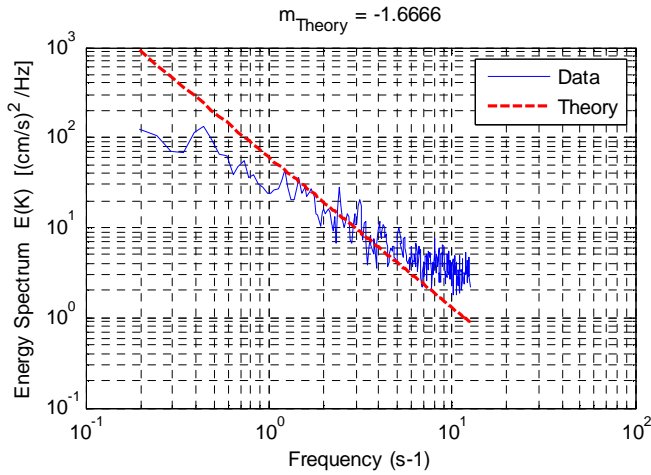
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 45\text{-cm}$, $y = 15$, $z = 1\text{-cm}$ (left – Probe 4) and $x = 55\text{-cm}$, $y = 25$, $z = 1\text{-cm}$ (right – Probe 5).



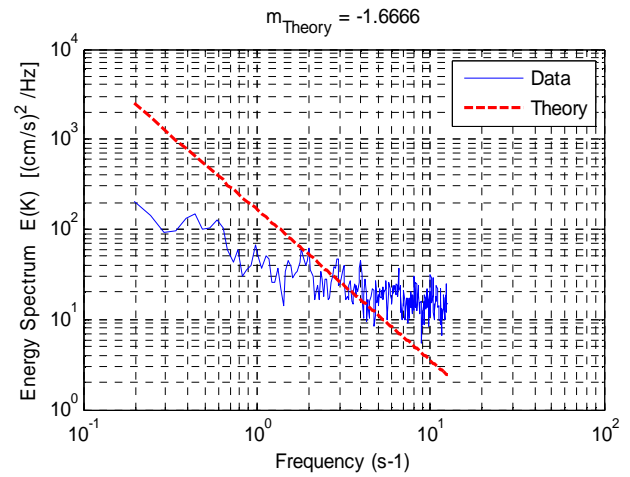
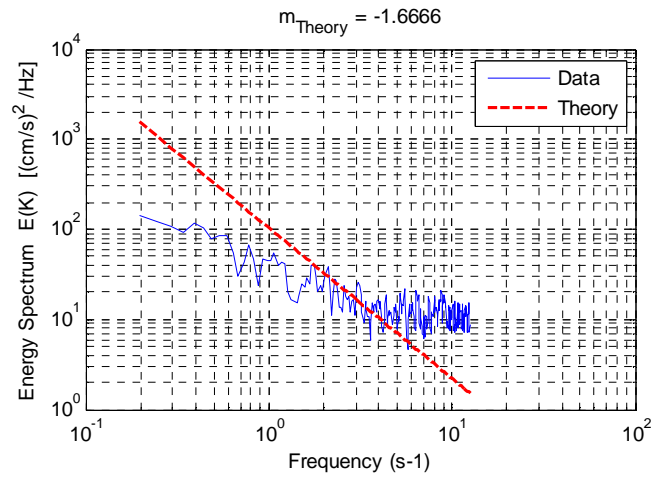
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 60\text{-cm}$, $y = 34$, $z = 1\text{-cm}$ (left – Probe 6) and $x = -25\text{-cm}$, $y = -25$, $z = 2\text{-cm}$ (right – Probe 0).



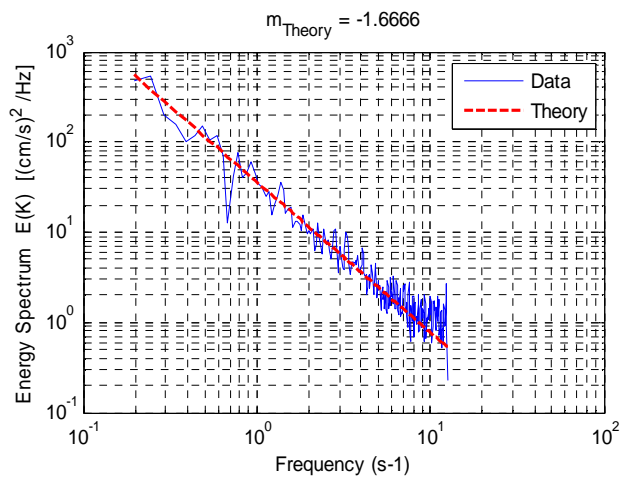
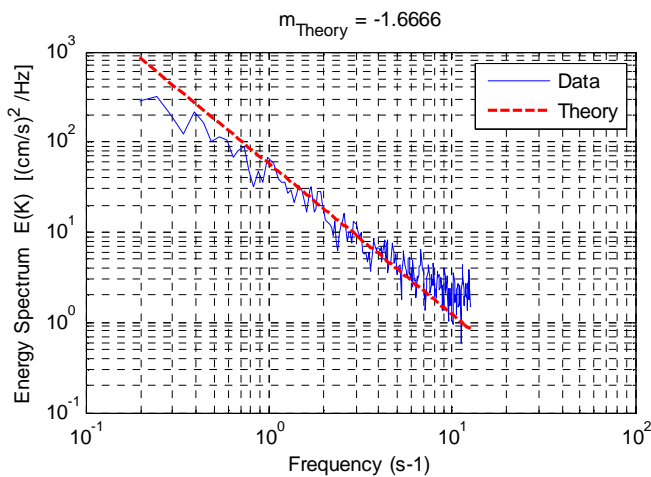
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 15\text{-cm}$, $y = -15$, $z = 2\text{-cm}$ (left – Probe 1) and $x = 25\text{-cm}$, $y = -5$, $z = 2\text{-cm}$ (right – Probe 2).



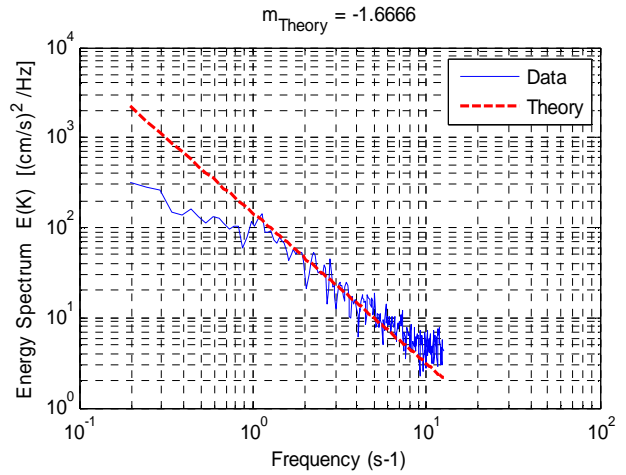
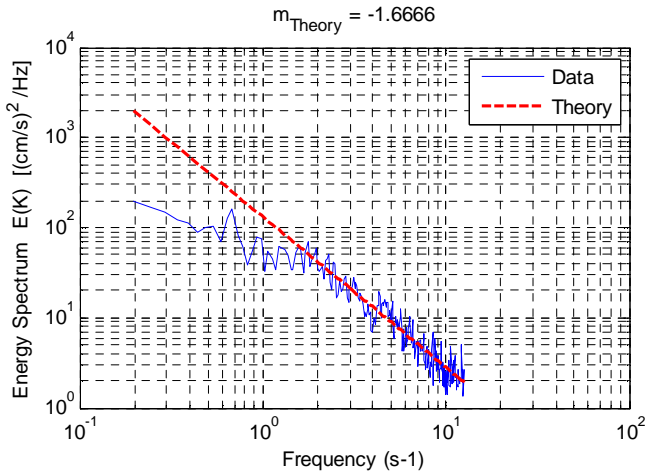
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 35\text{-cm}, y = 0, z = 2\text{-cm}$ (left – Probe 3) and $x = 45\text{-cm}, y = 15, z = 2\text{-cm}$ (left – Probe 4).



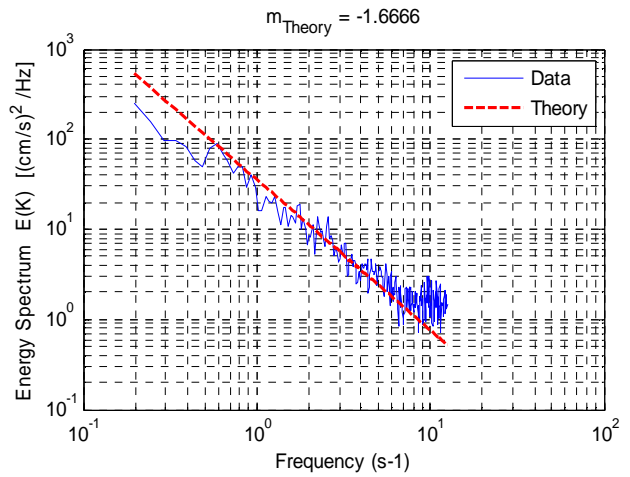
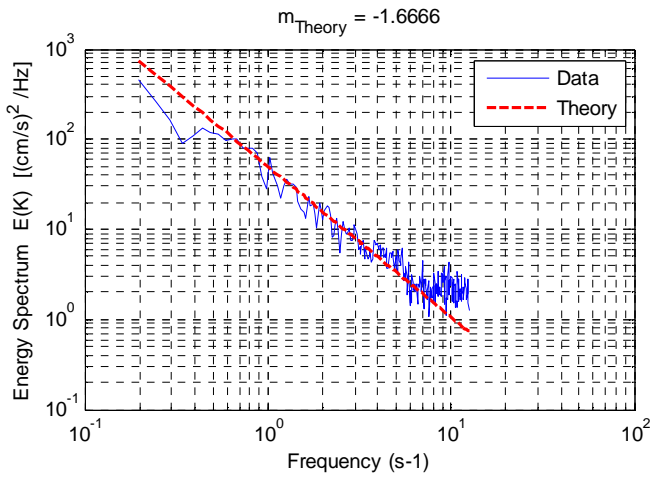
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 55\text{-cm}, y = 25, z = 2\text{-cm}$ (left – Probe 5) and $x = 60\text{-cm}, y = 34, z = 2\text{-cm}$ (right – Probe 6).



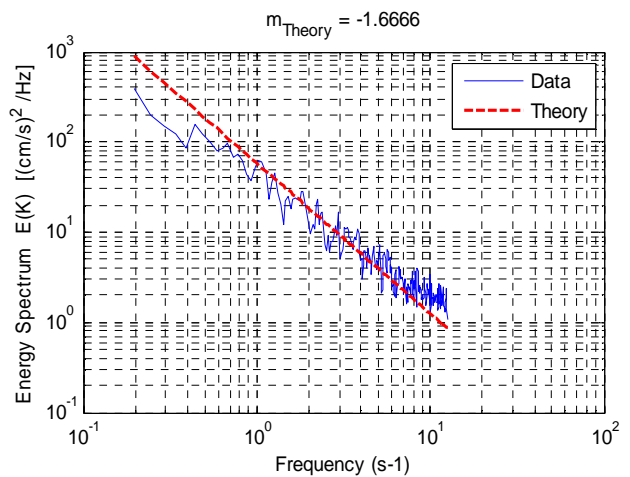
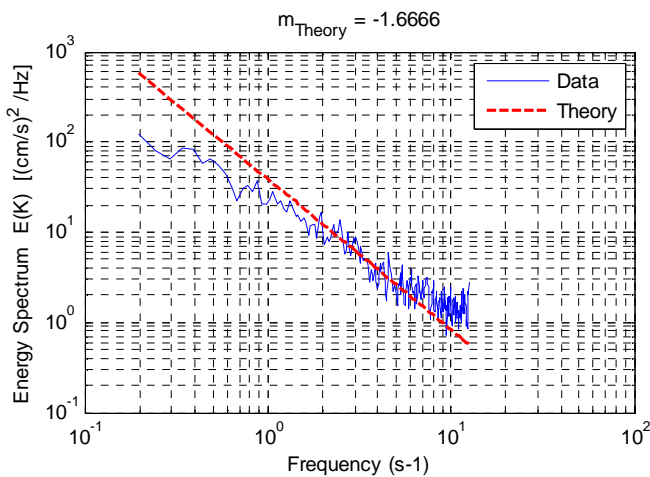
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = -25\text{-cm}, y = -25, z = 3\text{-cm}$ (left – Probe 0) and $x = 15\text{-cm}, y = -15, z = 3\text{-cm}$ (right – Probe 1).



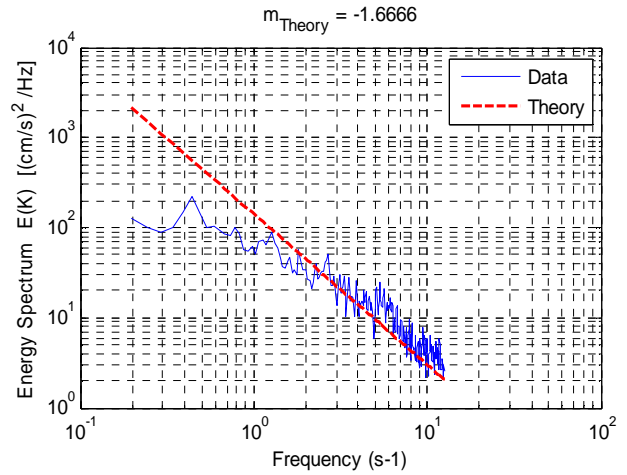
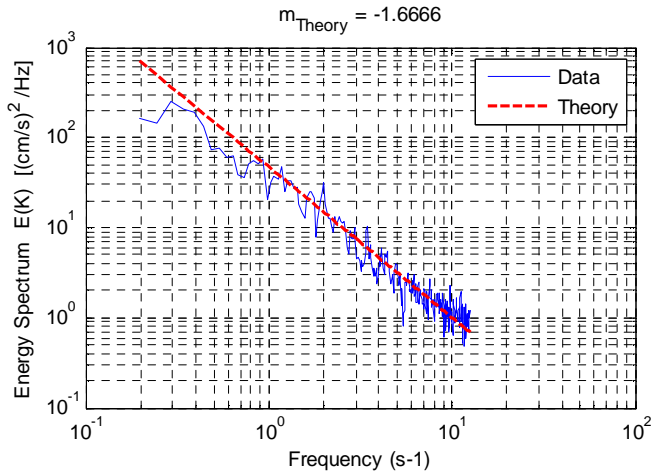
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 25\text{-cm}$, $y = -5$, $z = 3\text{-cm}$ (left – Probe 2) and $x = 35\text{-cm}$, $y = 0$, $z = 3\text{-cm}$ (right – Probe 3).



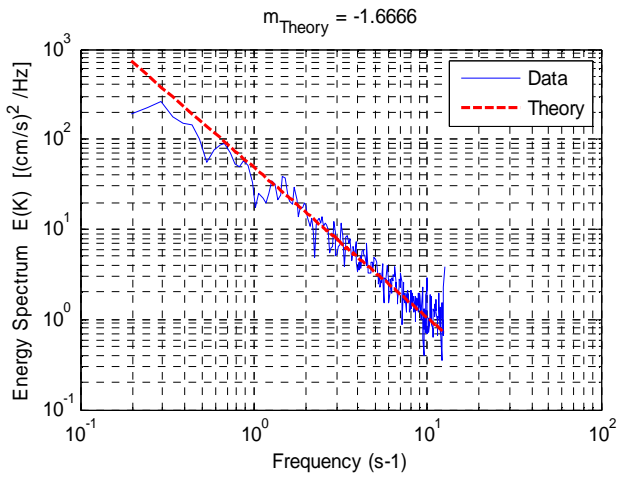
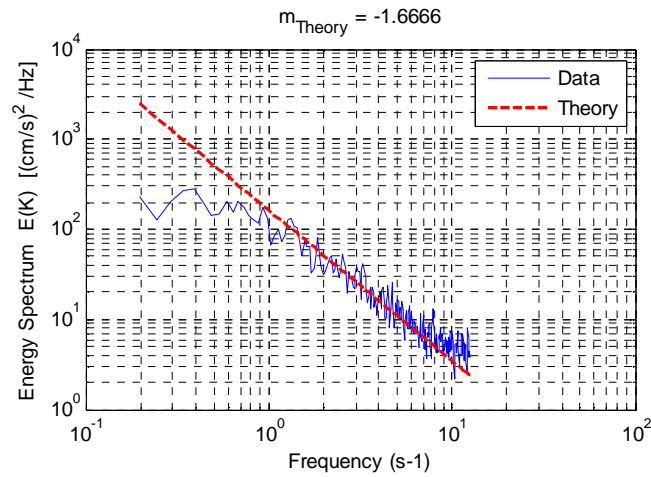
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 45\text{-cm}$, $y = 15$, $z = 3\text{-cm}$ (left – Probe 4) and $x = 55\text{-cm}$, $y = 25$, $z = 3\text{-cm}$ (right – Probe 5).



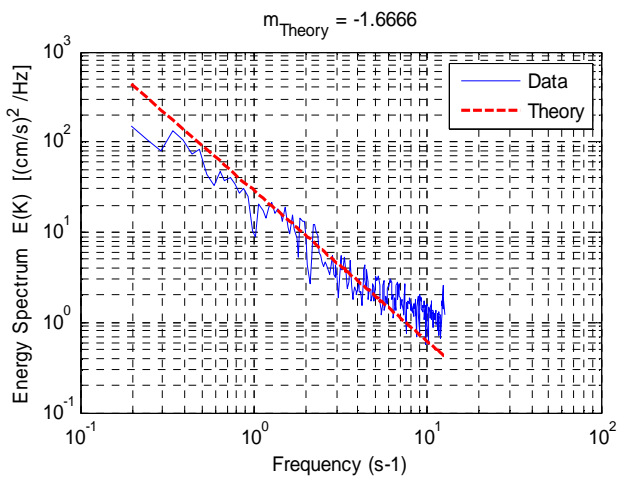
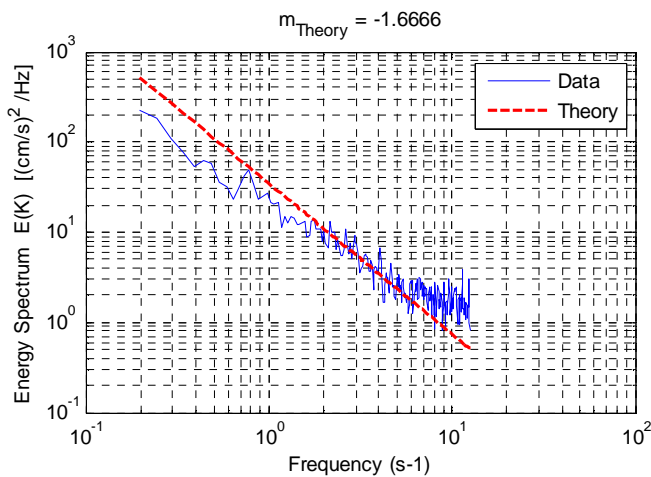
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 60\text{-cm}$, $y = 34$, $z = 3\text{-cm}$ (left – Probe 6) and $x = -25\text{-cm}$, $y = -25$, $z = 4\text{-cm}$ (right – Probe 0).



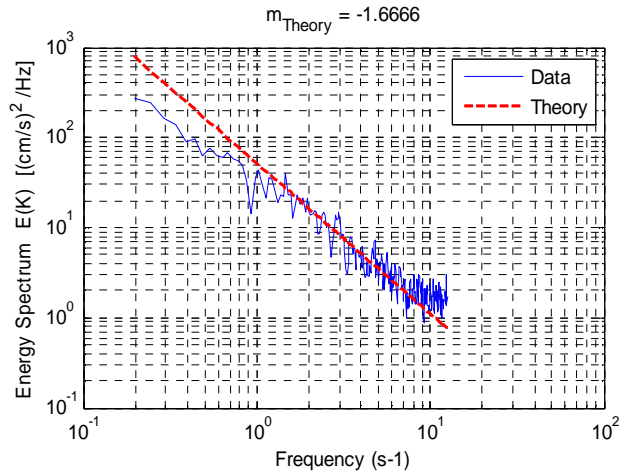
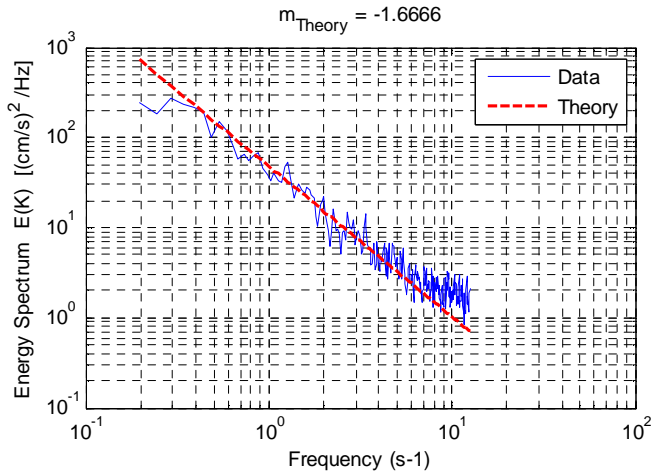
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 15\text{-cm}$, $y = -15$, $z = 4\text{-cm}$ (left – Probe 1) and $x = 25\text{-cm}$, $y = -5$, $z = 4\text{-cm}$ (right – Probe 2).



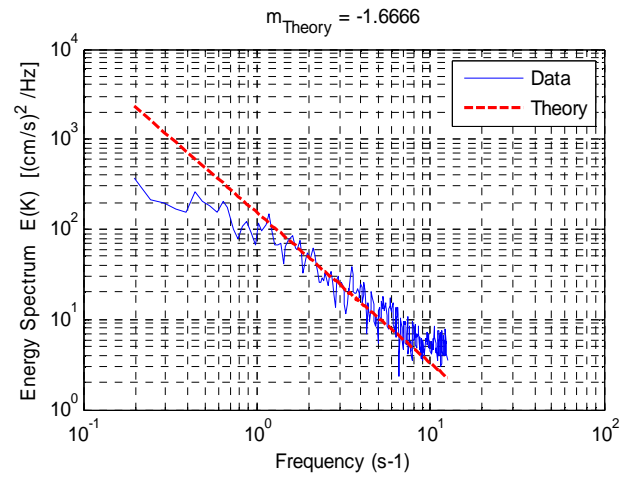
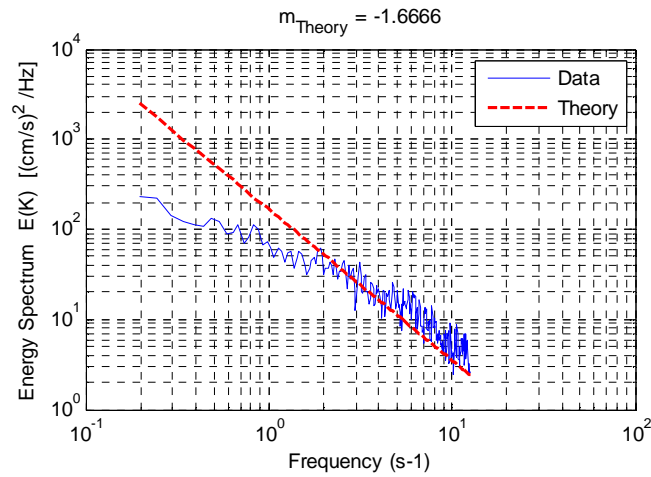
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 35\text{-cm}$, $y = 0$, $z = 4\text{-cm}$ (left – Probe 3) and $x = 45\text{-cm}$, $y = 15$, $z = 4\text{-cm}$ (left – Probe 4).



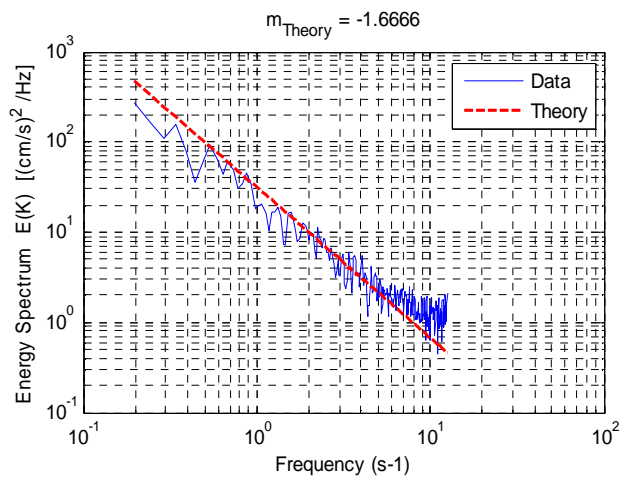
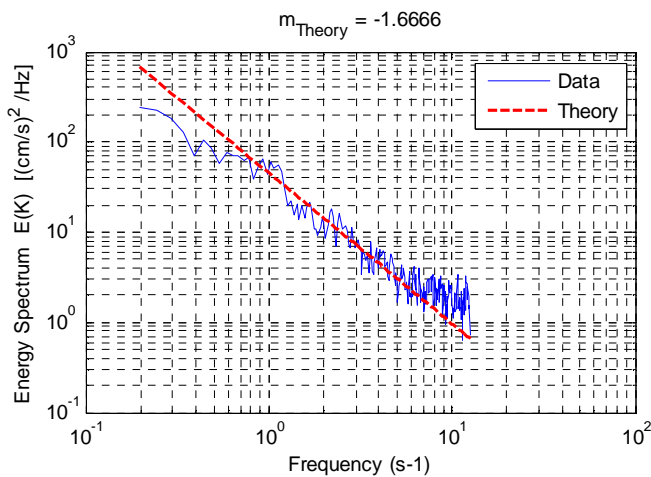
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 55\text{-cm}$, $y = 25$, $z = 4\text{-cm}$ (left – Probe 5) and $x = 60\text{-cm}$, $y = 34$, $z = 4\text{-cm}$ (right – Probe 6).



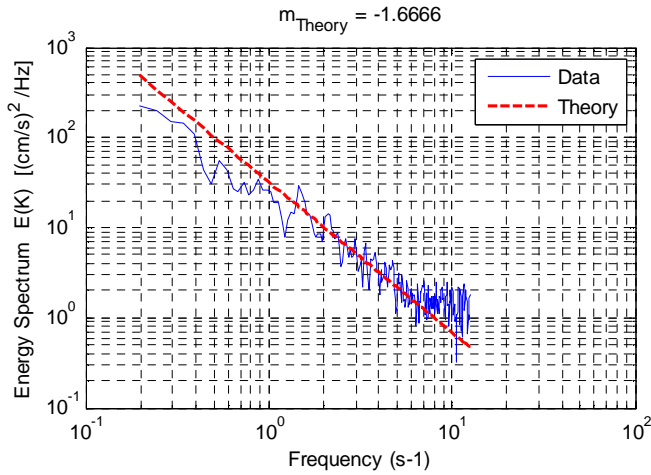
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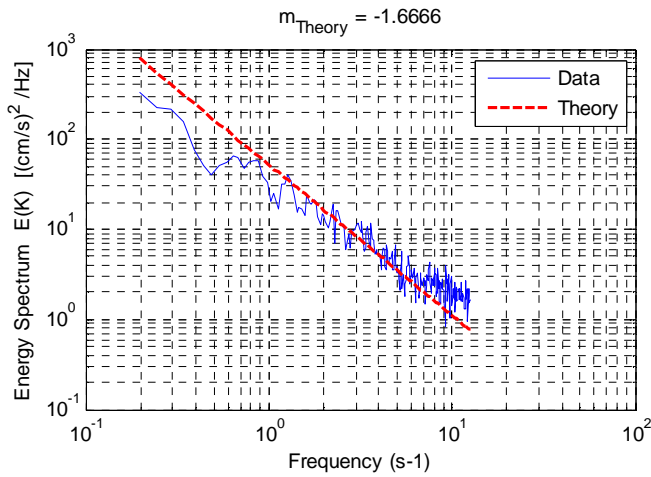
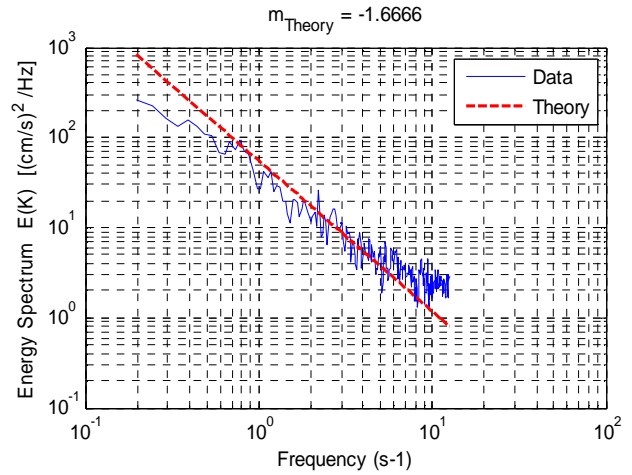
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 25\text{-cm}$, $y = -5$, $z = 5\text{-cm}$ (left – Probe 2) and $x = 35\text{-cm}$, $y = 0$, $z = 5\text{-cm}$ (right – Probe 3).



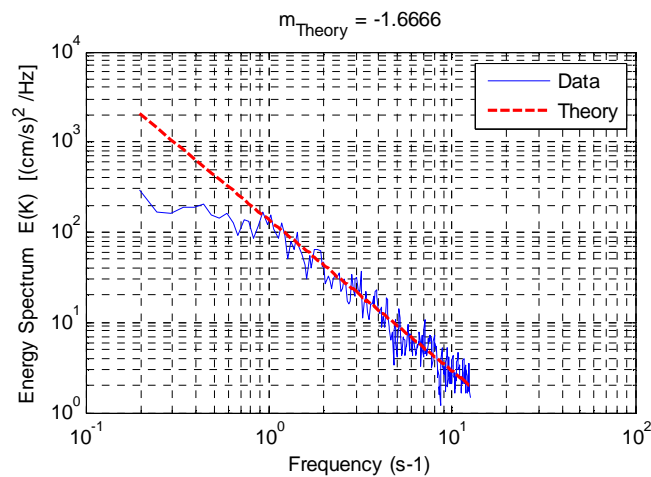
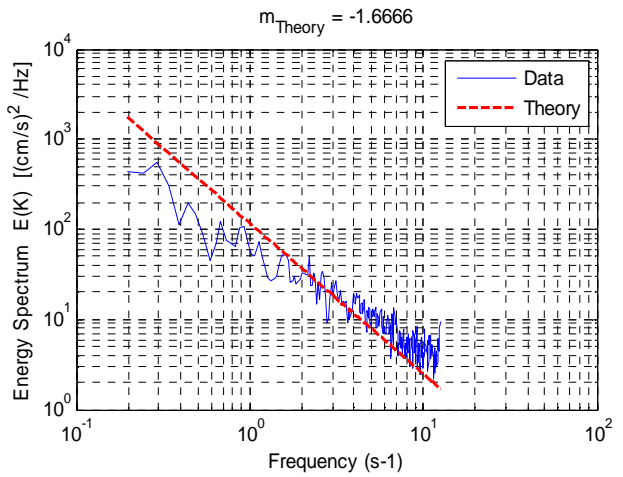
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 45\text{-cm}$, $y = 15$, $z = 5\text{-cm}$ (left – Probe 4) and $x = 55\text{-cm}$, $y = 25$, $z = 5\text{-cm}$ (right – Probe 5).



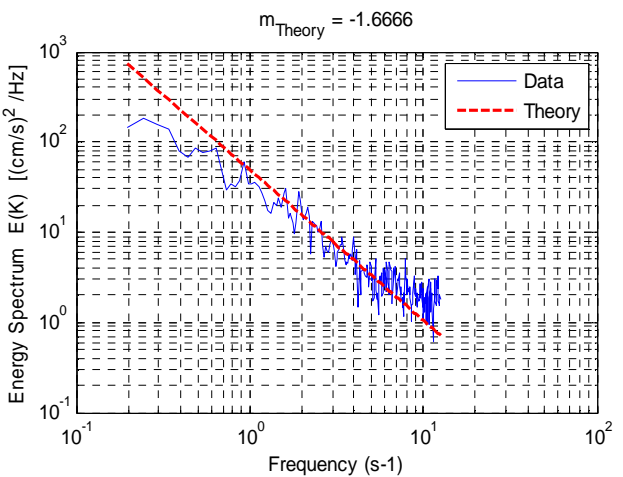
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 60\text{-cm}$, $y = 34$, $z = 5\text{-cm}$ (left – Probe 6) and $x = -25\text{-cm}$, $y = -25$, $z = 6\text{-cm}$ (right– Probe 0).

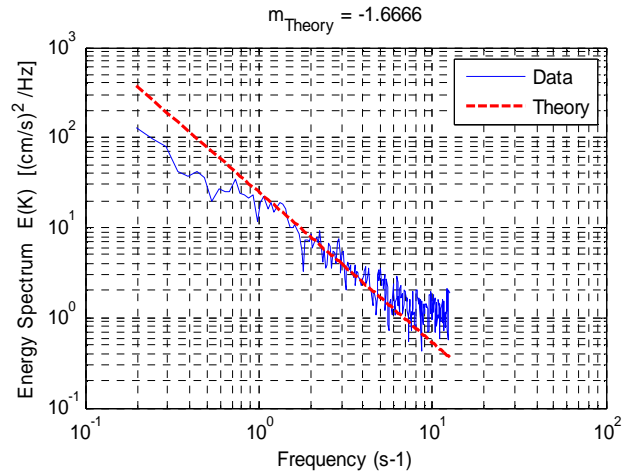
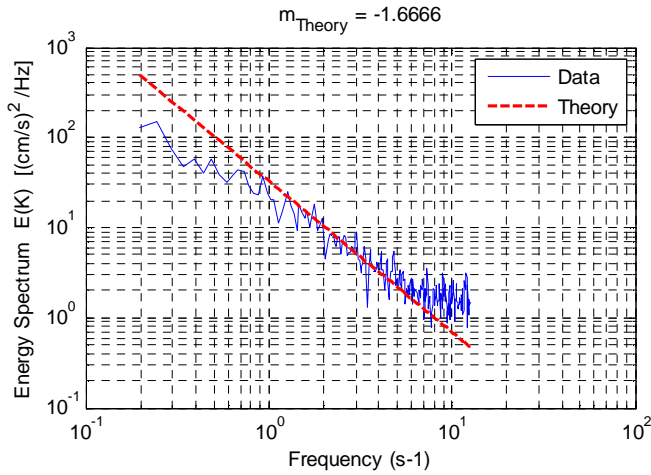


Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 15\text{-cm}$, $y = -15$, $z = 6\text{-cm}$ (left – Probe 1) and $x = 25\text{-cm}$, $y = -5$, $z = 6\text{-cm}$ (right – Probe 2).

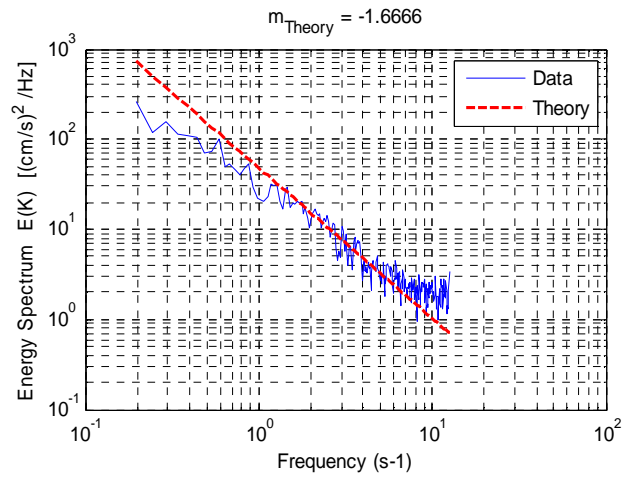
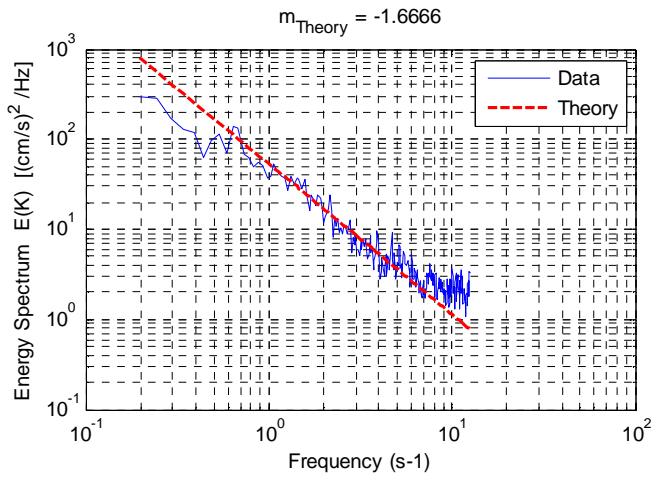


Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 35\text{-cm}$, $y = 0$, $z = 6\text{-cm}$ (left – Probe 3) and $x = 45\text{-cm}$, $y = 15$, $z = 6\text{-cm}$ (left – Probe 4).

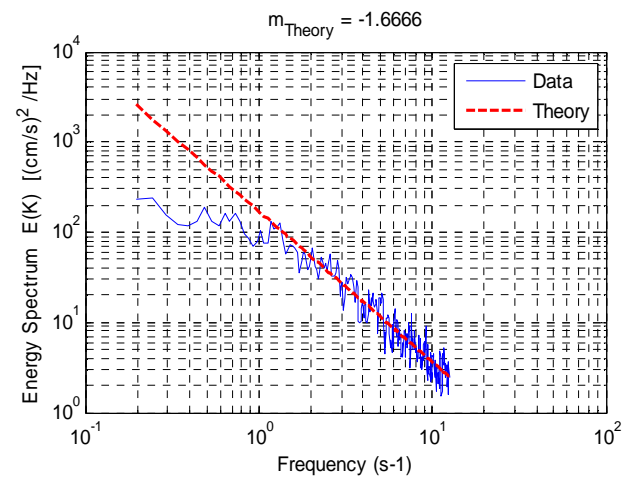
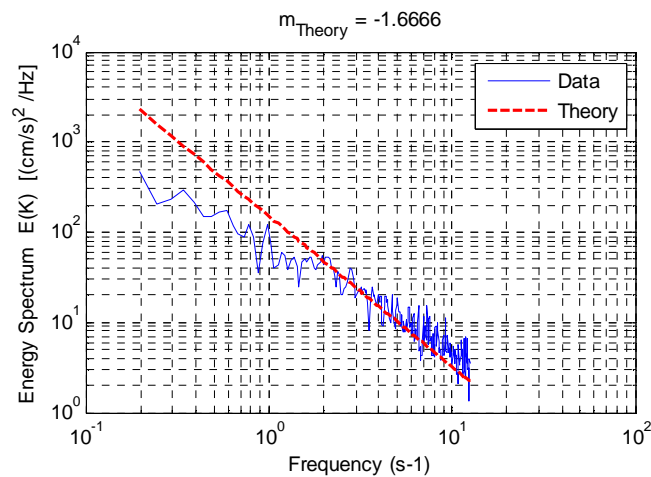




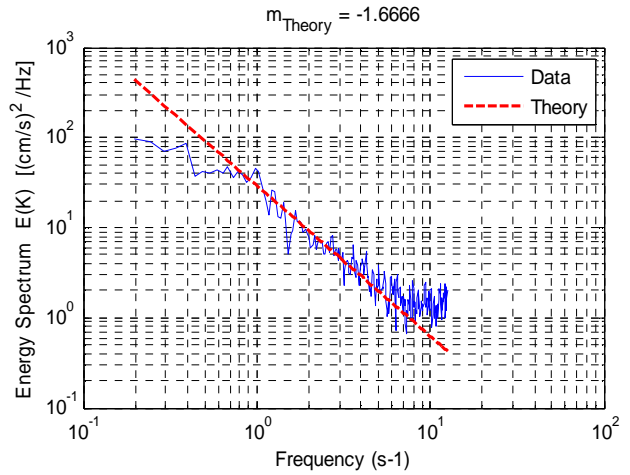
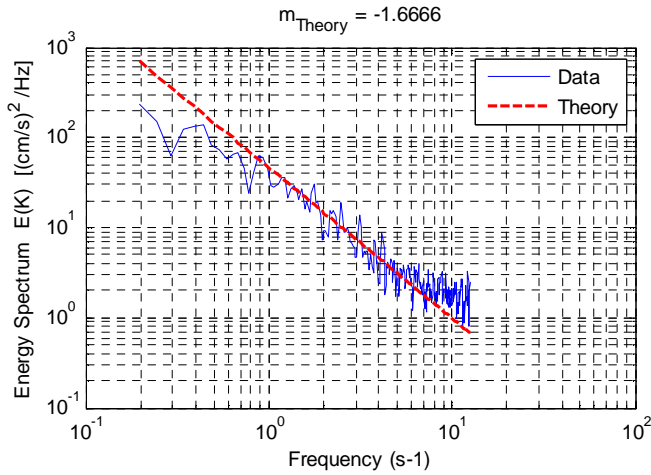
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 55\text{-cm}$, $y = 25$, $z = 6\text{-cm}$ (left – Probe 5) and $x = 60\text{-cm}$, $y = 34$, $z = 6\text{-cm}$ (right – Probe 6).



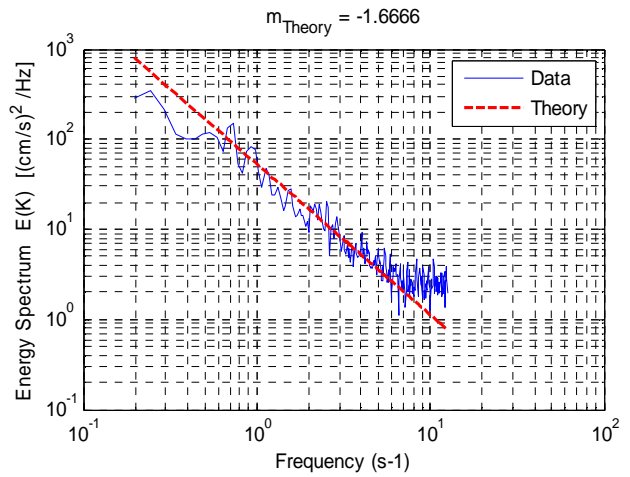
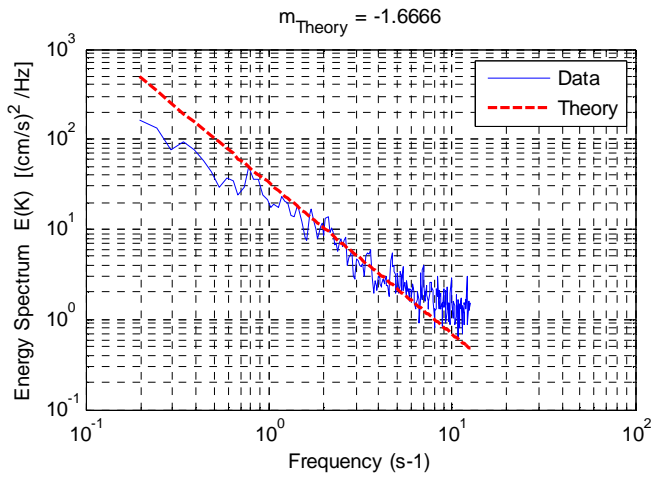
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = -25\text{-cm}$, $y = -25$, $z = 7\text{-cm}$ (left – Probe 0) and $x = 15\text{-cm}$, $y = -15$, $z = 7\text{-cm}$ (right – Probe 1).



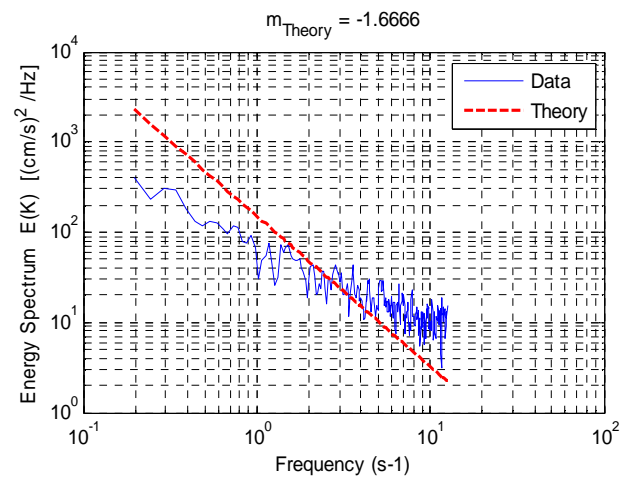
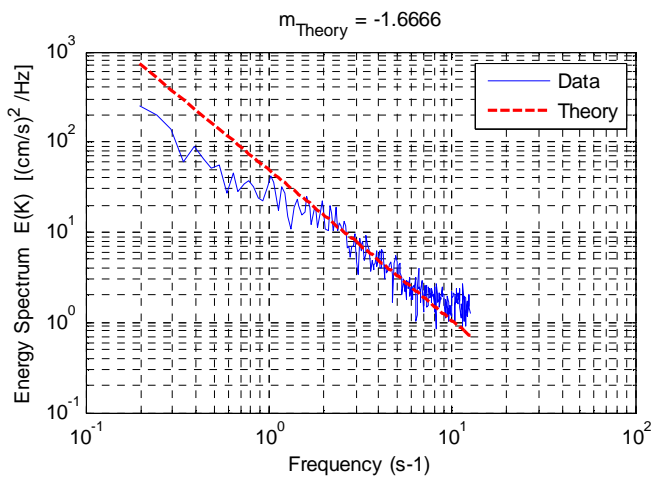
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 25\text{-cm}$, $y = -5$, $z = 7\text{-cm}$ (left – Probe 2) and $x = 35\text{-cm}$, $y = 0$, $z = 7\text{-cm}$ (right – Probe 3).



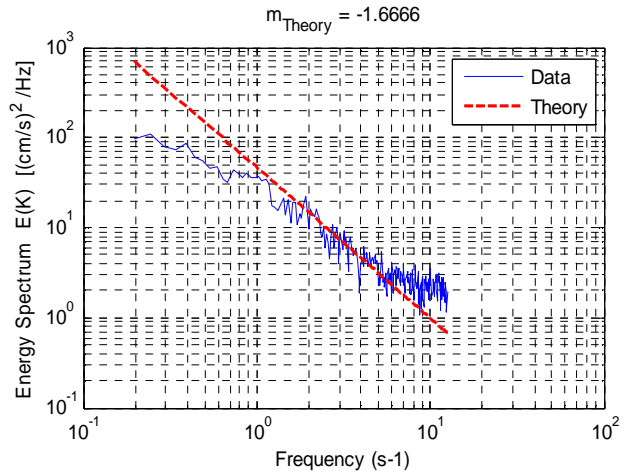
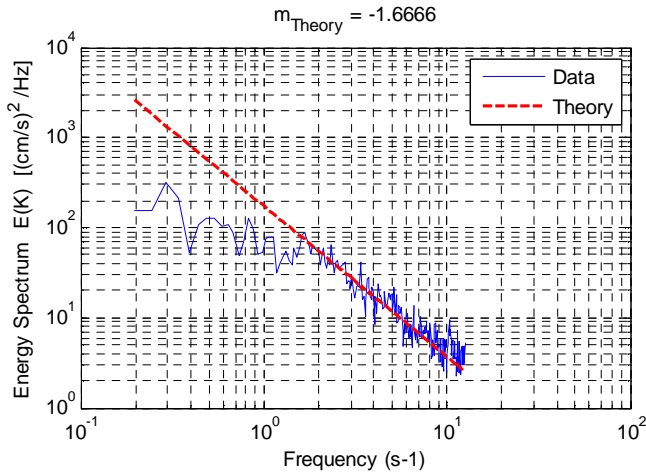
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 45\text{-cm}, y = 15, z = 7\text{-cm}$ (left – Probe 4) and $x = 55\text{-cm}, y = 25, z = 7\text{-cm}$ (right – Probe 5).



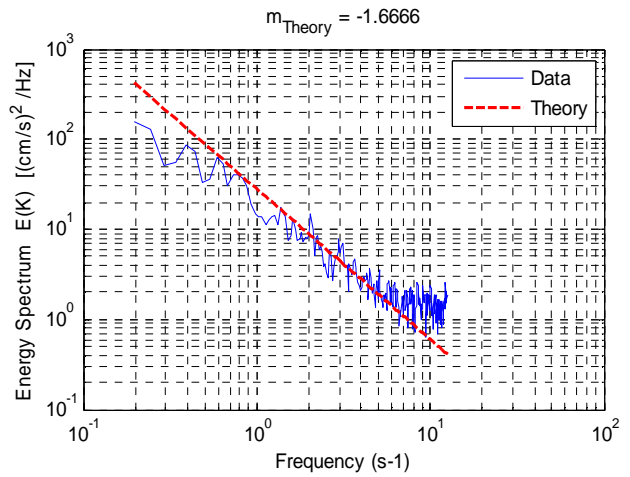
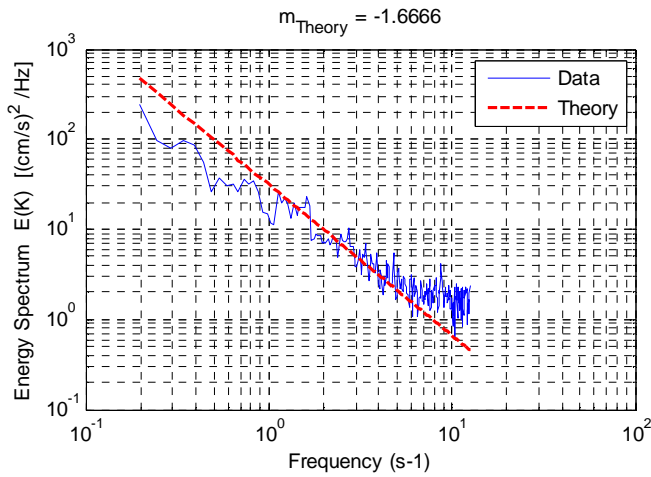
Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 60\text{-cm}, y = 34, z = 7\text{-cm}$ (left – Probe 6) and $x = -25\text{-cm}, y = -25, z = 8\text{-cm}$ (right – Probe 0).



Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 15\text{-cm}, y = -15, z = 8\text{-cm}$ (left – Probe 1) and $x = 25\text{-cm}, y = -5, z = 8\text{-cm}$ (right – Probe 2).

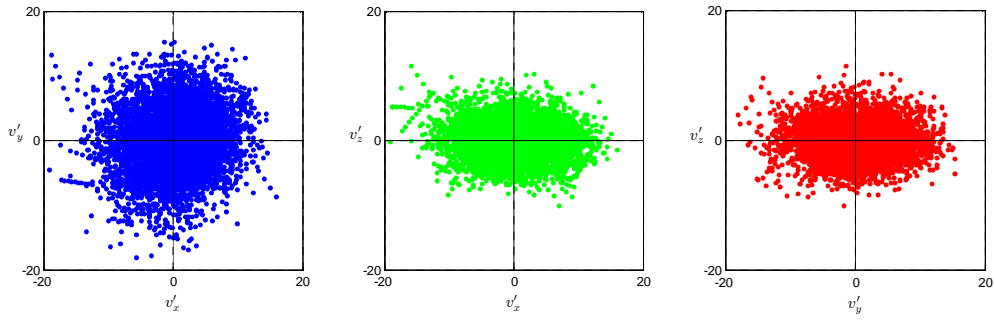


Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 35\text{-cm}$, $y = 0$, $z = 8\text{-cm}$ (left – Probe 3) and $x = 45\text{-cm}$, $y = 15$, $z = 8\text{-cm}$ (left – Probe 4).

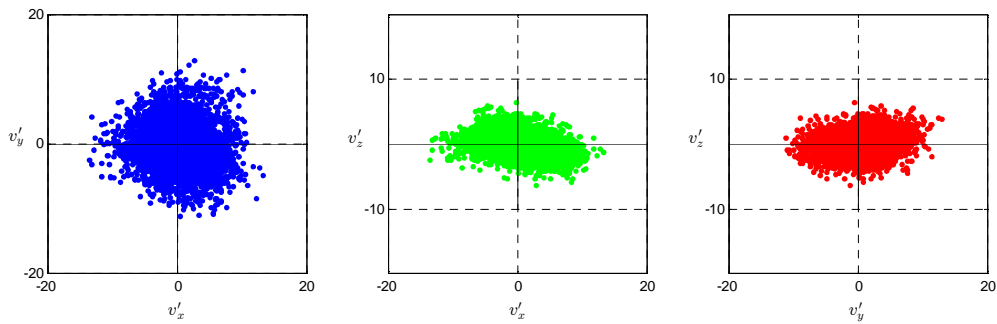


Energy spectrum $E(k)$ versus frequency compared with Kolmogorov's universal equilibrium $(-5/3)$ theorem, at points: $x = 55\text{-cm}$, $y = 25$, $z = 8\text{-cm}$ (left – Probe 5) and $x = 60\text{-cm}$, $y = 34$, $z = 8\text{-cm}$ (right – Probe 6).

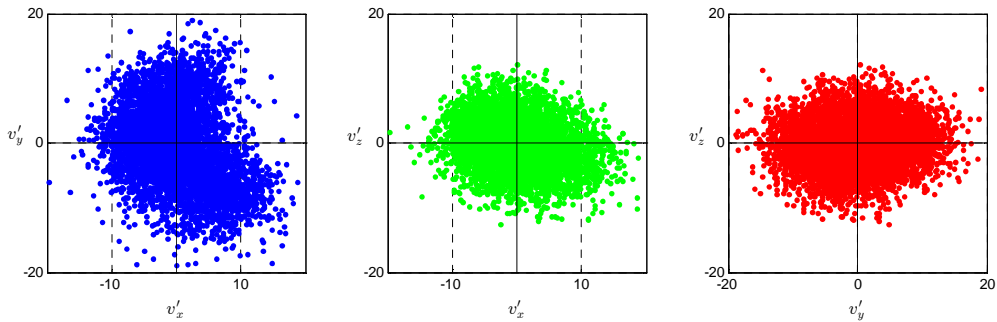
D.2 Turbulent Velocities Fields



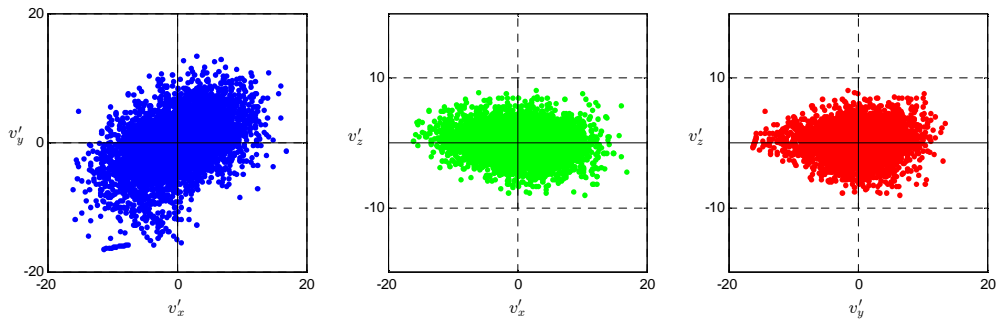
Turbulent velocities fields at point (x = -25-cm, y = -25, z = 1-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



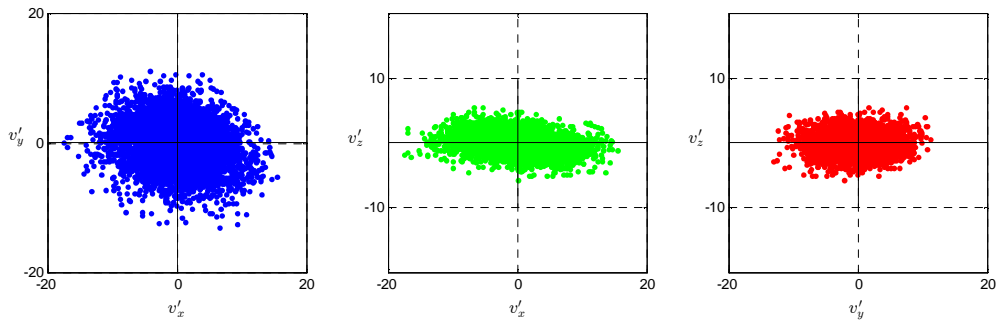
Turbulent velocities fields at point (x = 15-cm, y = -15, z = 1-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



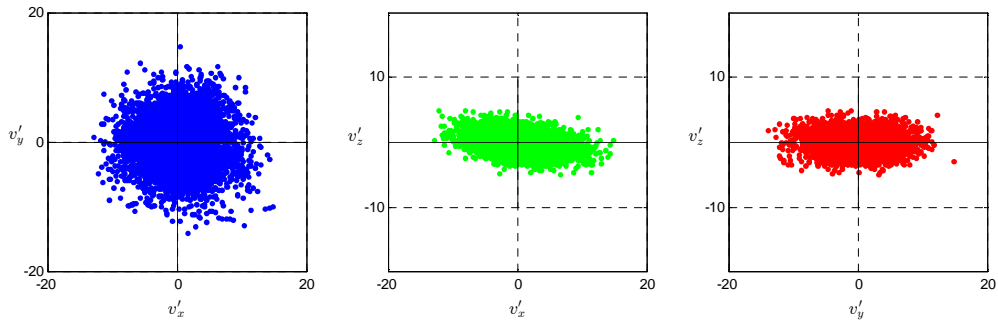
Turbulent velocities fields at point (x = 25-cm, y = -5, z = 1-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



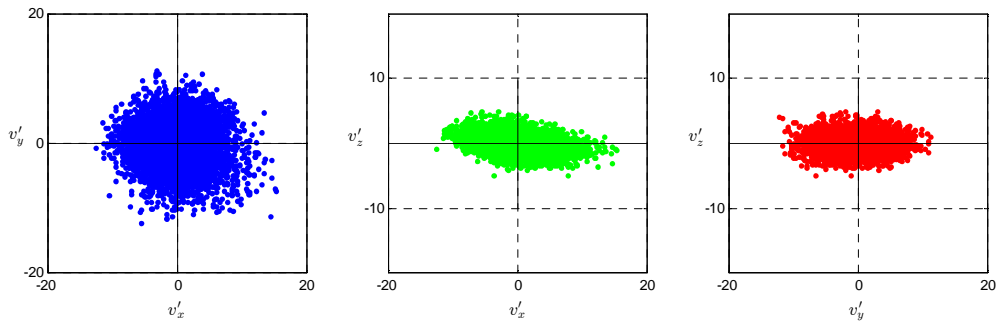
Turbulent velocities fields at point ($x = 35\text{-cm}$, $y = 0$, $z = 1\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



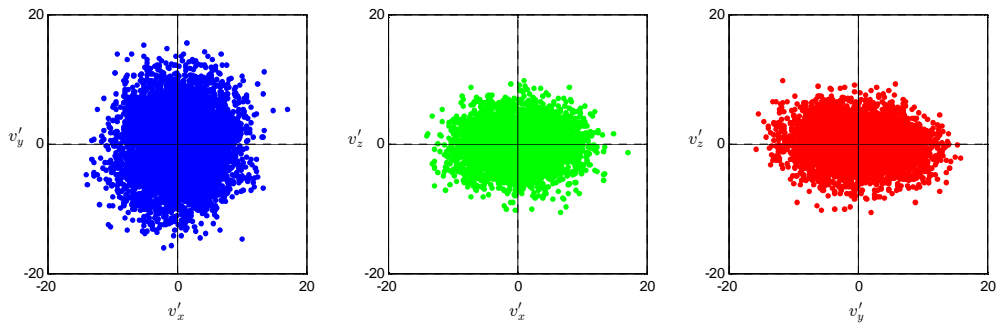
Turbulent velocities fields at point ($x = 45\text{-cm}$, $y = 15$, $z = 1\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



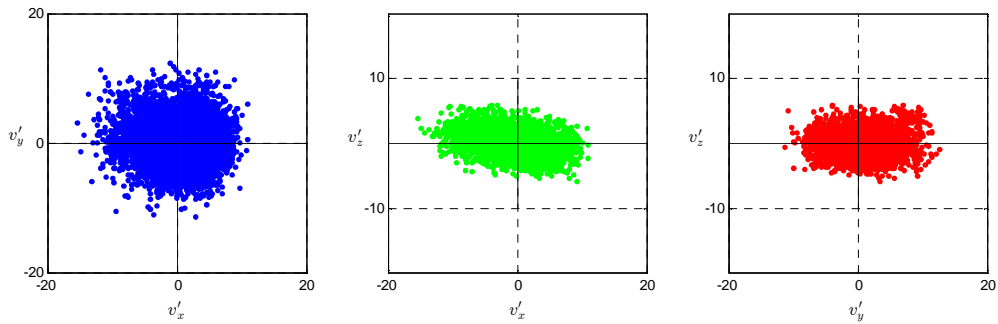
Turbulent velocities fields at point ($x = 55\text{-cm}$, $y = 25$, $z = 1\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



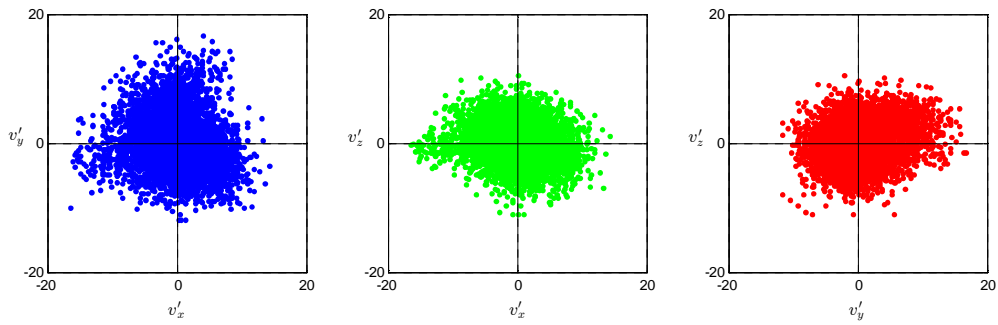
Turbulent velocities fields at point ($x = 60\text{-cm}$, $y = 34$, $z = 1\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



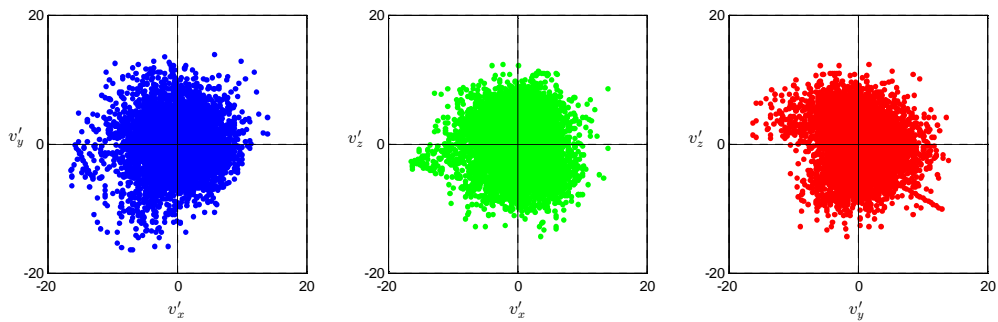
Turbulent velocities fields at point ($x = -25\text{-cm}$, $y = -25$, $z = 2\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



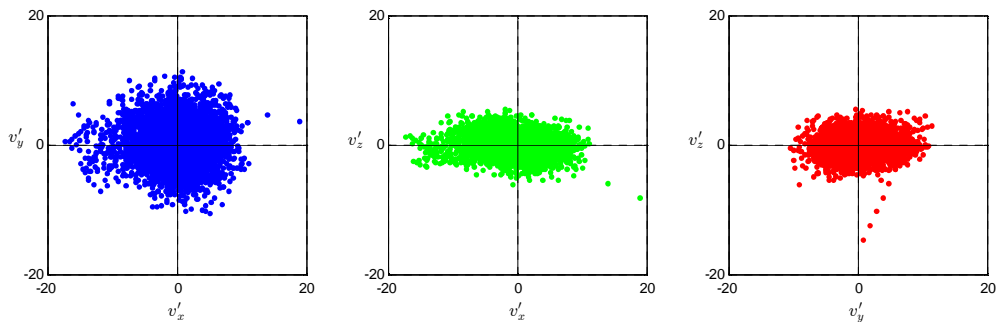
Turbulent velocities fields at point ($x = 15\text{-cm}$, $y = -15$, $z = 2\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



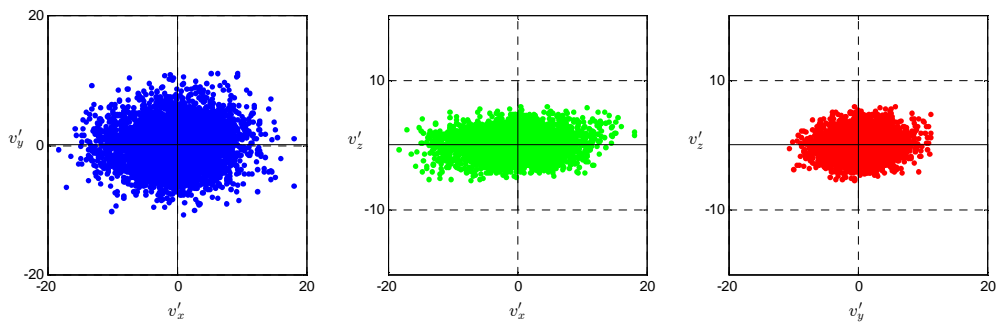
Turbulent velocities fields at point (x = 25-cm, y = -5 z = 2-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



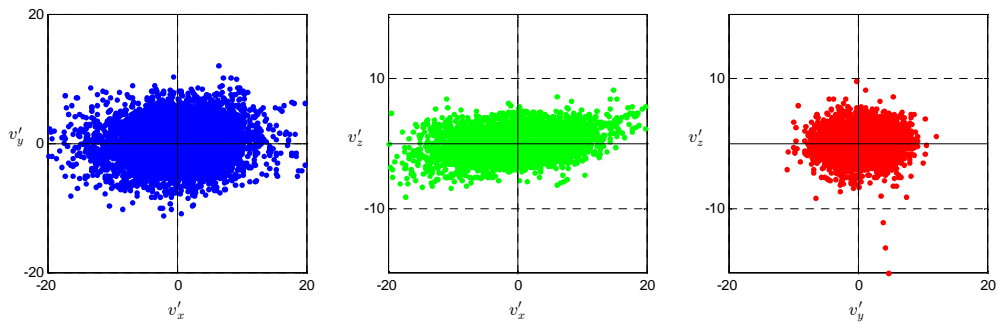
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 2-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



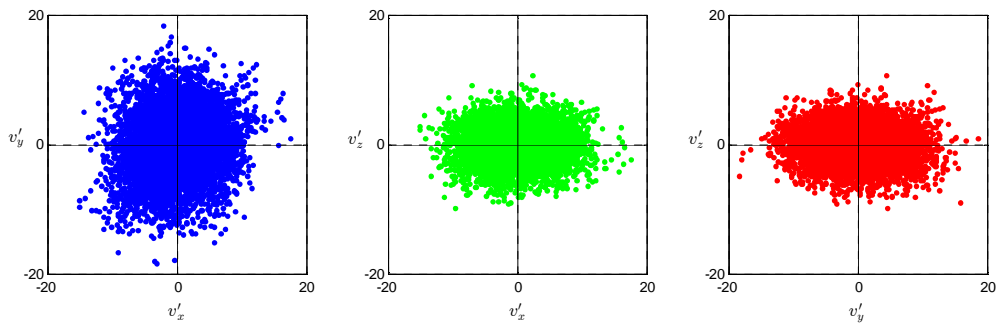
Turbulent velocities fields at point (x = 45-cm, y = 15, z = 2-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



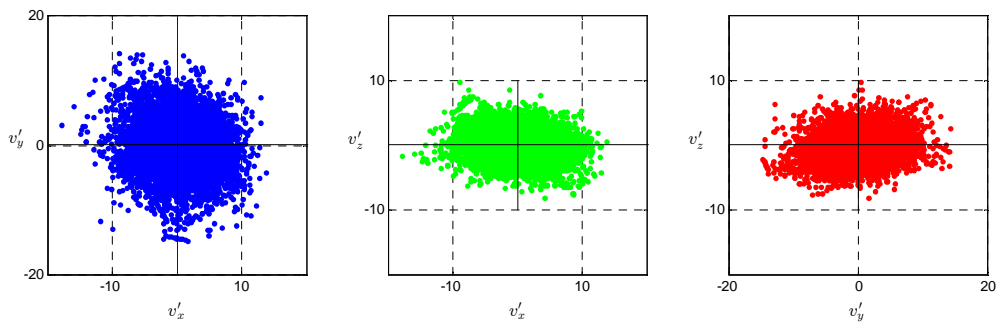
Turbulent velocities fields at point (x = 55-cm, y = 25, z = 2-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



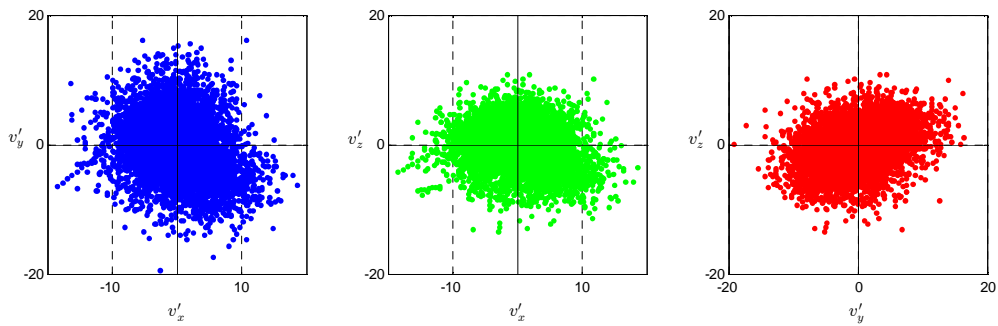
Turbulent velocities fields at point (x = 60-cm, y = 34, z = 2-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



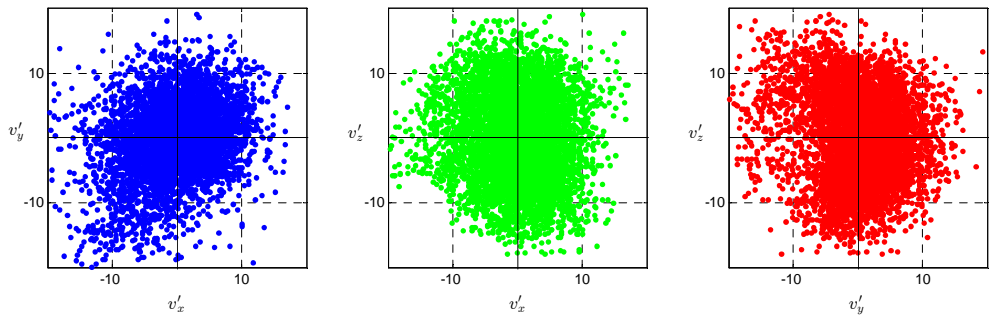
Turbulent velocities fields at point (x = -25-cm, y = -25, z = 3-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



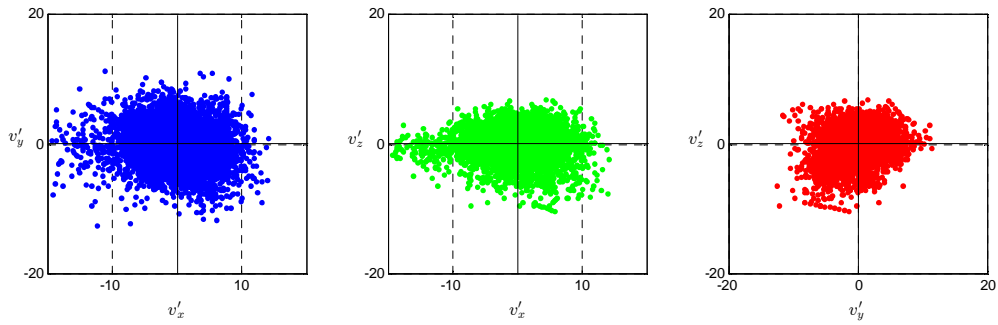
Turbulent velocities fields at point (x = 15-cm, y = -15, z = 3-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



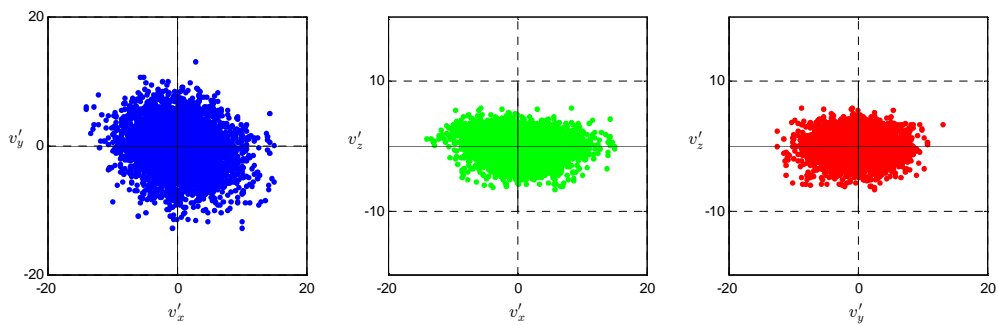
Turbulent velocities fields at point (x = 25-cm, y = -5, z = 3-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



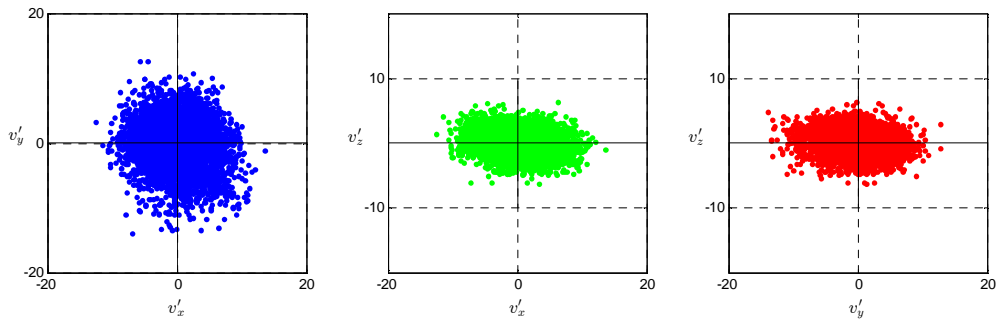
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 3-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



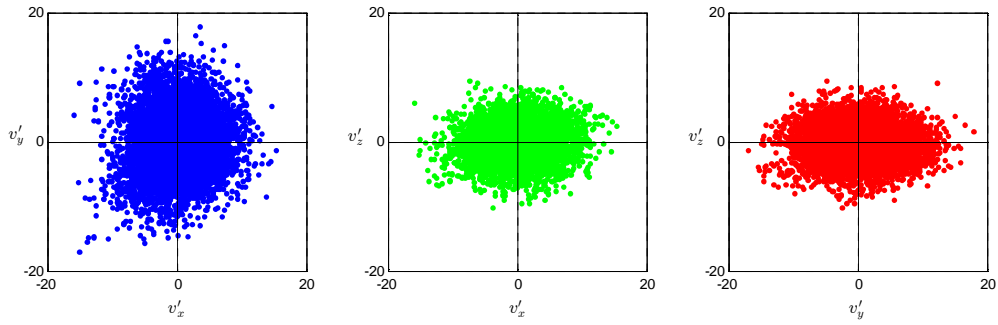
Turbulent velocities fields at point ($x = 45\text{-cm}$, $y = 15$, $z = 3\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



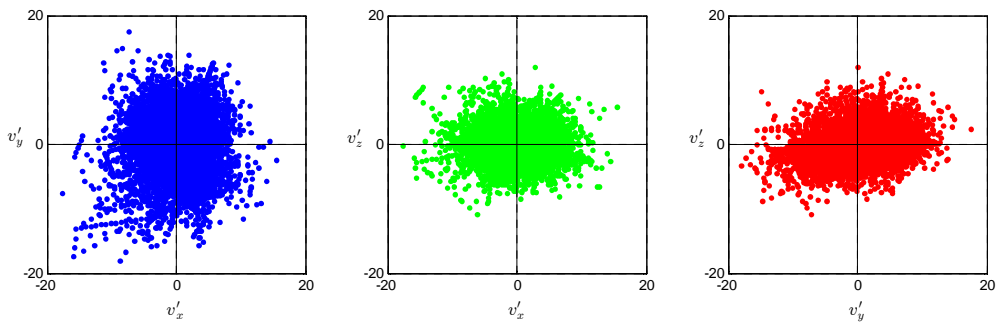
Turbulent velocities fields at point ($x = 55\text{-cm}$, $y = 25$, $z = 3\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



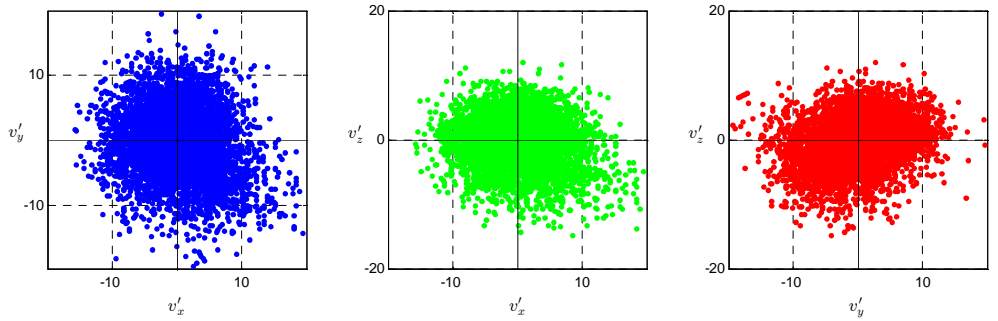
Turbulent velocities fields at point ($x = 60\text{-cm}$, $y = 34$, $z = 3\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



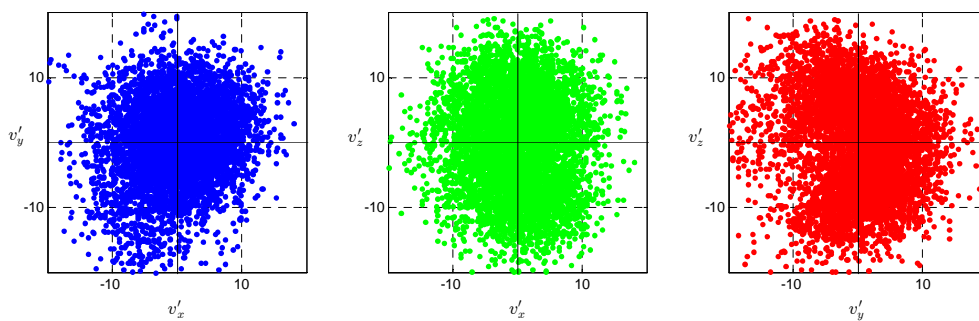
**Turbulent velocities fields at point (x = -25-cm, y = -25, z = 4-cm), each dot represents a pair at a certain time:
 (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream – Experimental results.**



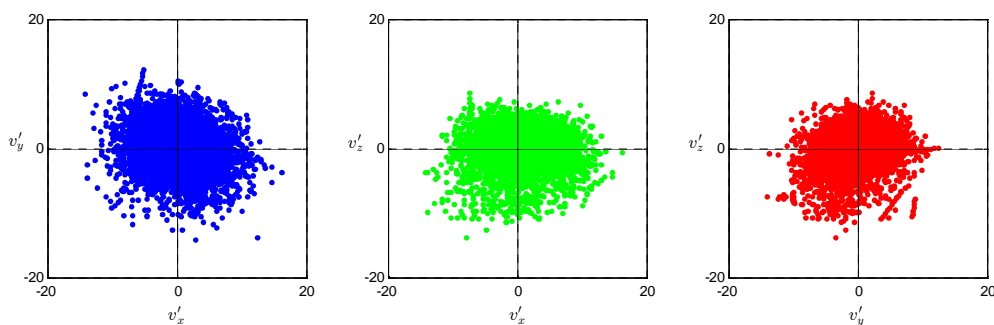
**Turbulent velocities fields at point (x = 15-cm, y = -15, z = 4-cm), each dot represents a pair at a certain time:
 (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.**



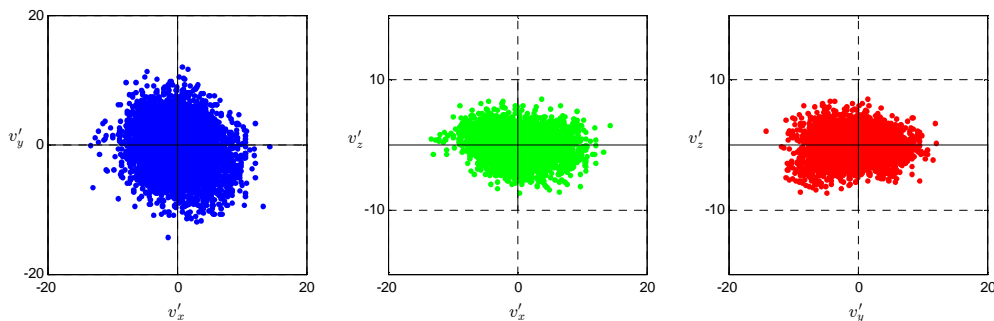
**Turbulent velocities fields at point (x = 25-cm, y = -5 z = 4-cm), each dot represents a pair at a certain time:
 (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.**



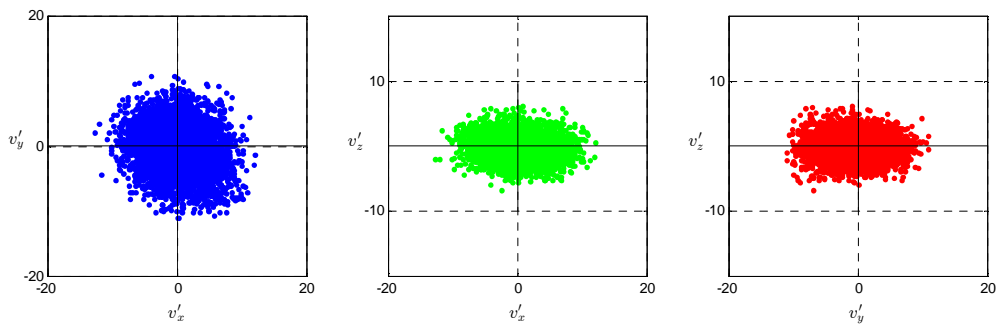
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 4-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



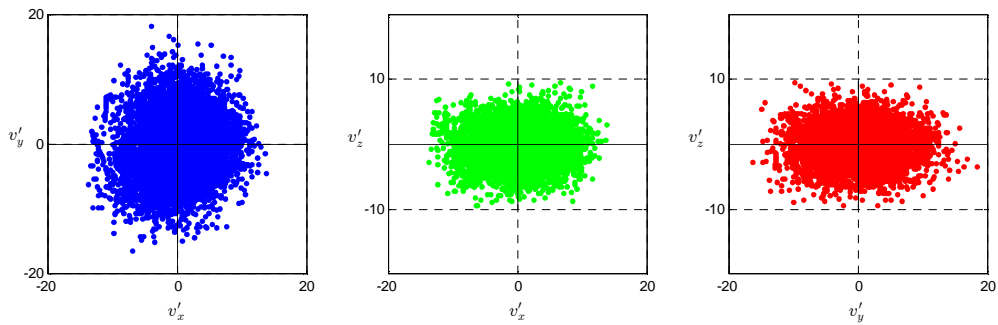
Turbulent velocities fields at point (x = 45-cm, y = 15, z = 4-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



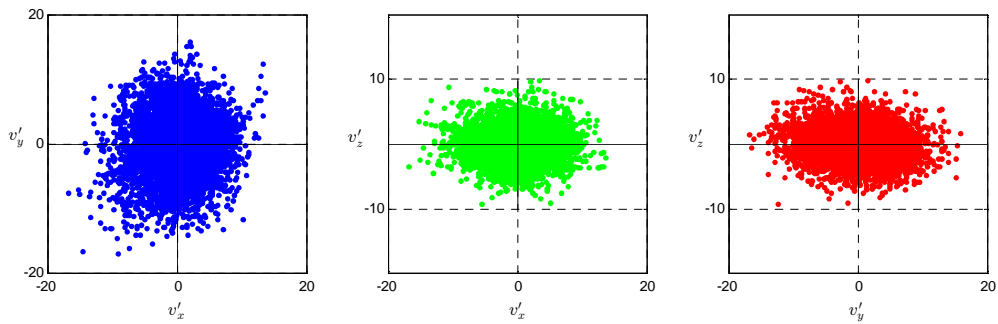
Turbulent velocities fields at point (x = 55-cm, y = 25, z = 4-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



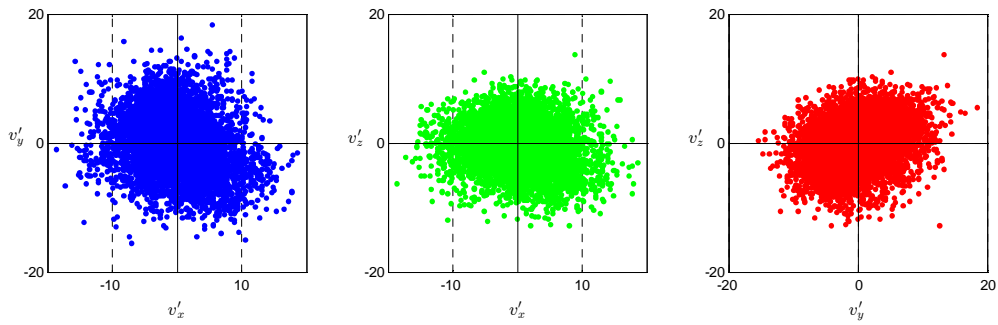
Turbulent velocities fields at point (x = 60-cm, y = 34, z = 4-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



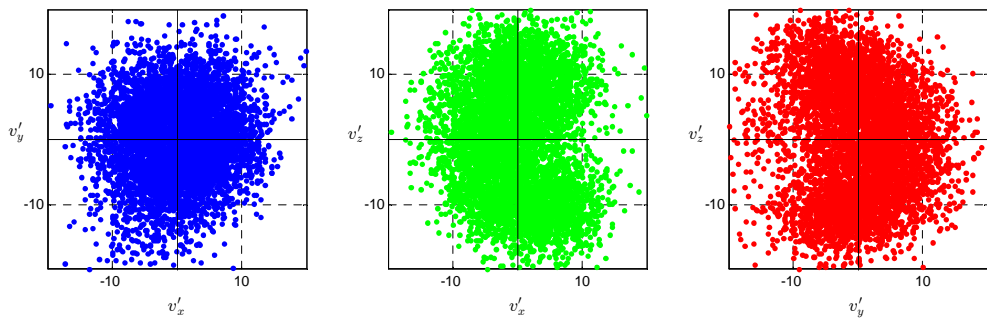
Turbulent velocities fields at point (x = -25-cm, y = -25, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



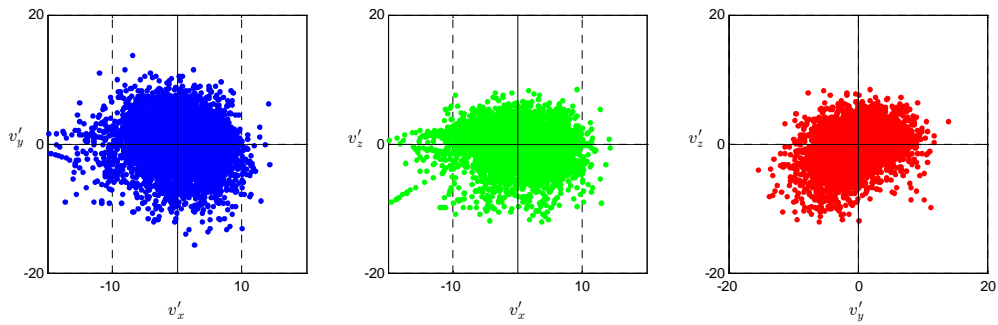
Turbulent velocities fields at point (x = 15-cm, y = -15, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



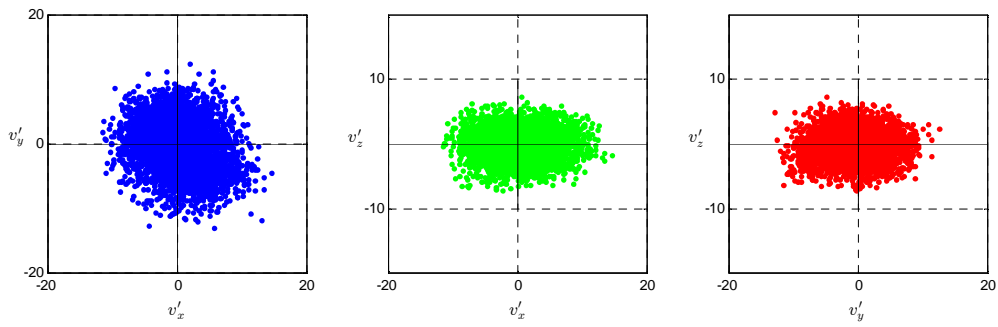
Turbulent velocities fields at point (x = 25-cm, y = -5, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



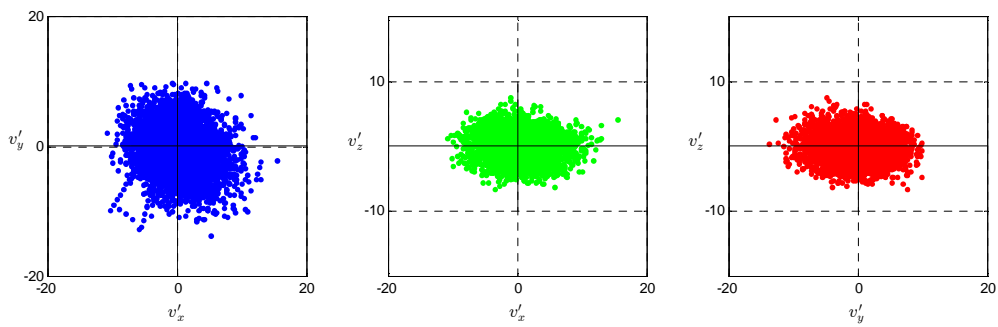
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



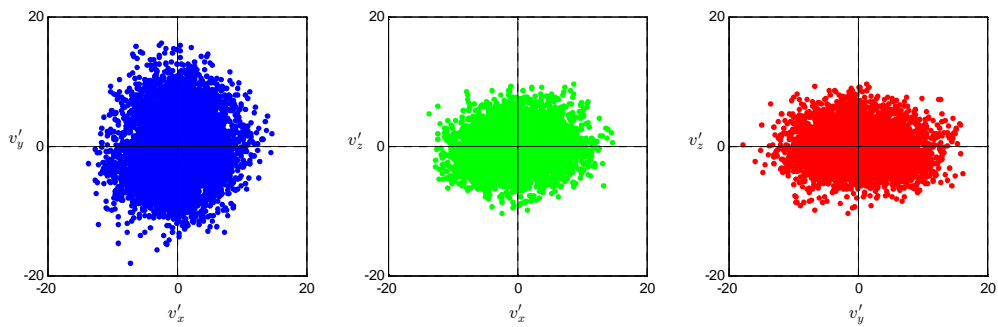
Turbulent velocities fields at point (x = 45-cm, y = 15, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



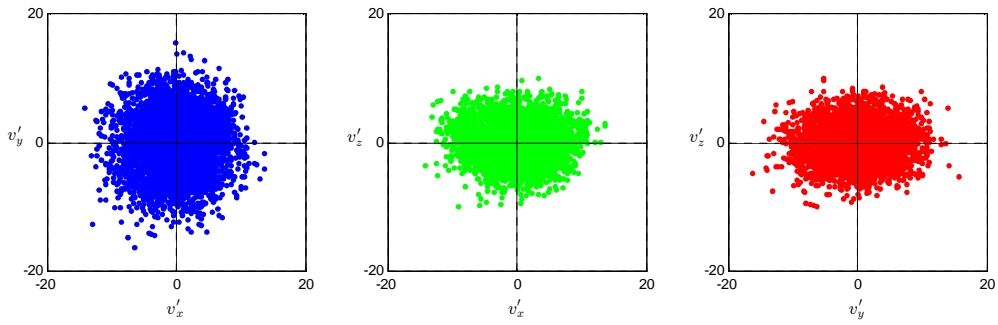
Turbulent velocities fields at point (x = 55-cm, y = 25, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



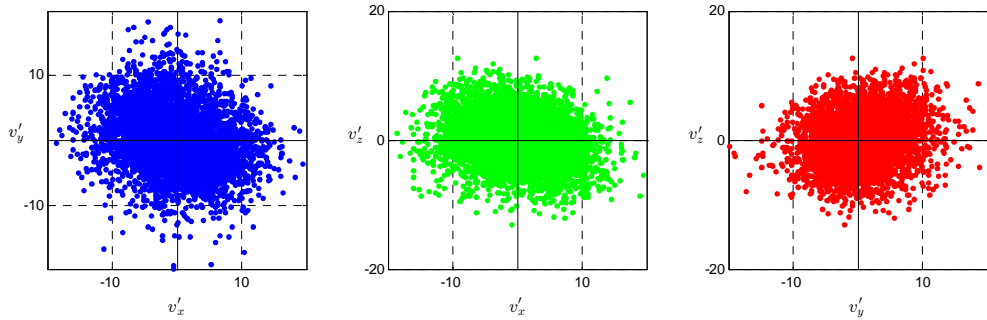
Turbulent velocities fields at point (x = 60-cm, y = 34, z = 5-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



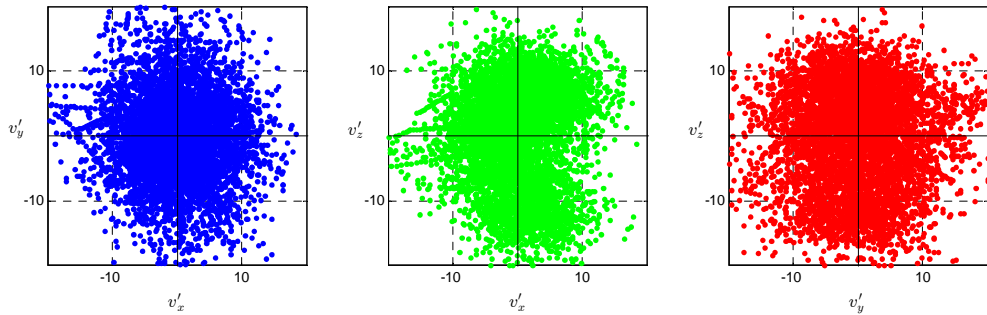
Turbulent velocities fields at point (x = -25-cm, y = -25, z = 6-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



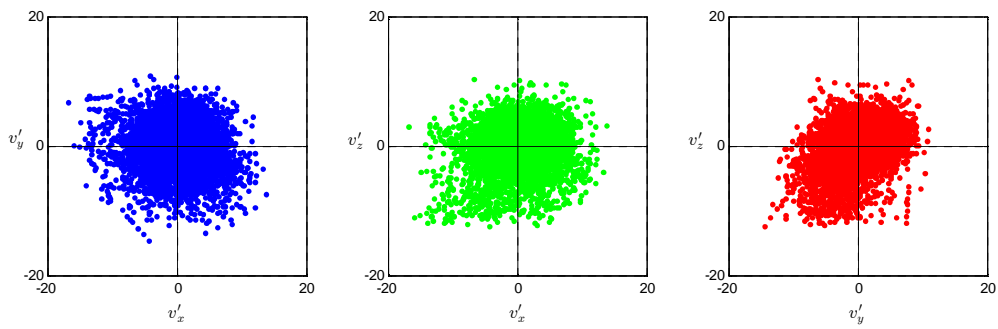
Turbulent velocities fields at point (x = 15-cm, y = -15, z = 6-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



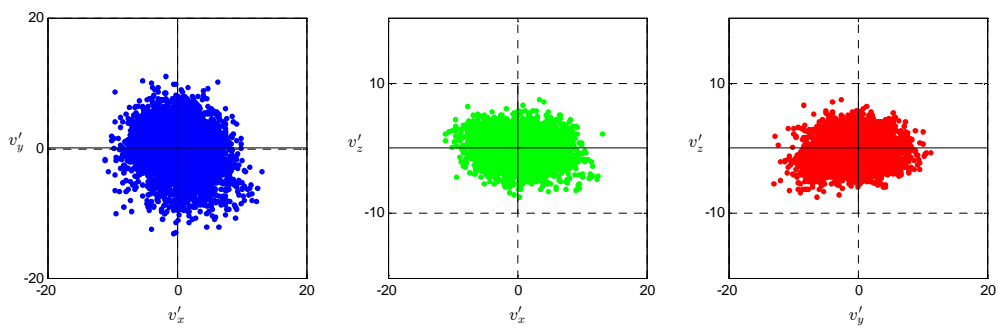
Turbulent velocities fields at point (x = 25-cm, y = -5, z = 6-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



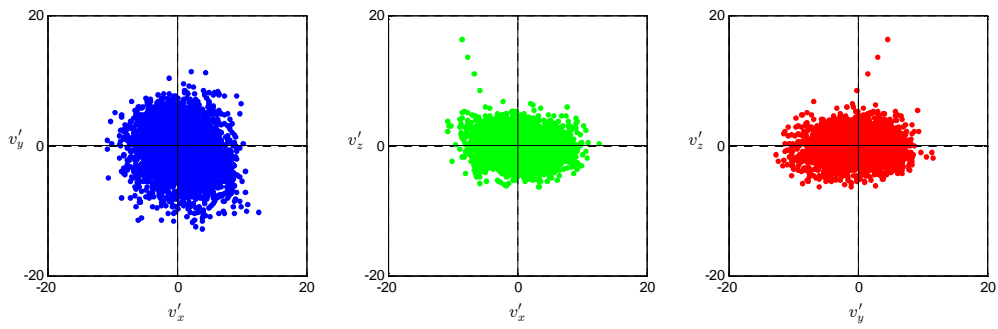
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 6-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



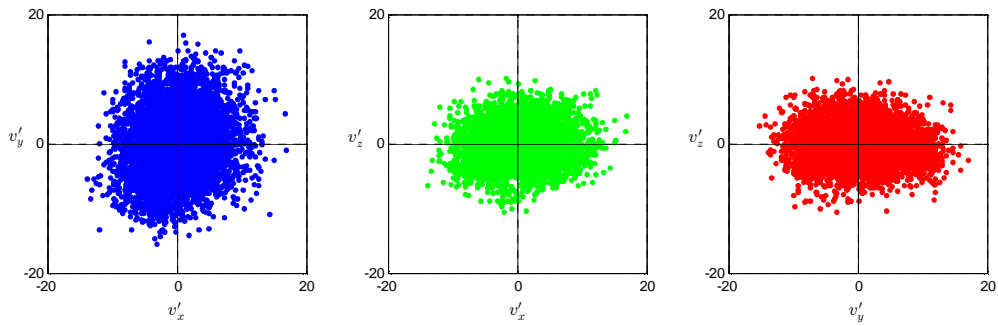
Turbulent velocities fields at point ($x = 45\text{-cm}$, $y = 15$, $z = 6\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



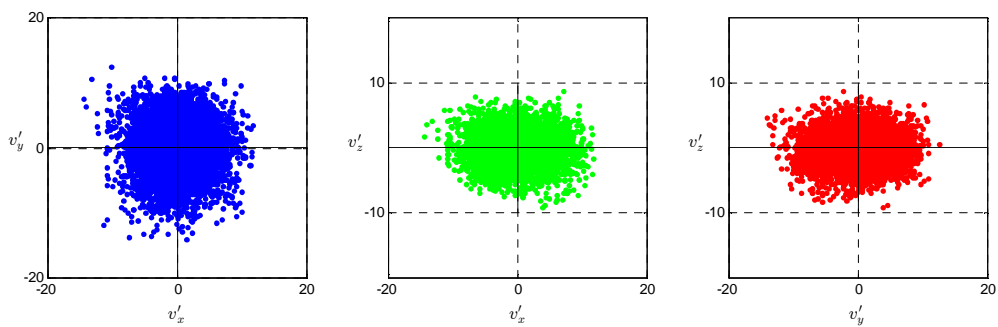
Turbulent velocities fields at point ($x = 55\text{-cm}$, $y = 25$, $z = 6\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



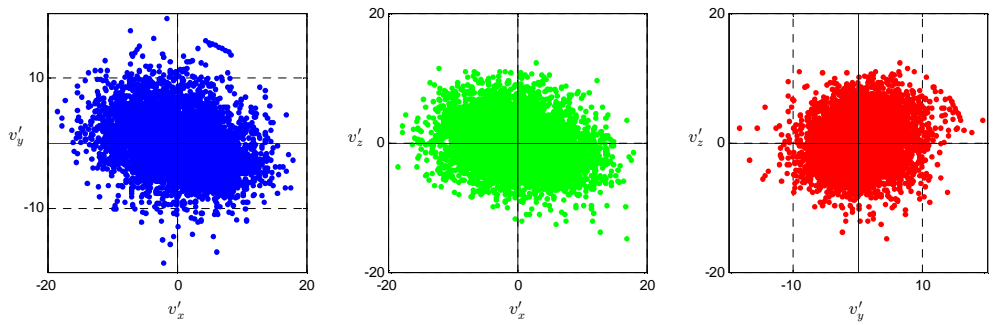
Turbulent velocities fields at point ($x = 60\text{-cm}$, $y = 34$, $z = 6\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



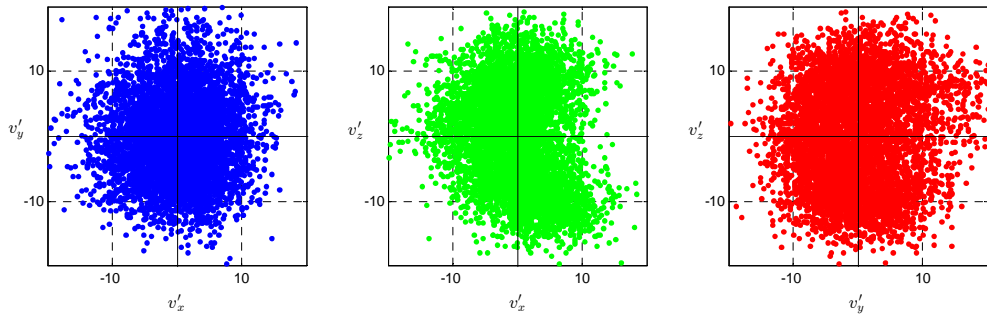
Turbulent velocities fields at point (x = -25-cm, y = -25, z = 7-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



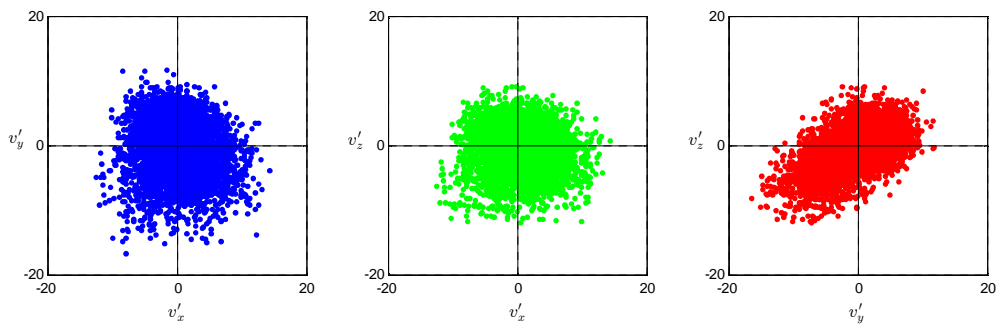
Turbulent velocities fields at point (x = 15-cm, y = -15, z = 7-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



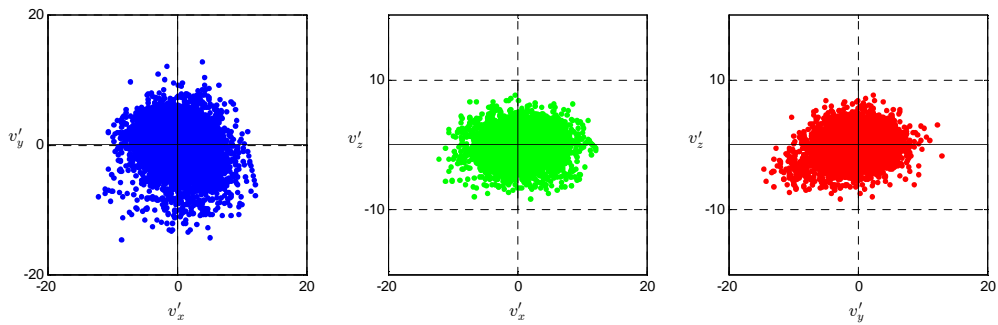
Turbulent velocities fields at point (x = 25-cm, y = -5 z = 7-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



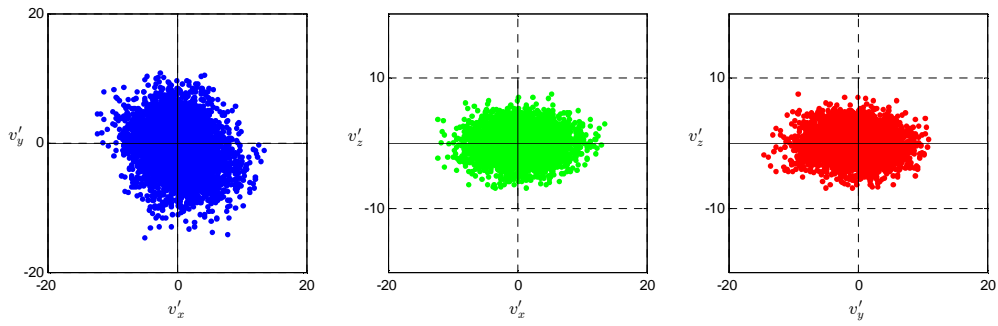
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 7-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



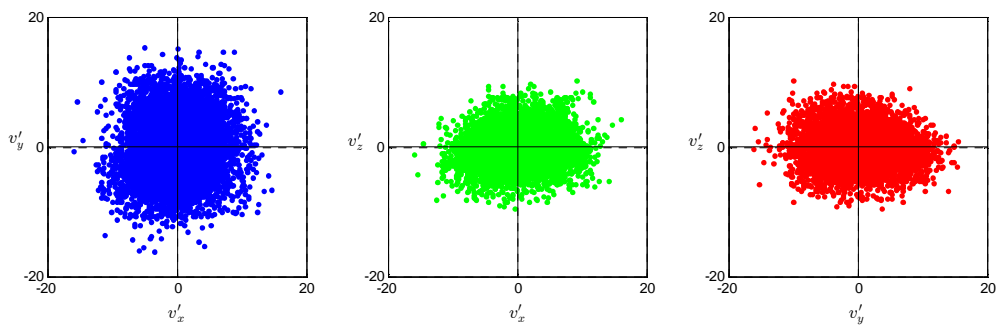
Turbulent velocities fields at point (x = 45-cm, y = 15, z = 7-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



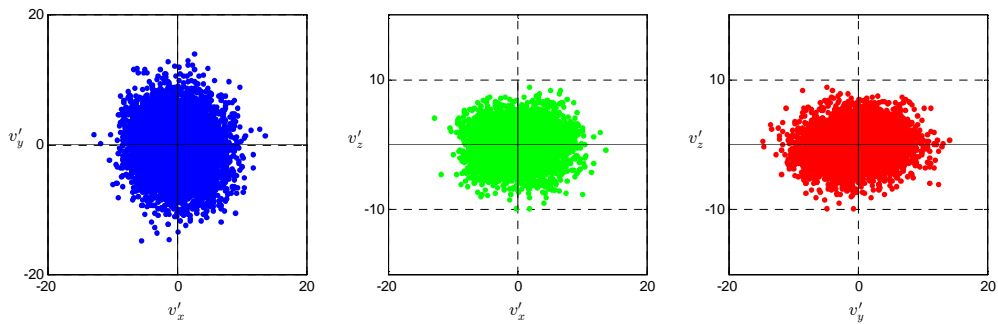
Turbulent velocities fields at point (x = 55-cm, y = 25, z = 7-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



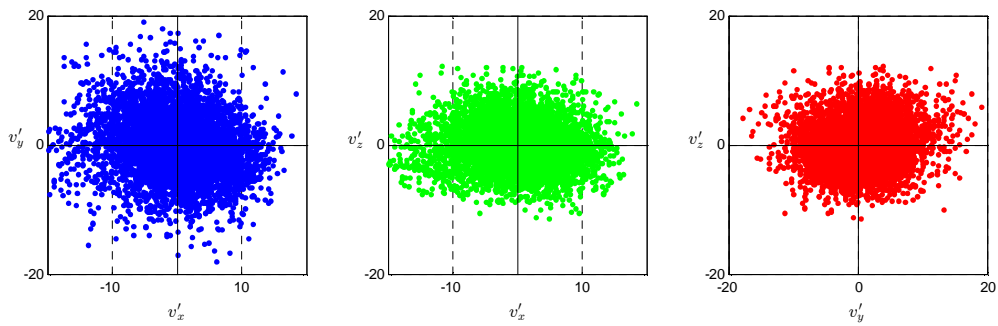
Turbulent velocities fields at point ($x = 60\text{-cm}$, $y = 34$, $z = 7\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



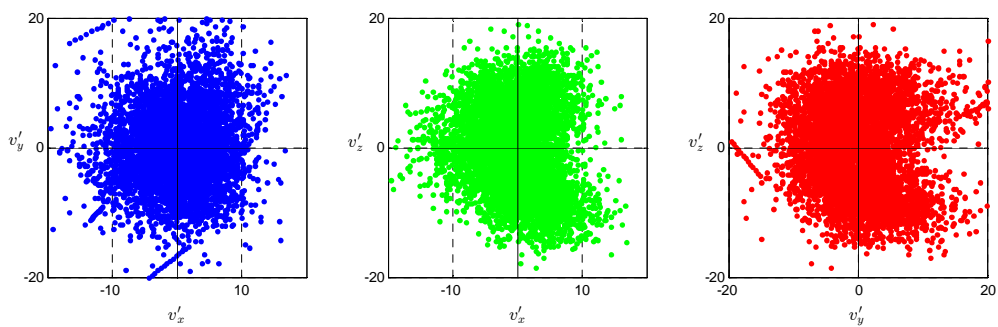
Turbulent velocities fields at point ($x = -25\text{-cm}$, $y = -25$, $z = 8\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – upstream of vane – Experimental results.



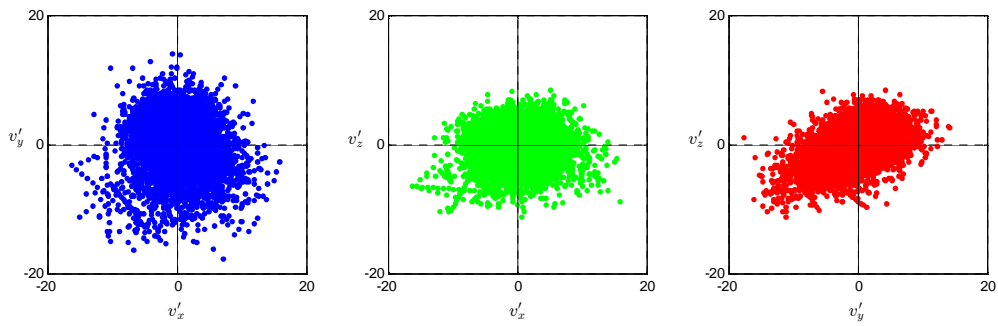
Turbulent velocities fields at point ($x = 15\text{-cm}$, $y = -15$, $z = 8\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



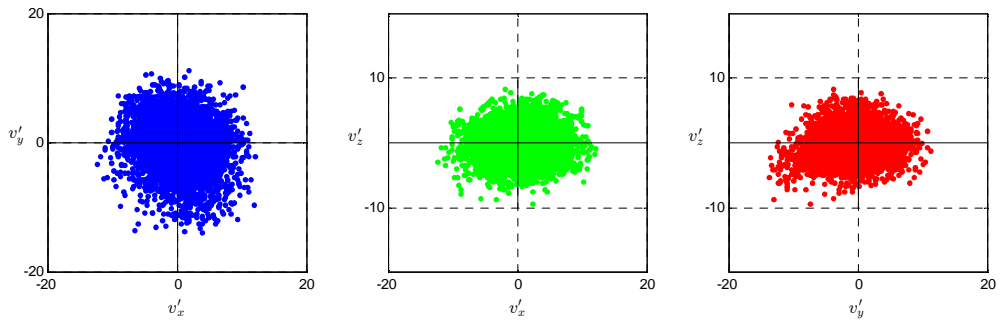
Turbulent velocities fields at point (x = 25-cm, y = -5, z = 8-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



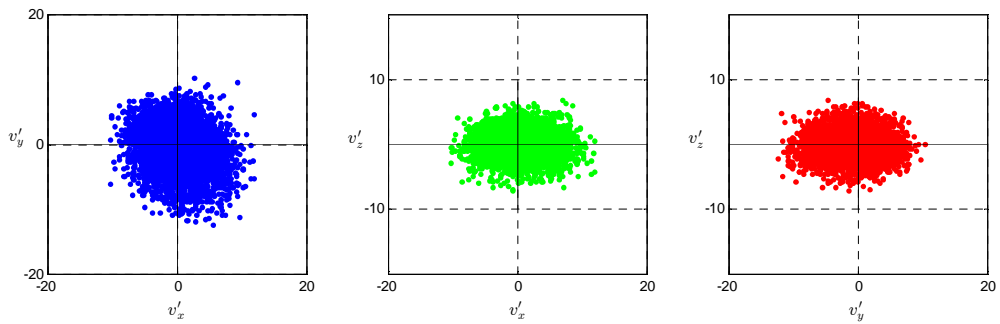
Turbulent velocities fields at point (x = 35-cm, y = 0, z = 8-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



Turbulent velocities fields at point (x = 45-cm, y = 15, z = 8-cm), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



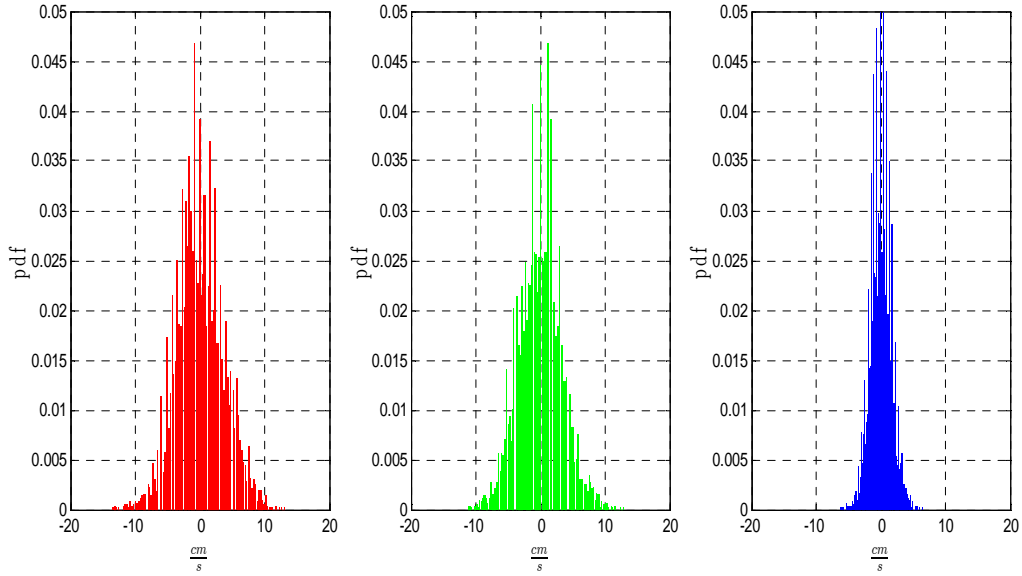
Turbulent velocities fields at point ($x = 55\text{-cm}$, $y = 25$, $z = 8\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.



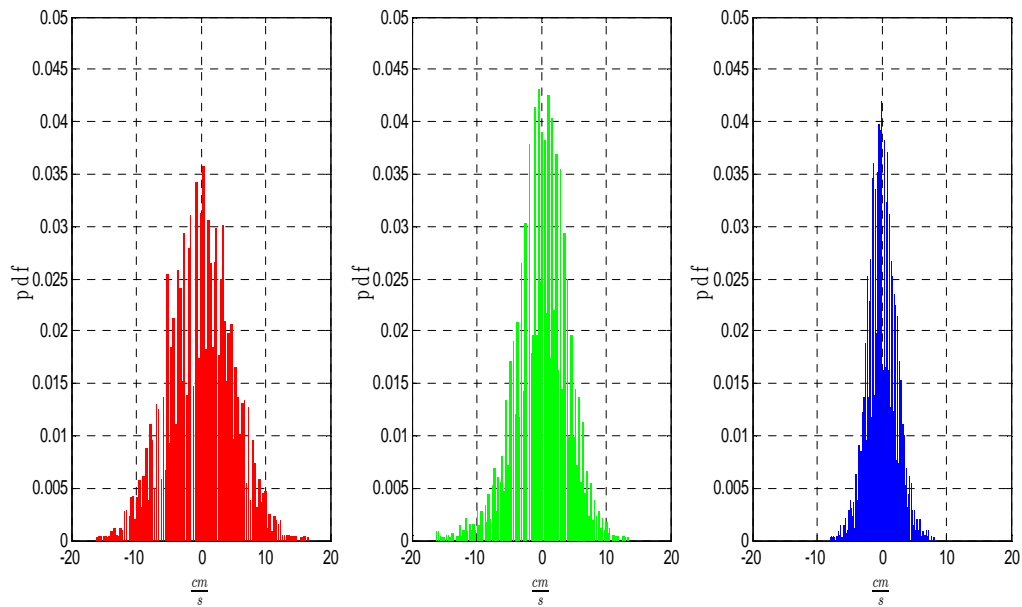
Turbulent velocities fields at point ($x = 60\text{-cm}$, $y = 34$, $z = 8\text{-cm}$), each dot represents a pair at a certain time: (blue) v'_x, v'_y , (green) v'_x, v'_z and (red) v'_y, v'_z – downstream of vane – Experimental results.

D.3 Fluctuating Velocities and Reynolds Stresses Histograms

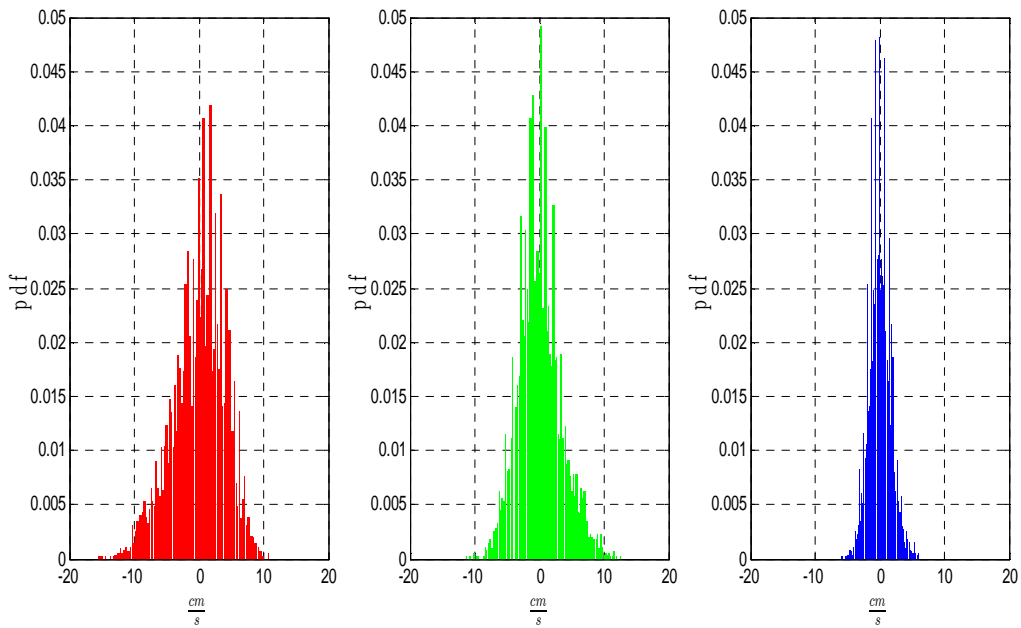
I. Fluctuating Velocities



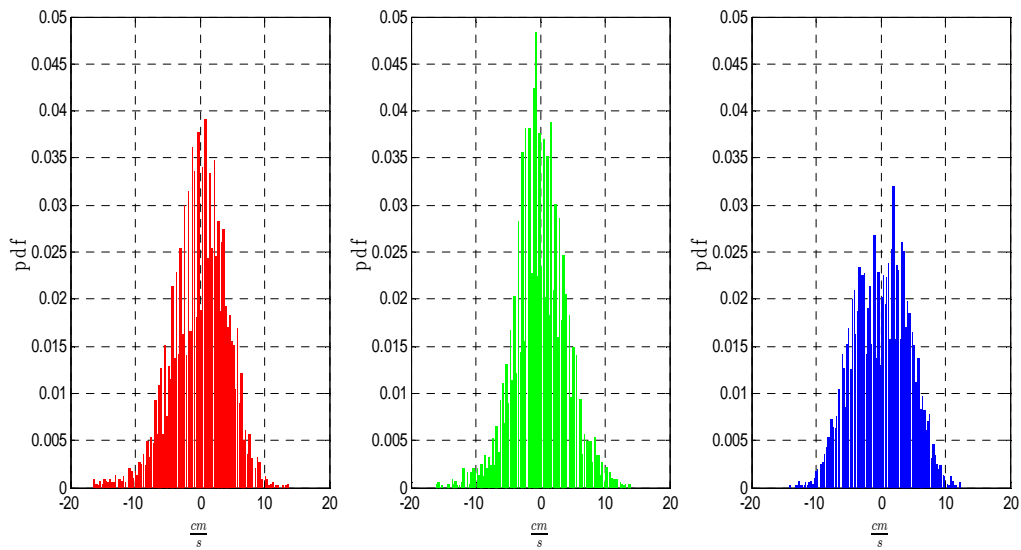
Histogram of the relative distribution of the instantaneous velocity field at point (x = 15-cm, y = -15, z = 1-cm): (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



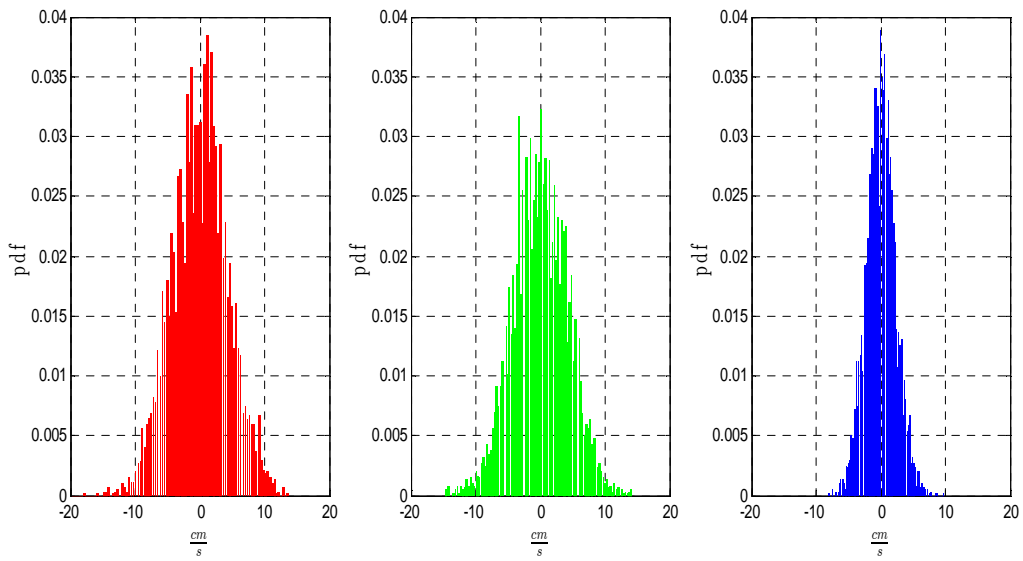
Histogram of the relative distribution of the instantaneous velocity field at point (x = 35-cm, y = 0, z = 1-cm): (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



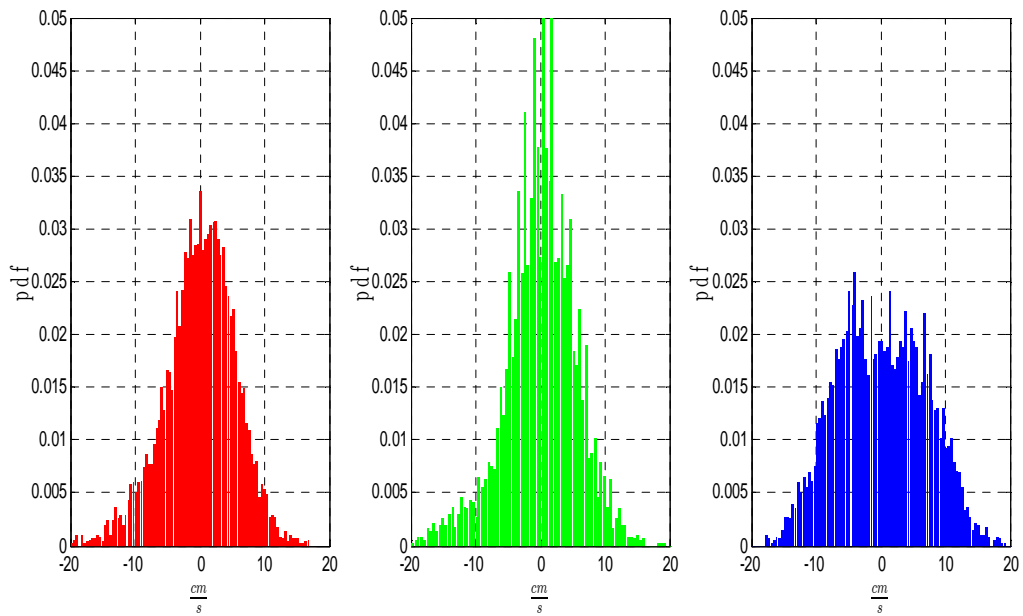
Histogram of the relative distribution of the instantaneous velocity field at point ($x = 15\text{-cm}$, $y = -15$, $z = 2\text{-cm}$): (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



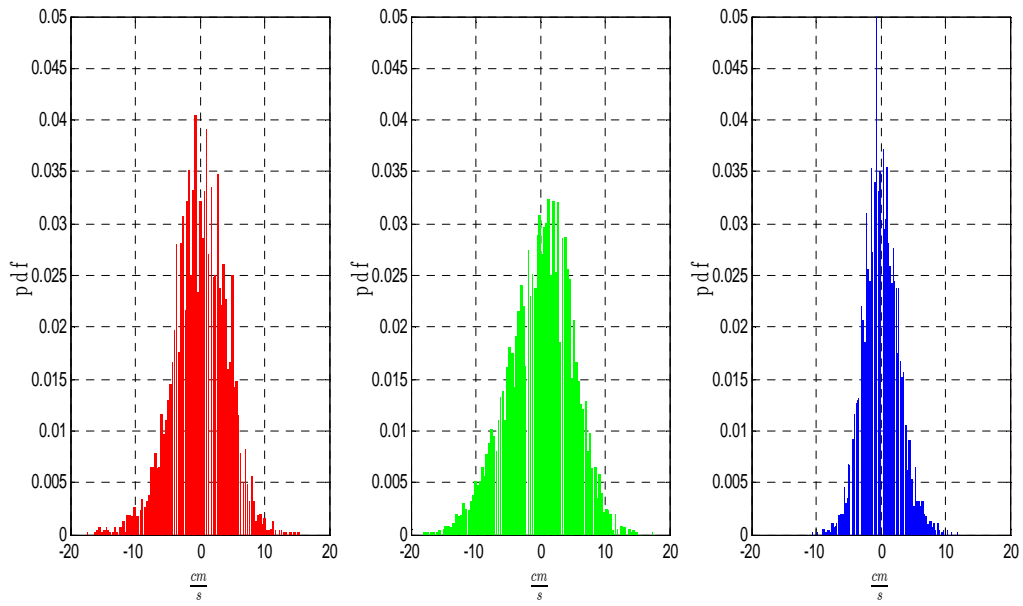
Histogram of the relative distribution of the instantaneous velocity field at point ($x = 35\text{-cm}$, $y = 0$, $z = 2\text{-cm}$): (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



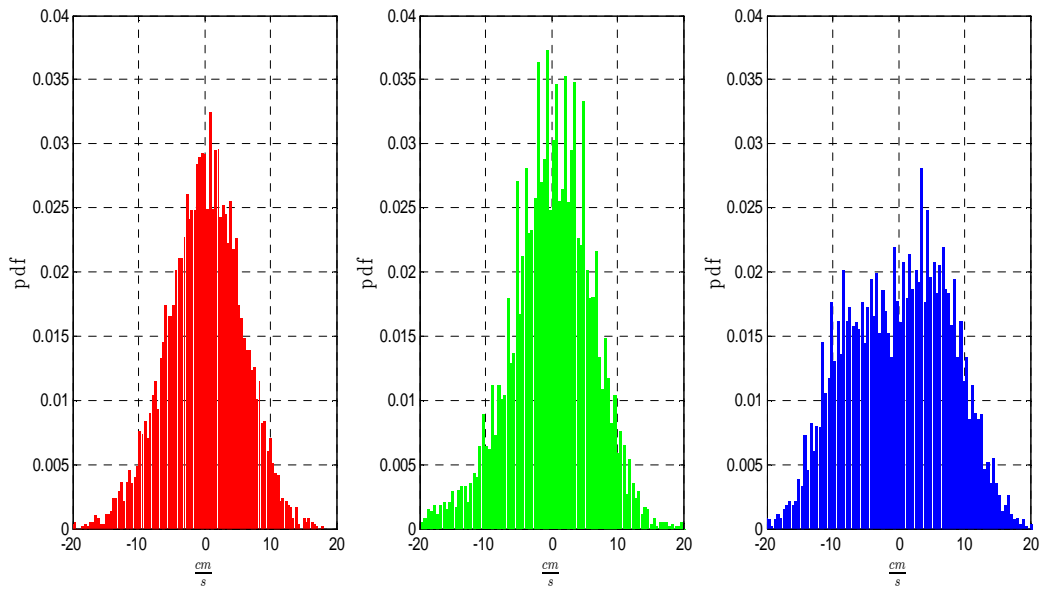
Histogram of the relative distribution of the instantaneous velocity field at point ($x = 15\text{-cm}$, $y = -15$, $z = 3\text{-cm}$):
(a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



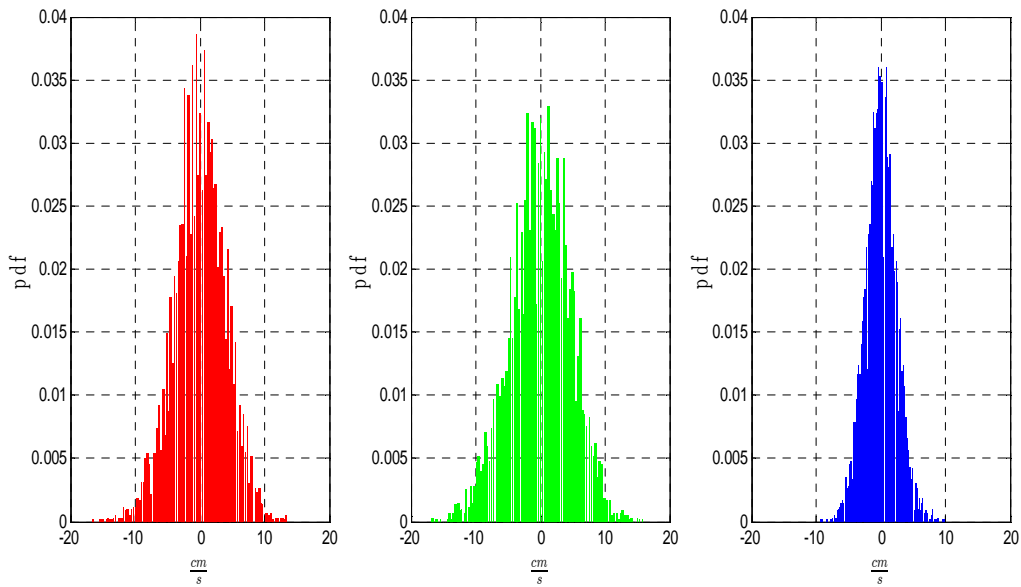
Histogram of the relative distribution of the instantaneous velocity field at point ($x = 35\text{-cm}$, $y = 0$, $z = 3\text{-cm}$):
(a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



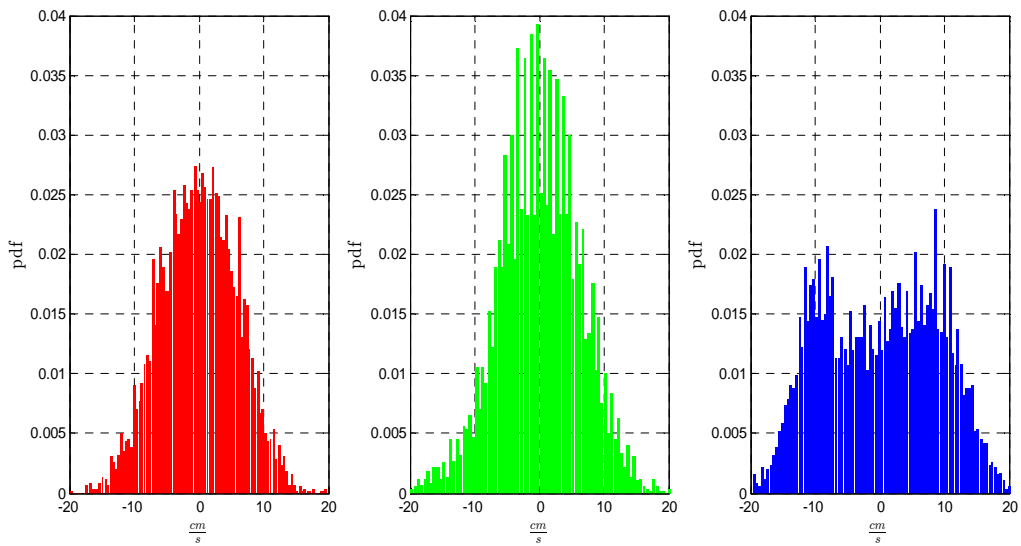
**Histogram of the relative distribution of the instantaneous velocity field at point (x = 15-cm, y = -15, z = 4-cm):
(a) v'_x , (b) v'_y and (c) v'_z - Experimental results.**



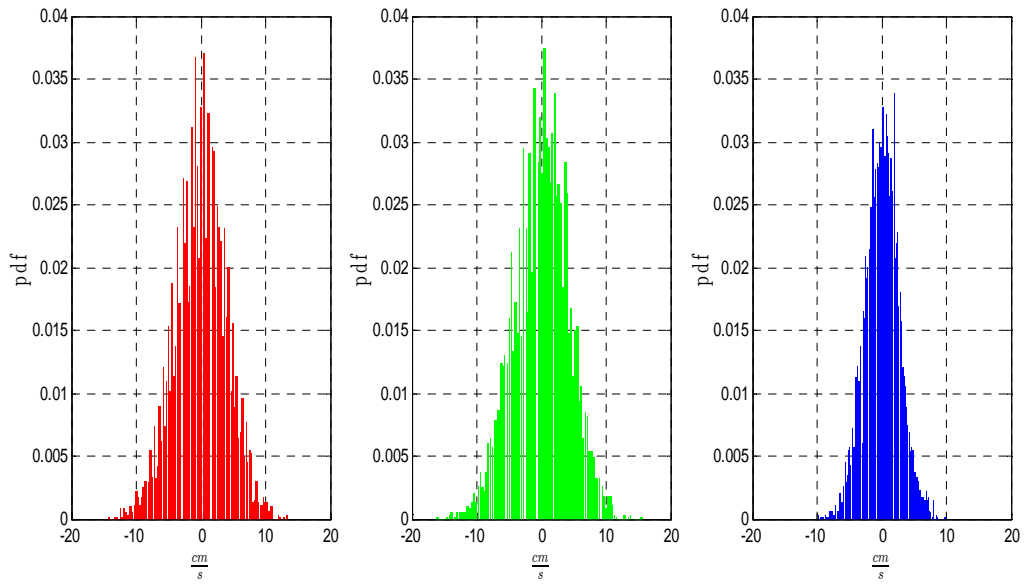
**Histogram of the relative distribution of the instantaneous velocity field at point (x = 35-cm, y = 0, z = 4-cm):
(a) v'_x , (b) v'_y and (c) v'_z - Experimental results.**



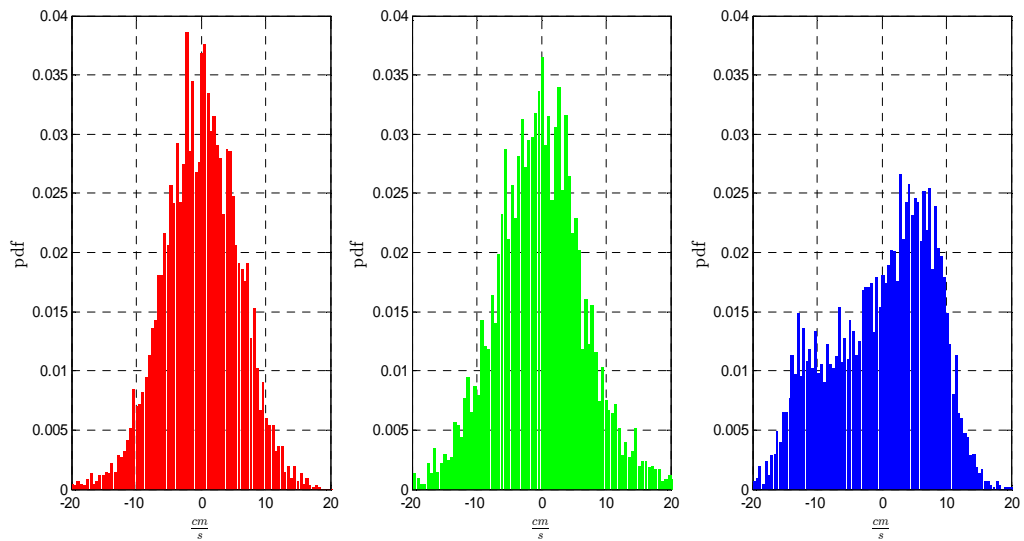
**Histogram of the relative distribution of the instantaneous velocity field at point (x = 15-cm, y = -15, z = 5-cm):
 (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.**



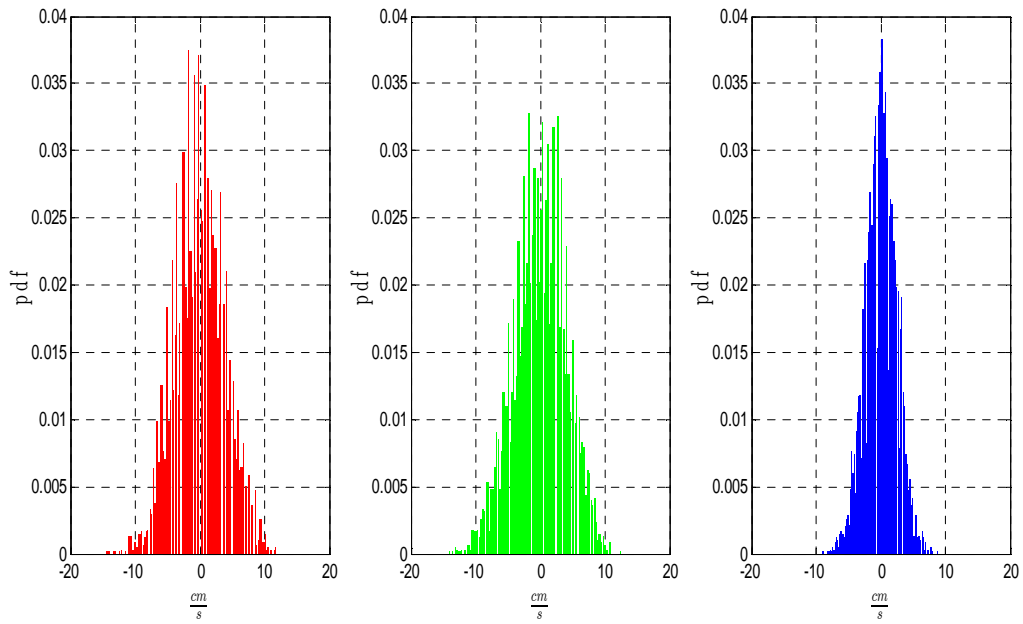
**Histogram of the relative distribution of the instantaneous velocity field at point (x = 35-cm, y = 0, z = 5-cm):
 (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.**



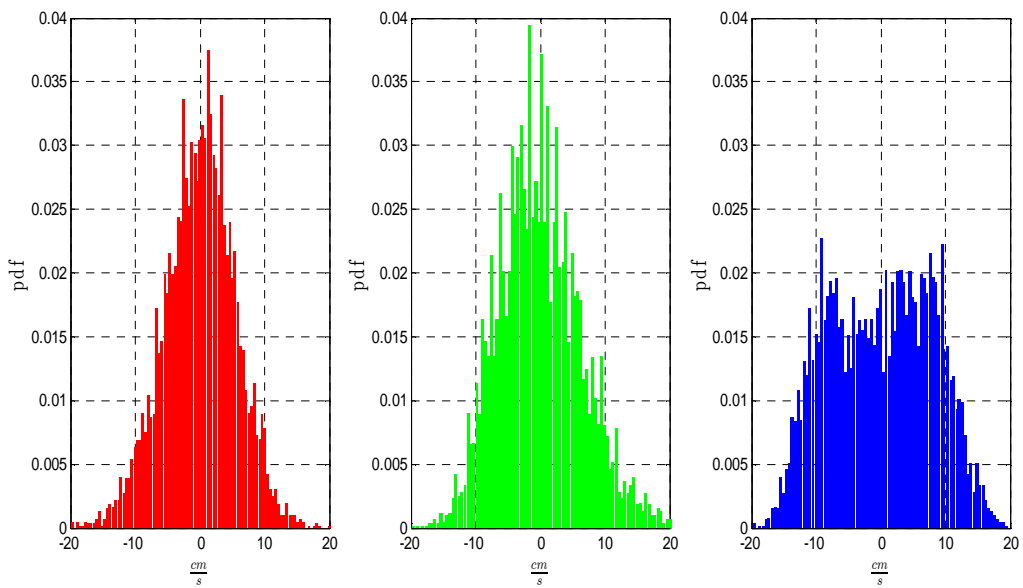
Histogram of the relative distribution of the instantaneous velocity field at point ($x = 15\text{-cm}$, $y = -15$, $z = 6\text{-cm}$): (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



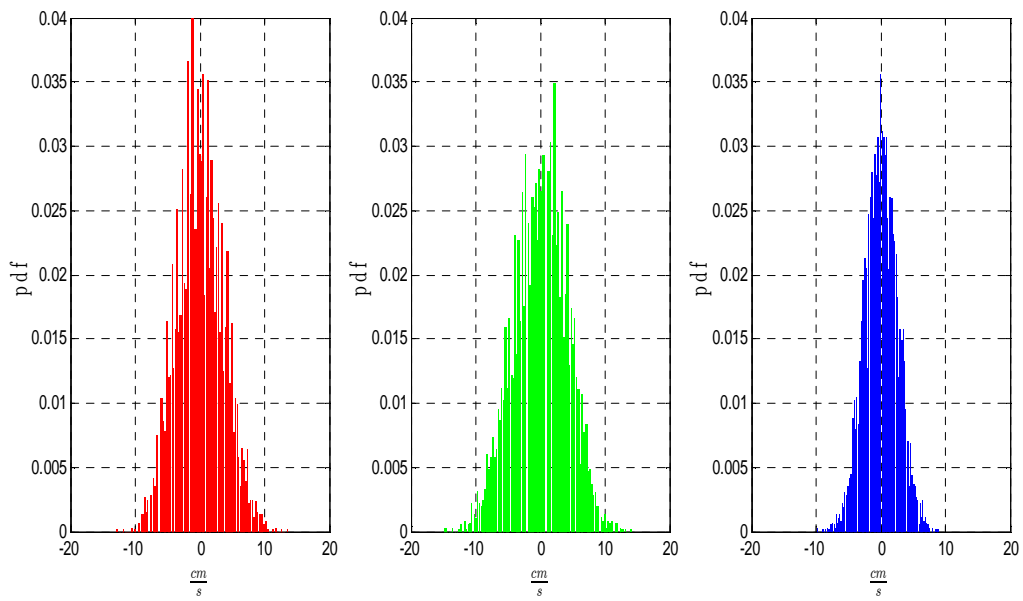
Histogram of the relative distribution of the instantaneous velocity field at point ($x = 35\text{-cm}$, $y = 0$, $z = 6\text{-cm}$): (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.



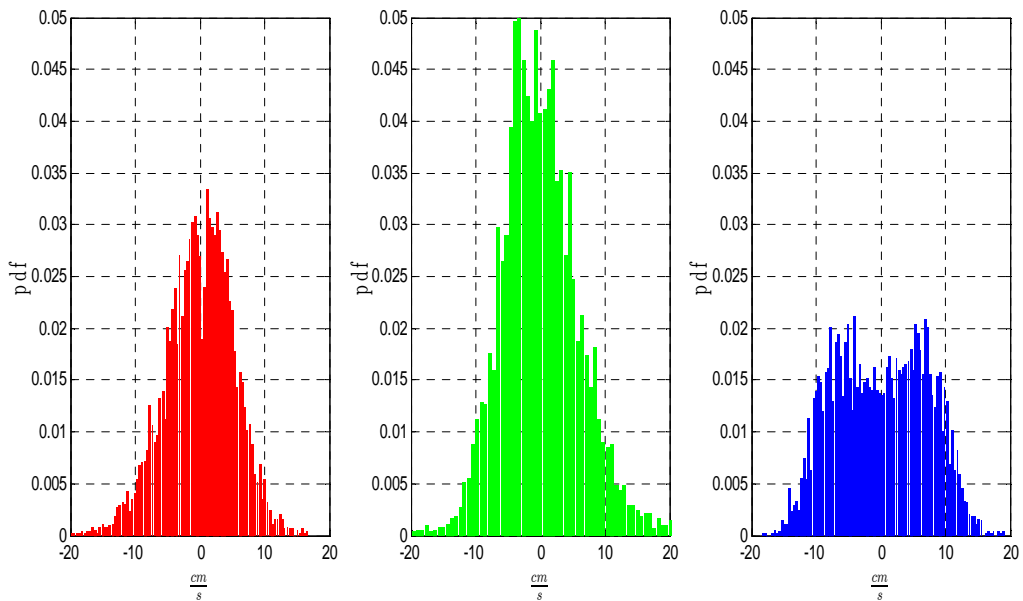
**Histogram of the relative distribution of the instantaneous velocity field at point (x = 15-cm, y = -15, z = 7-cm):
 (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.**



**Histogram of the relative distribution of the instantaneous velocity field at point (x = 35-cm, y = 0, z = 7-cm):
 (a) v'_x , (b) v'_y and (c) v'_z - Experimental results.**

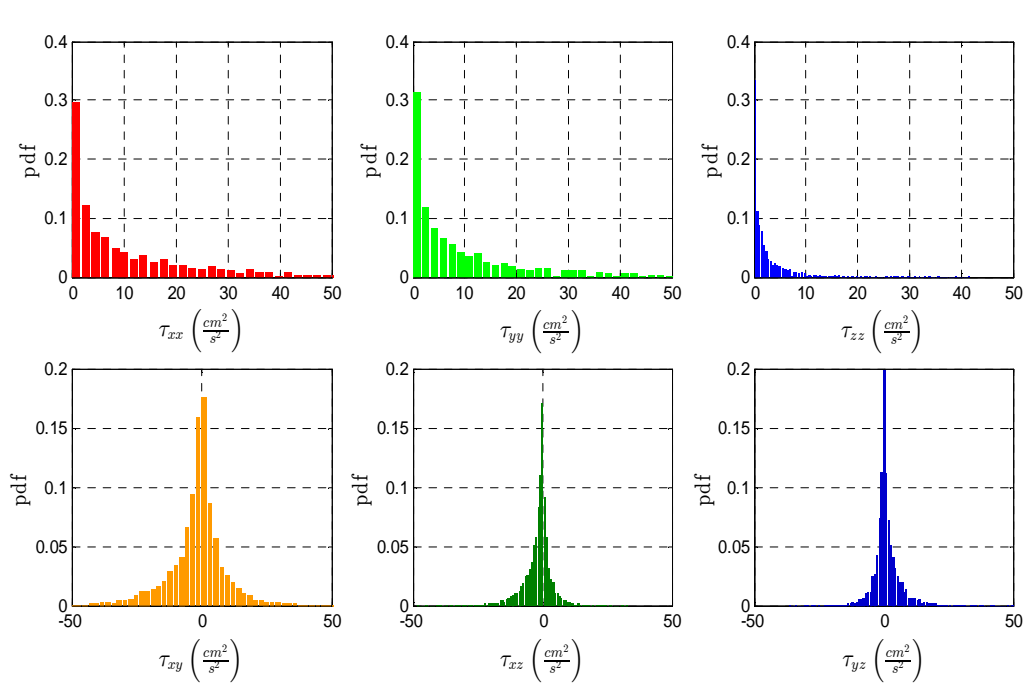


**Histogram of the relative distribution of the instantaneous velocity field at point (x = 15-cm, y = -15, z = 8-cm):
(a) v_x , (b) v_y and (c) v_z - Experimental results.**

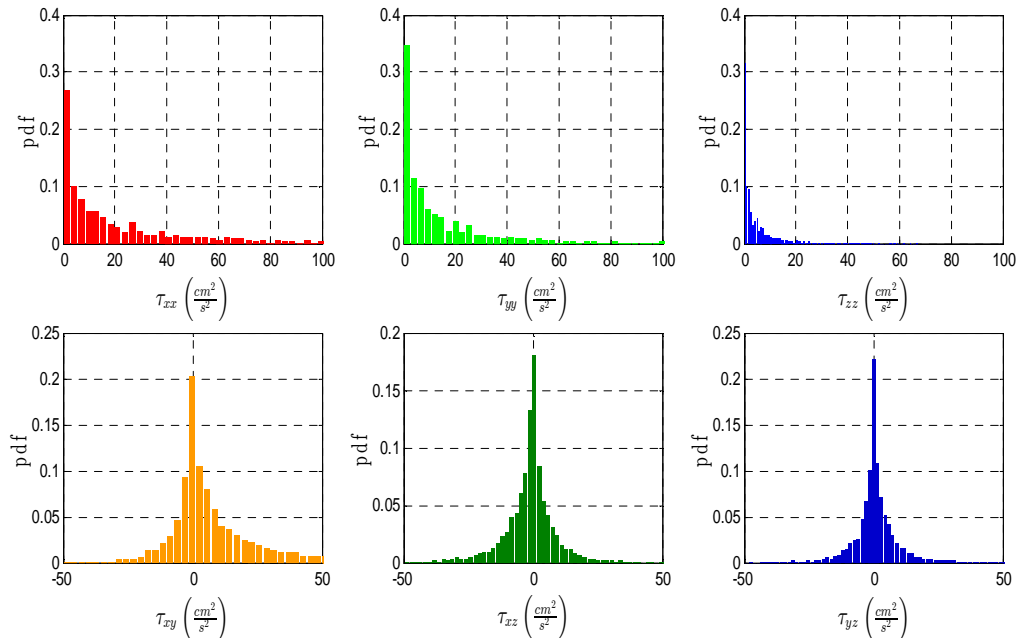


**Histogram of the relative distribution of the instantaneous velocity field at point (x = 35-cm, y = 0, z = 8-cm):
(a) v_x , (b) v_y and (c) v_z - Experimental results.**

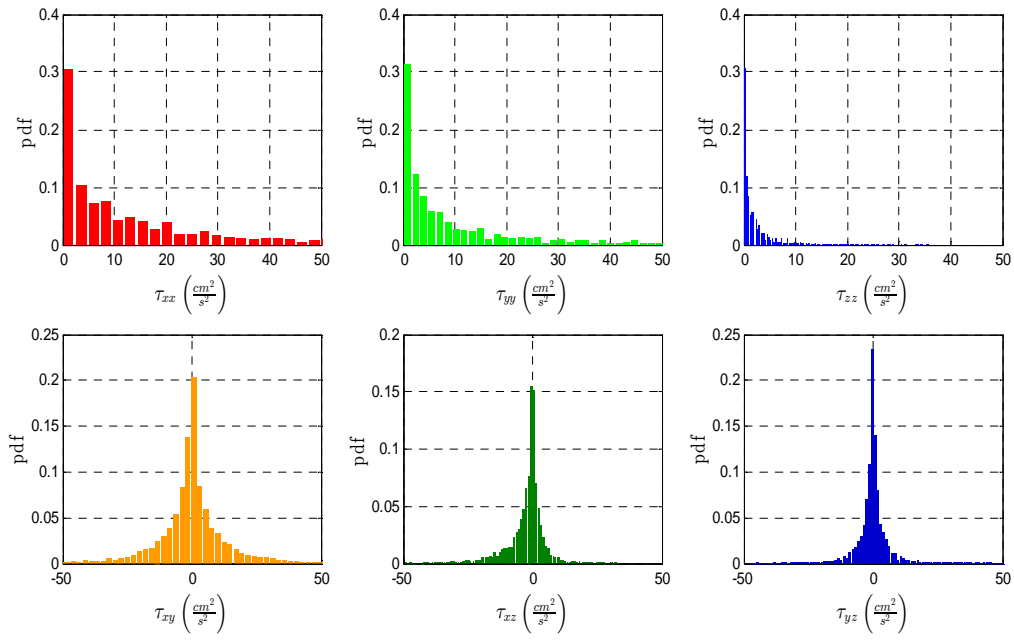
II. Reynolds Stresses



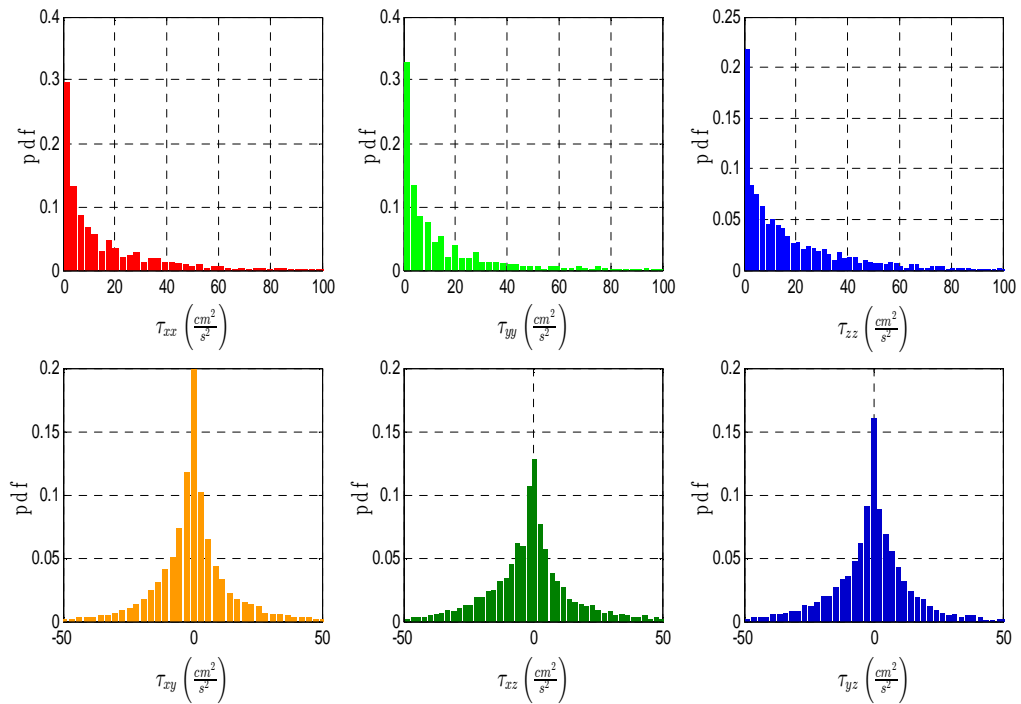
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 1-cm) – Experimental results.



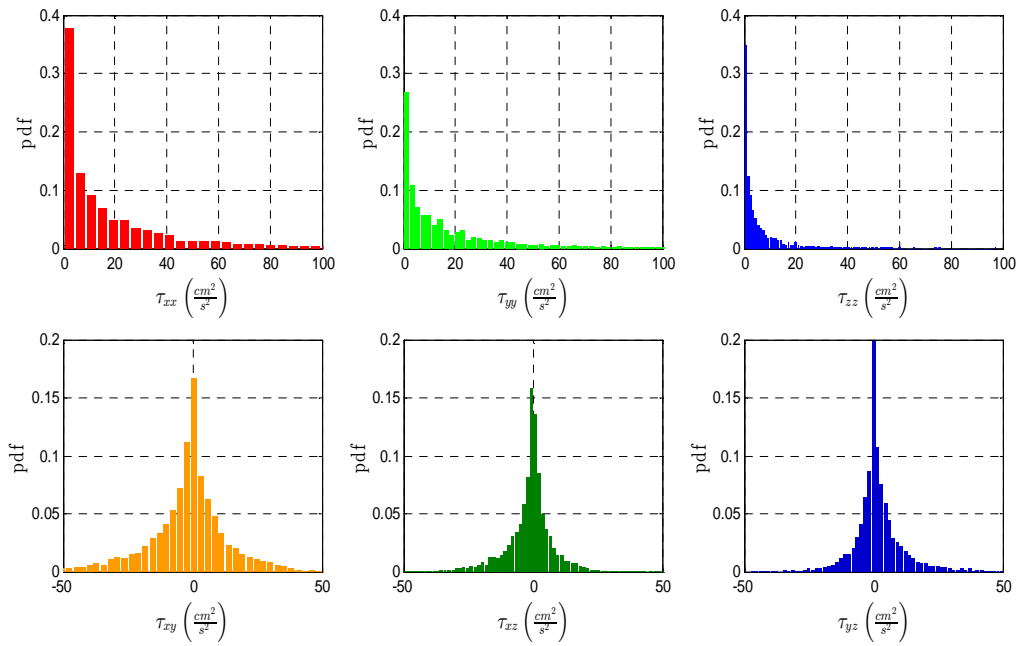
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 1-cm) – Experimental results.



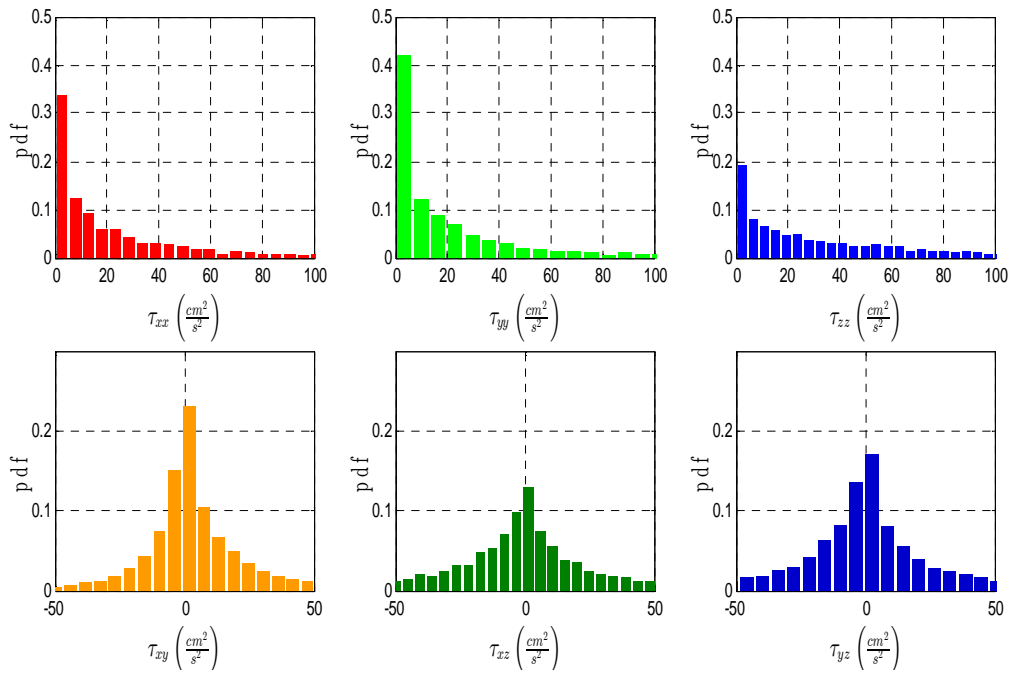
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 2-cm) – Experimental results.



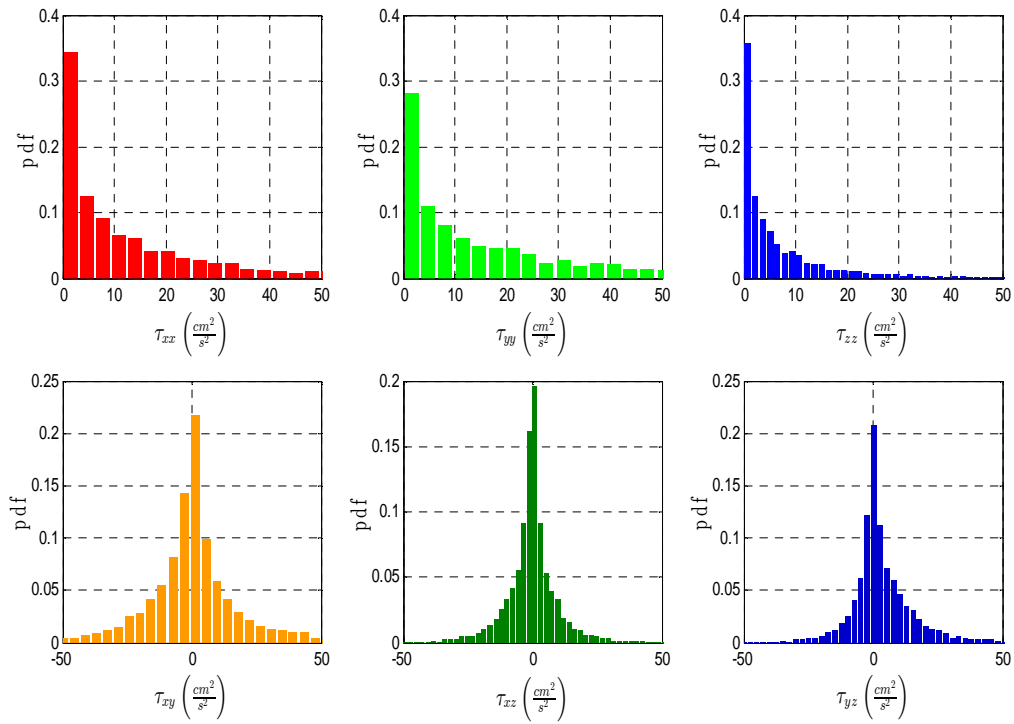
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 2-cm) – Experimental results.



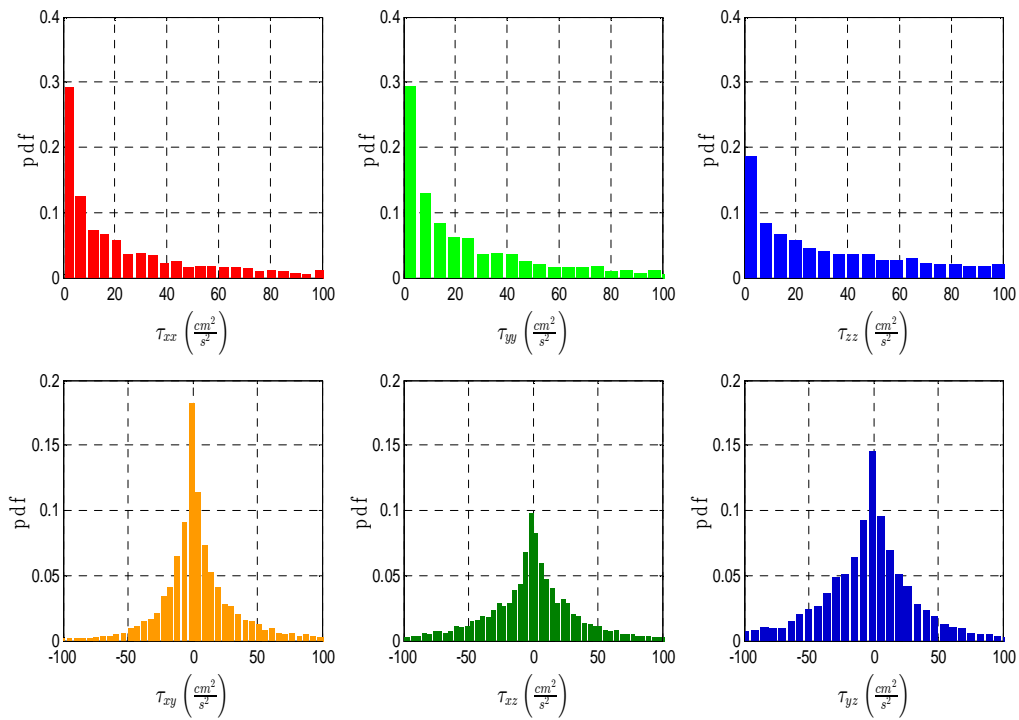
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 3-cm) – Experimental results.



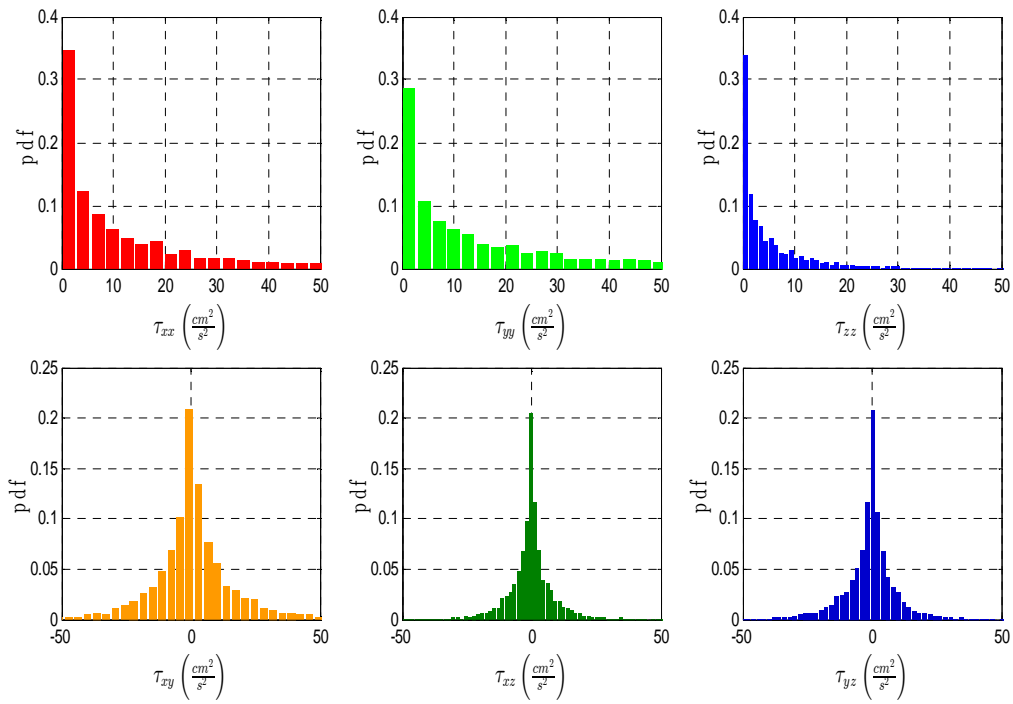
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 3-cm) – Experimental results.



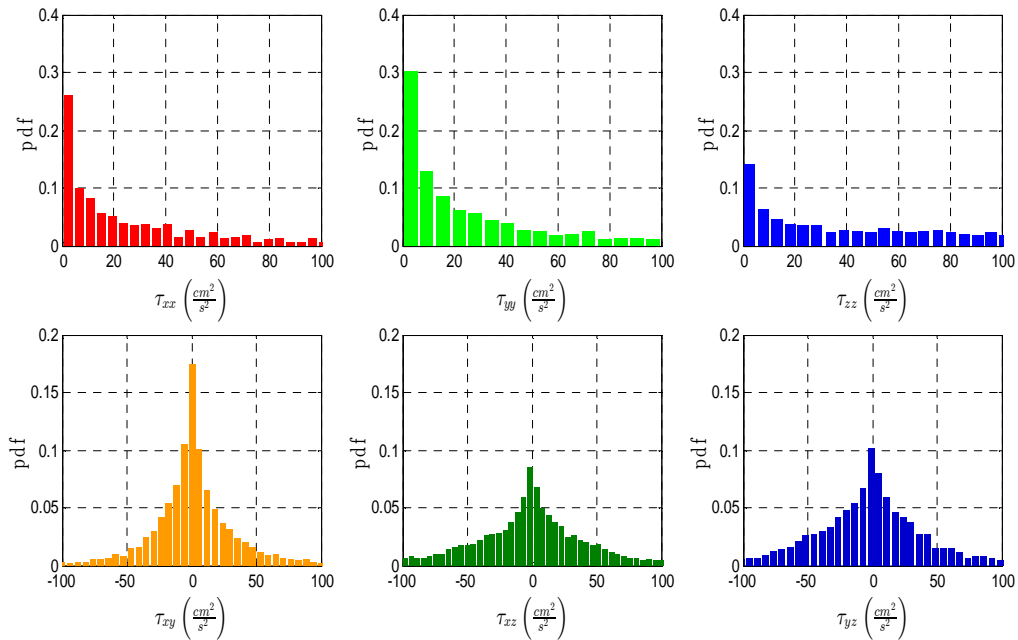
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 4-cm) – Experimental results.



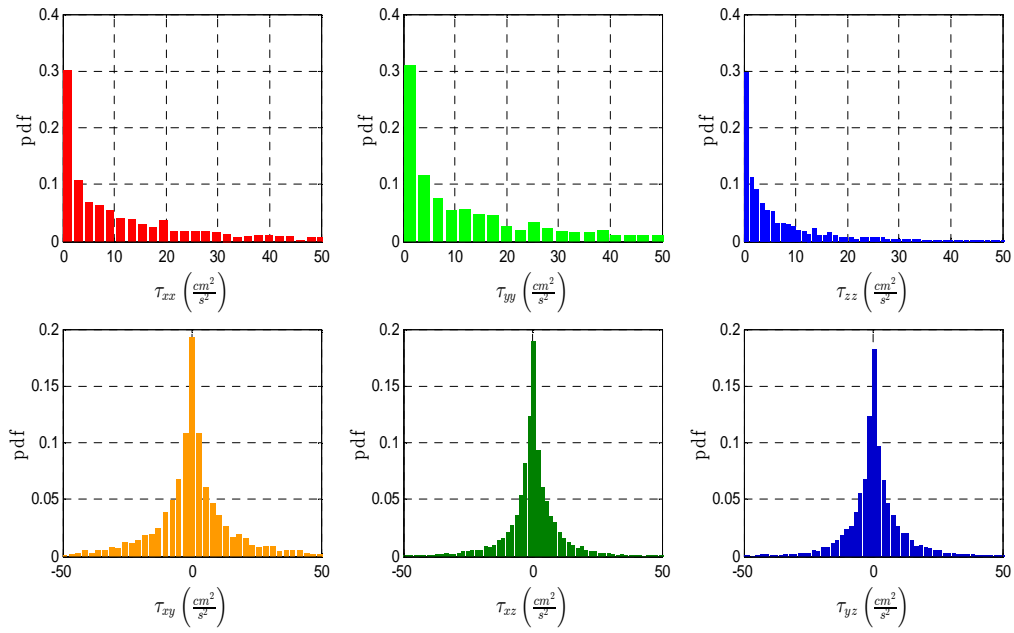
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 4-cm) – Experimental results.



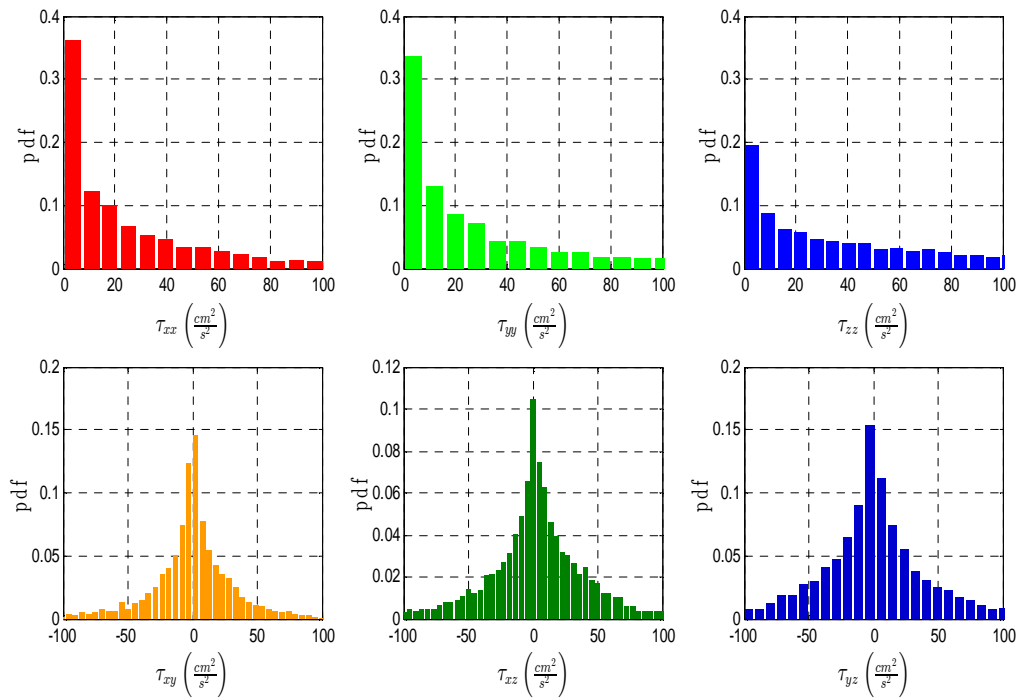
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 5-cm) – Experimental results.



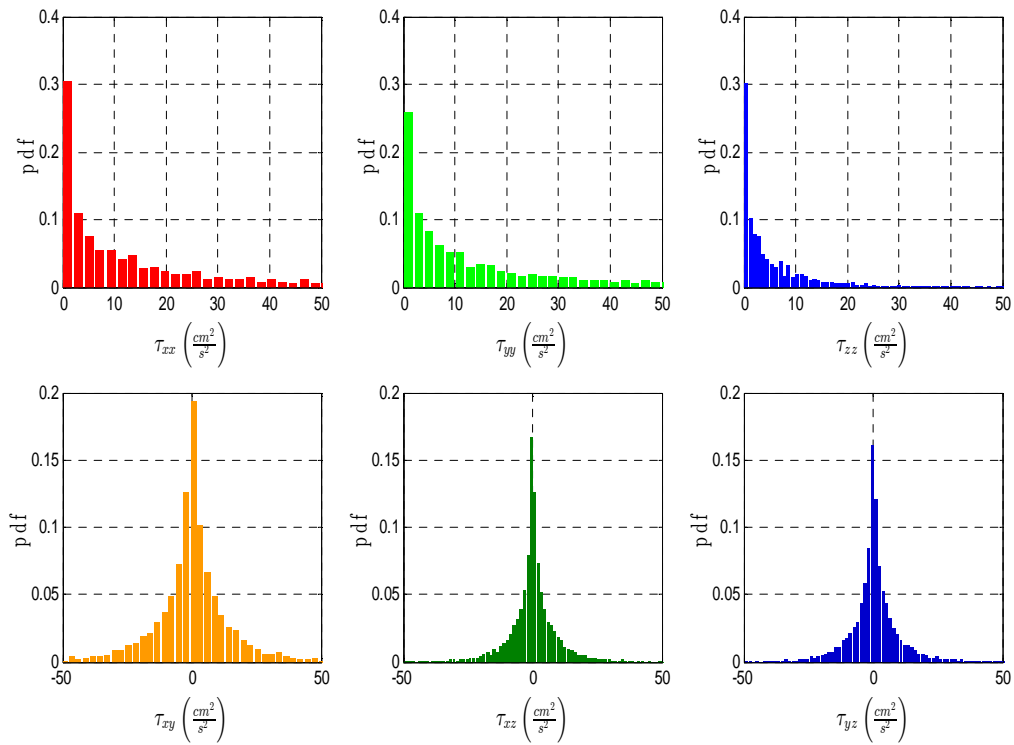
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 5-cm) – Experimental results.



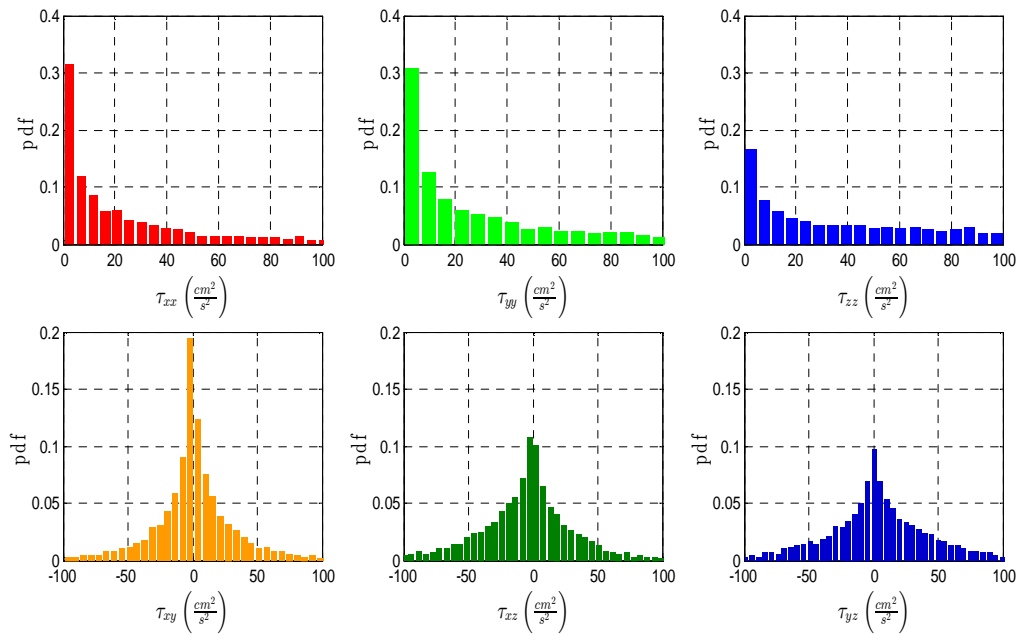
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 6-cm) – Experimental results.



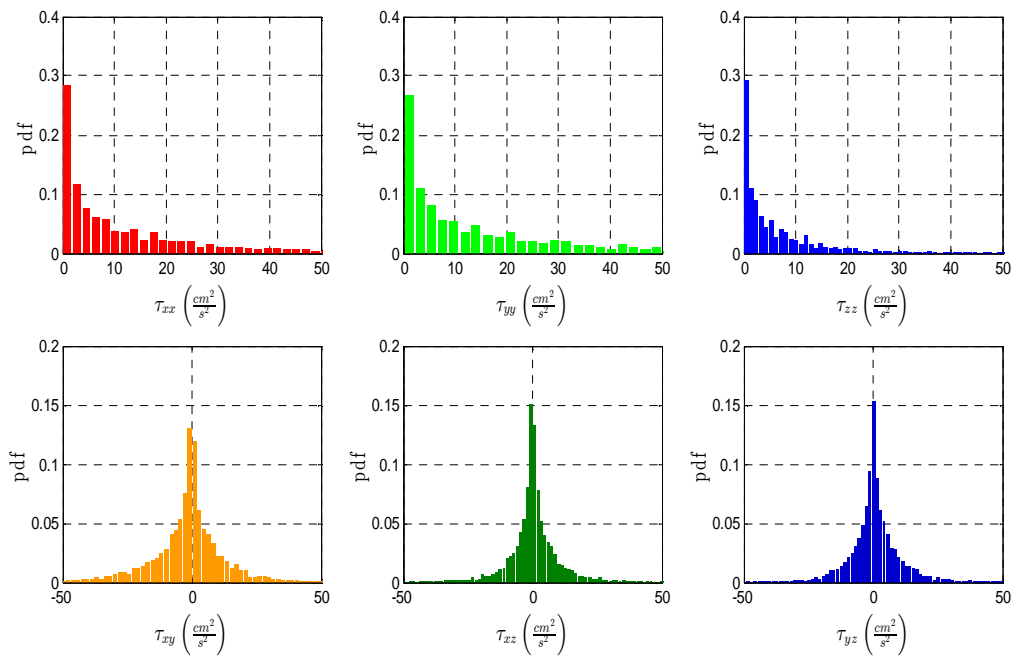
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 6-cm) – Experimental results.



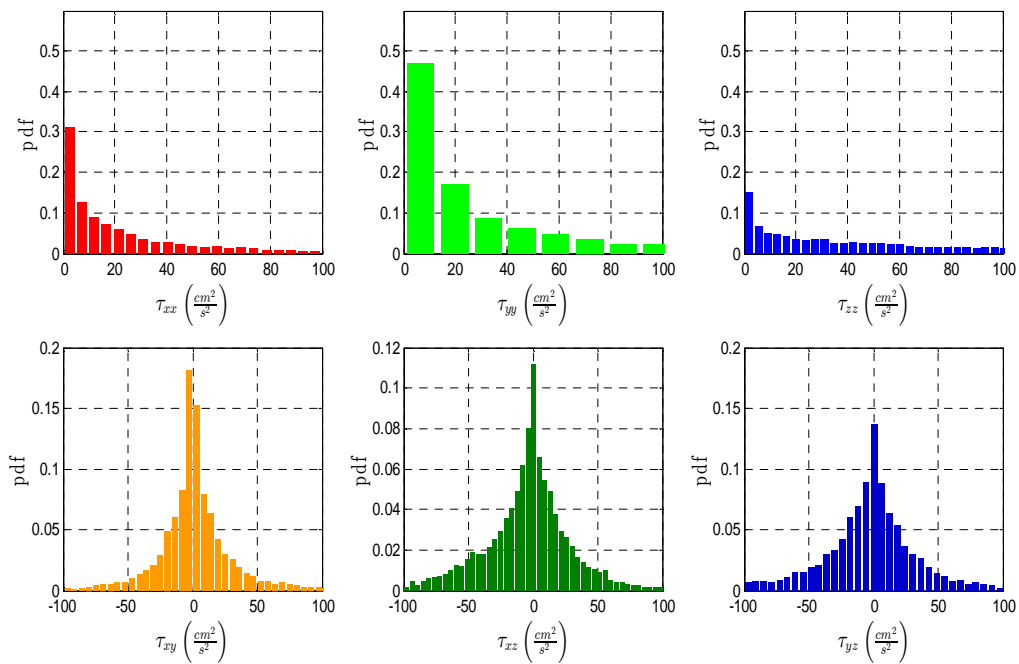
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 7-cm) – Experimental results.



Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 7-cm) – Experimental results.



Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 15-cm, y = -15, z = 8-cm) – Experimental results.



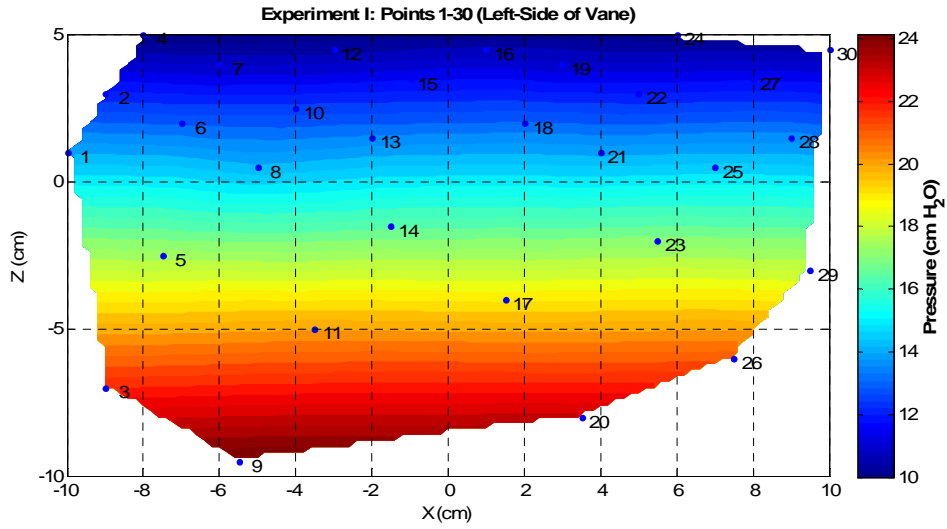
Histogram of the probability density function of Reynolds normal and shear stresses, in the x-y plane at point (x = 35-cm, y = 0, z = 8-cm) – Experimental results.

APPENDIX E.

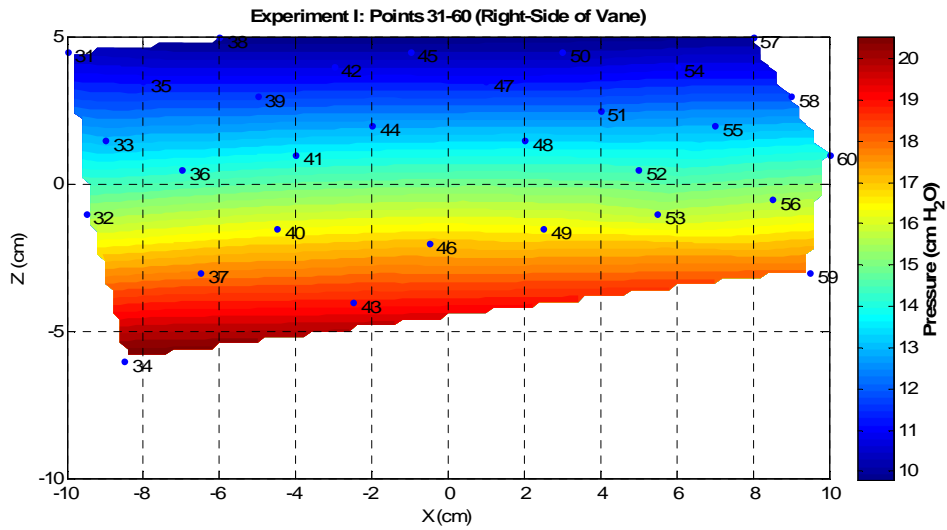
RESULTS – PRESSURES

Appendix E Results – Pressures

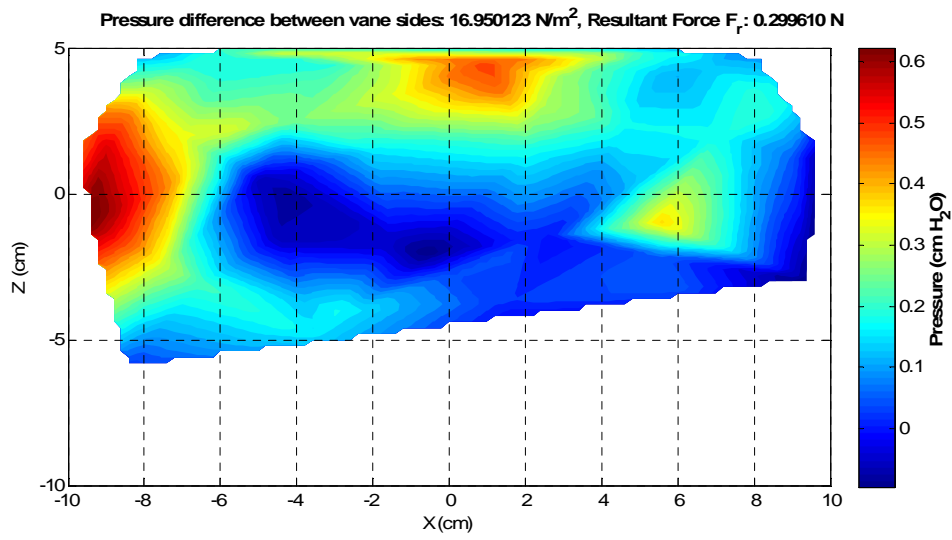
1. Experiment I – Total Pressures



Total pressures (cm-wc) on the left-side of vane, points from 1 to 30 – Experiment (I) results.

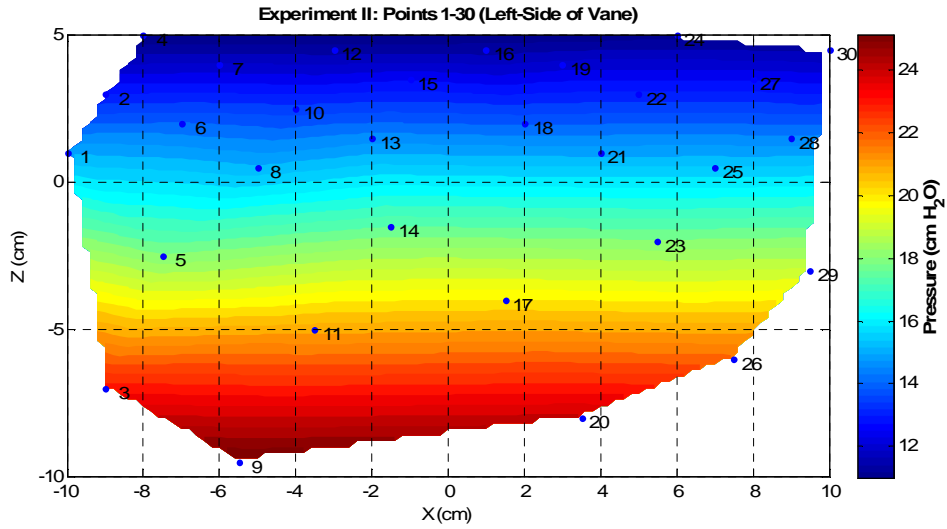


Total pressures (cm-wc) acts on the right-side of vane, points from 31 to 60 – Experiment (I) results.

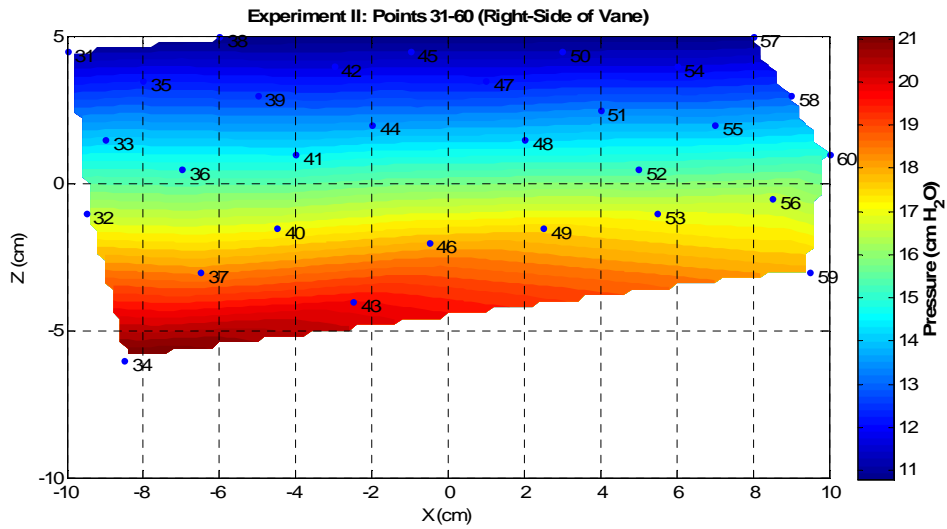


Pressures difference between submerged vane sides – Experiment (I) results.

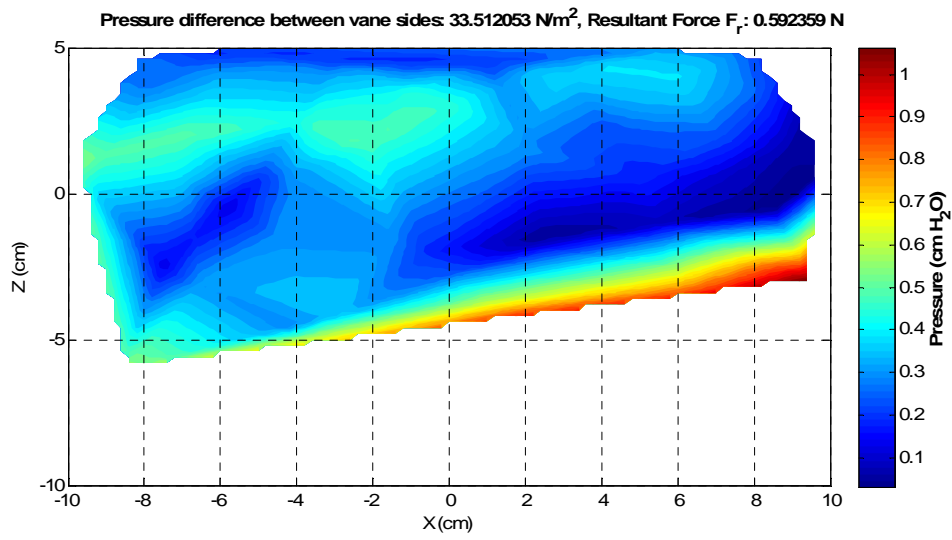
2. Experiment II – Total Pressures



Total pressures (cm-wc) on the left-side of vane, points from 1 to 30 – Experiment (II) results.

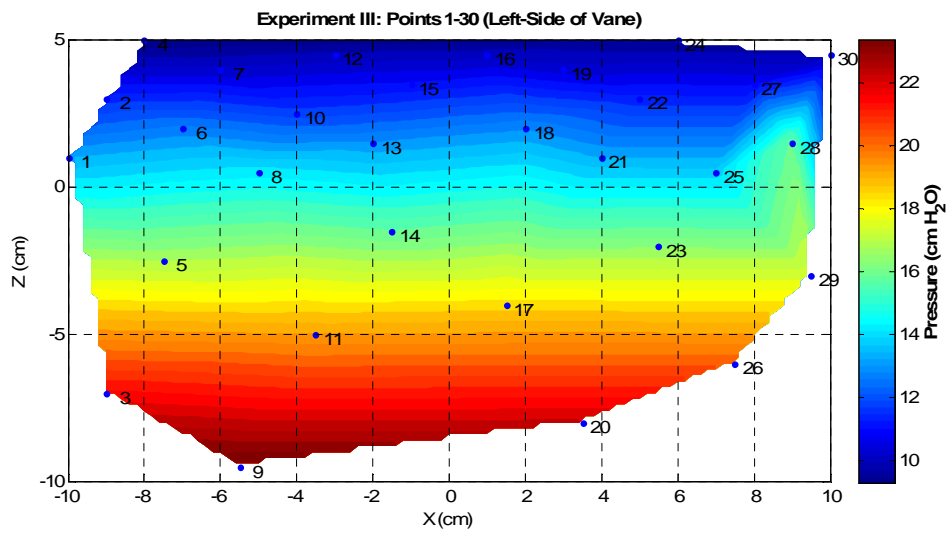


Total pressures (cm-wc) acts on the right-side of vane, points from 31 to 60 – Experiment (II) results.

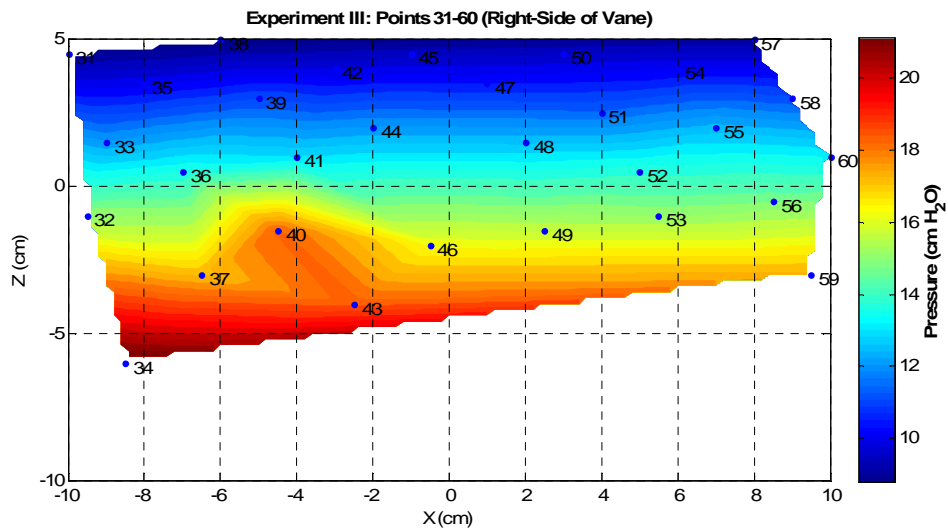


Pressures difference between submerged vane sides – Experiment (II) results.

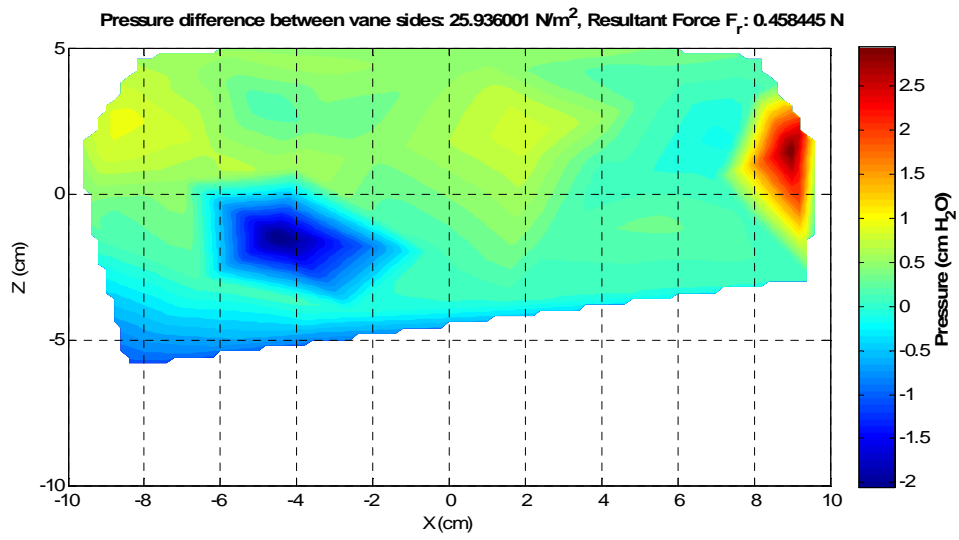
3. Experiment III – Total Pressures



Total pressures (cm-wc) on the left-side of vane, points from 1 to 30 – Experiment (III) results.

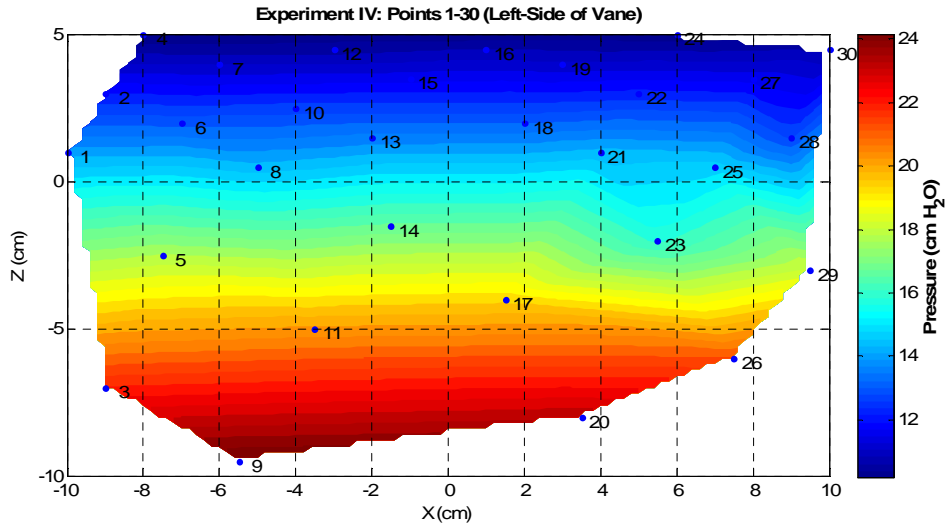


Total pressures (cm-wc) acts on the right-side of vane, points from 31 to 60 – Experiment (III) results.

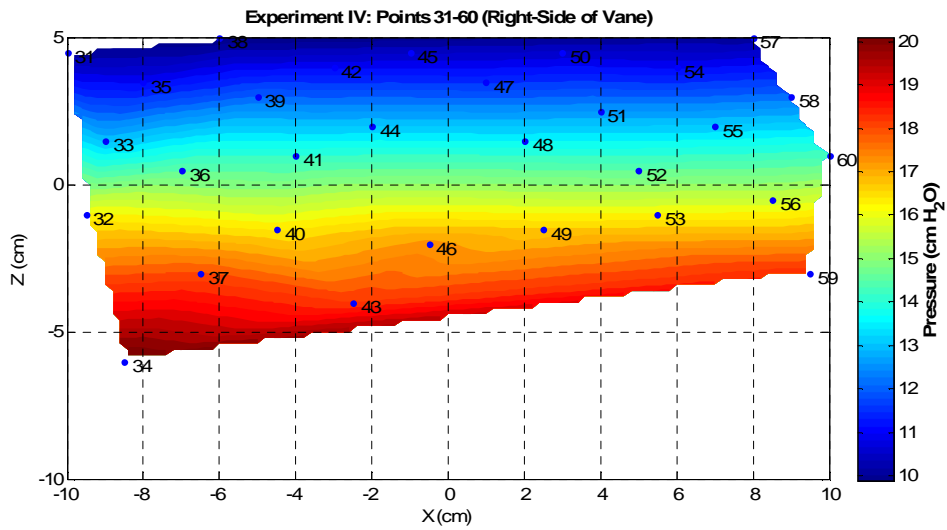


Pressures difference between submerged vane sides – Experiment (III) results.

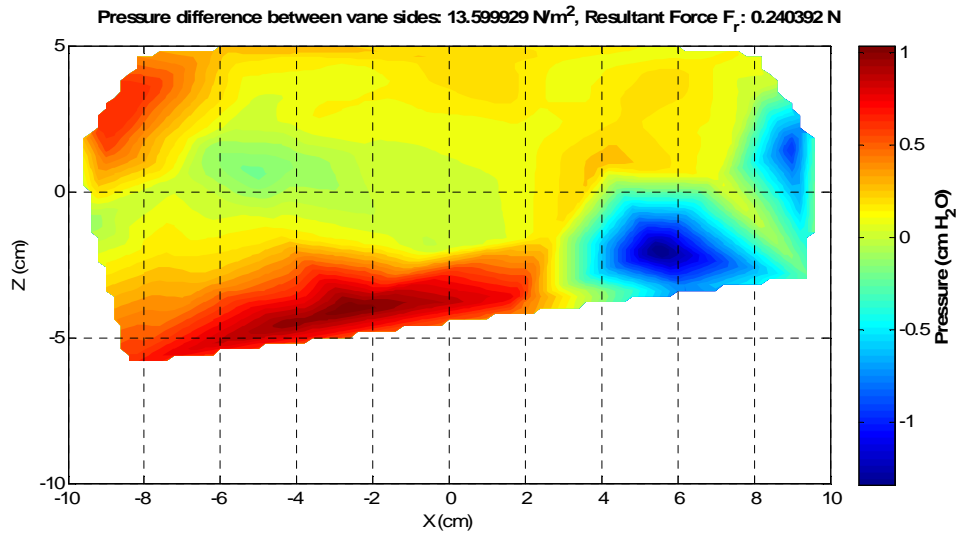
4. Experiment IV – Total Pressures



Total pressures (cm-wc) on the left-side of vane, points from 1 to 30 – Experiment (IV) results.

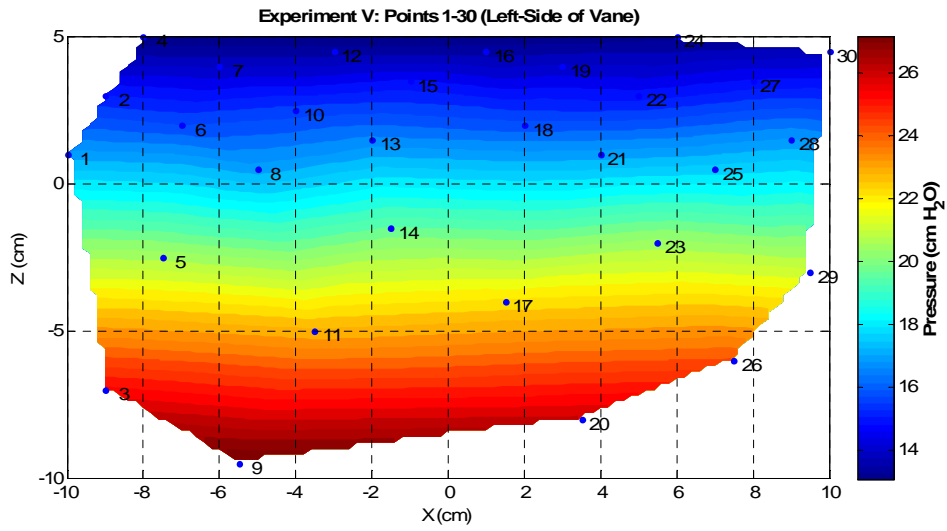


Total pressures (cm-wc) acts on the right-side of vane, points from 31 to 60 – Experiment (IV) results.

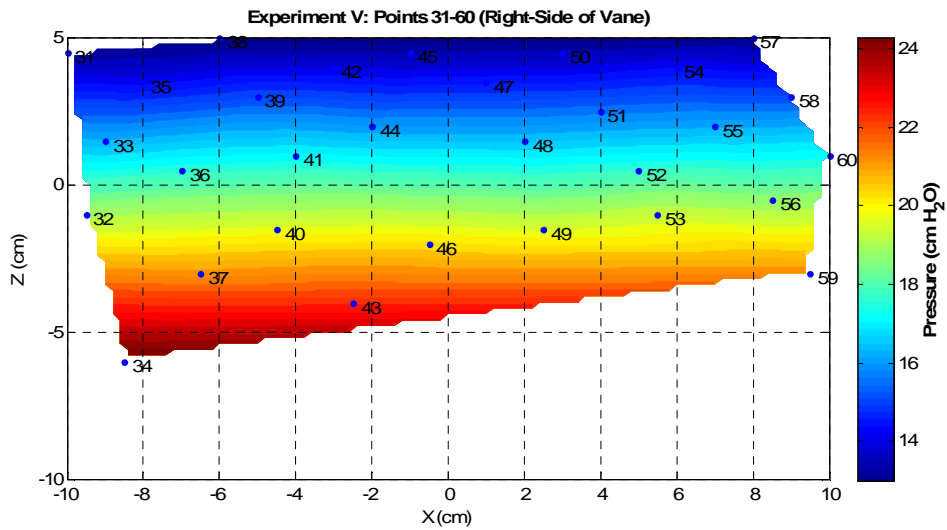


Pressures difference between submerged vane sides – Experiment (IV) results.

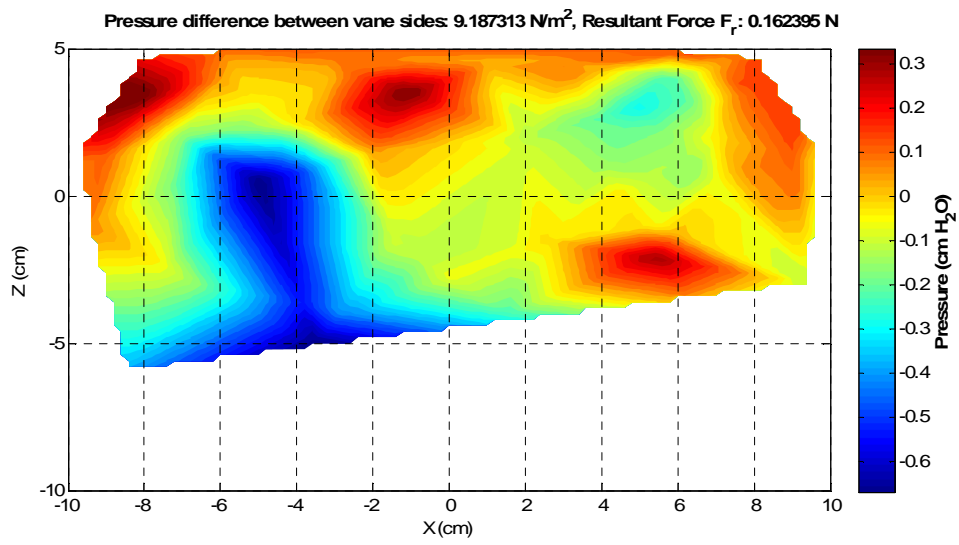
5. Experiment V – Total Pressures



Total pressures (cm-wc) on the left-side of vane, points from 1 to 30 – Experiment (V) results.

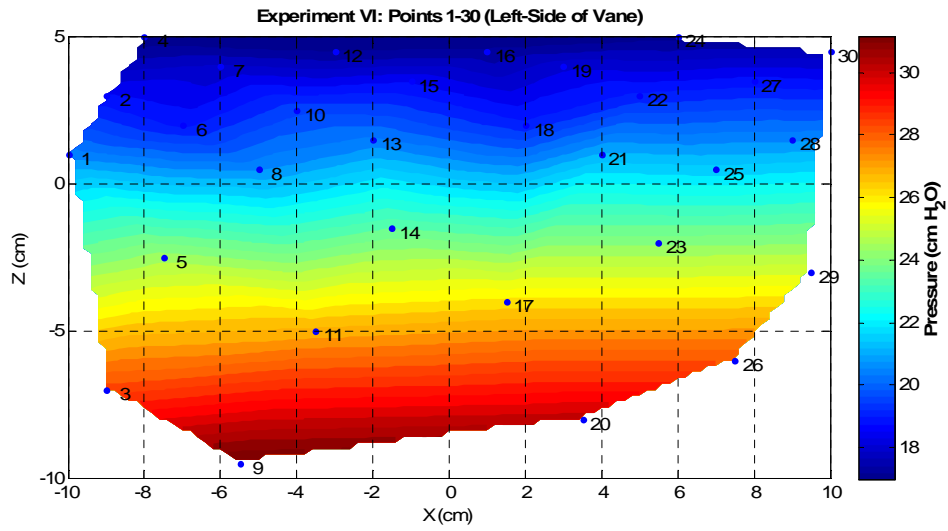


Total pressures (cm-wc) acts on the right-side of vane, points from 31 to 60 – Experiment (V) results.

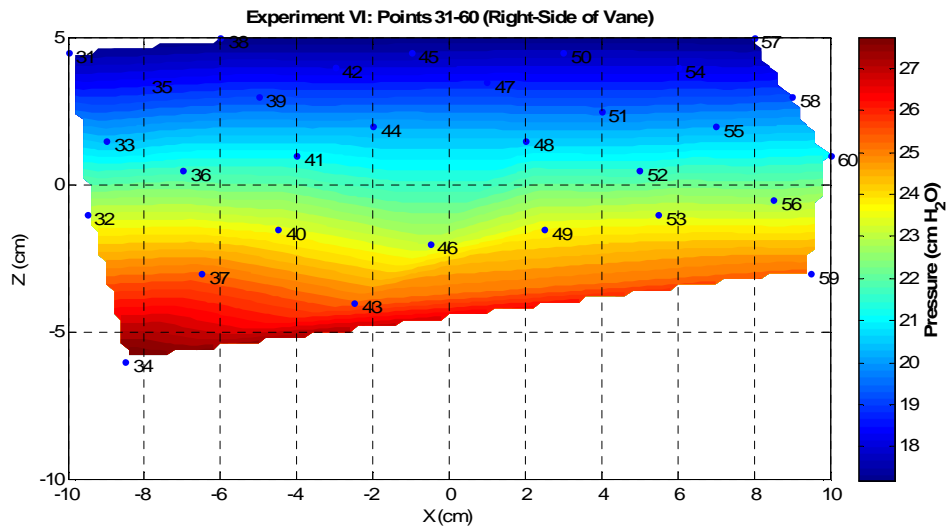


Pressures difference between submerged vane sides – Experiment (V) results.

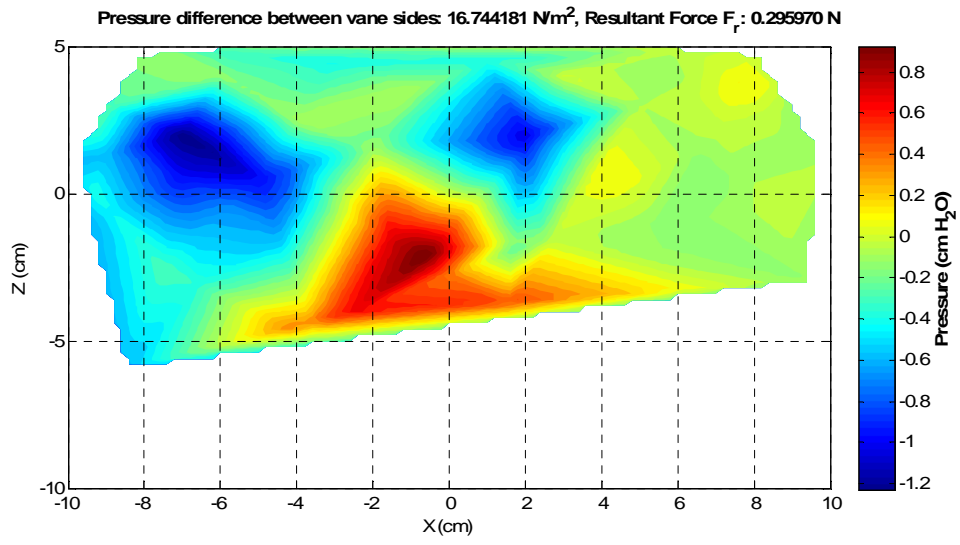
6. Experiment VI – Total Pressures



Total pressures (cm-wc) on the left-side of vane, points from 1 to 30 – Experiment (VI) results.



Total pressures (cm-wc) acts on the right-side of vane, points from 31 to 60 – Experiment (VI) results.



Pressures difference between submerged vane sides – Experiment (VI) results.