Velocity/Vorticity Measurements at the SLTEST Site, 13 June 2003

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Dr. Ronald Joslin, Monitor

SLTEST Site – Thanks to Joe Klewicki for his creative realization that it could be established *and* his incredible energy in making it work.

If the data gods are benevolent:

- R_θ of order $3x10^6$ and time series data to produce:

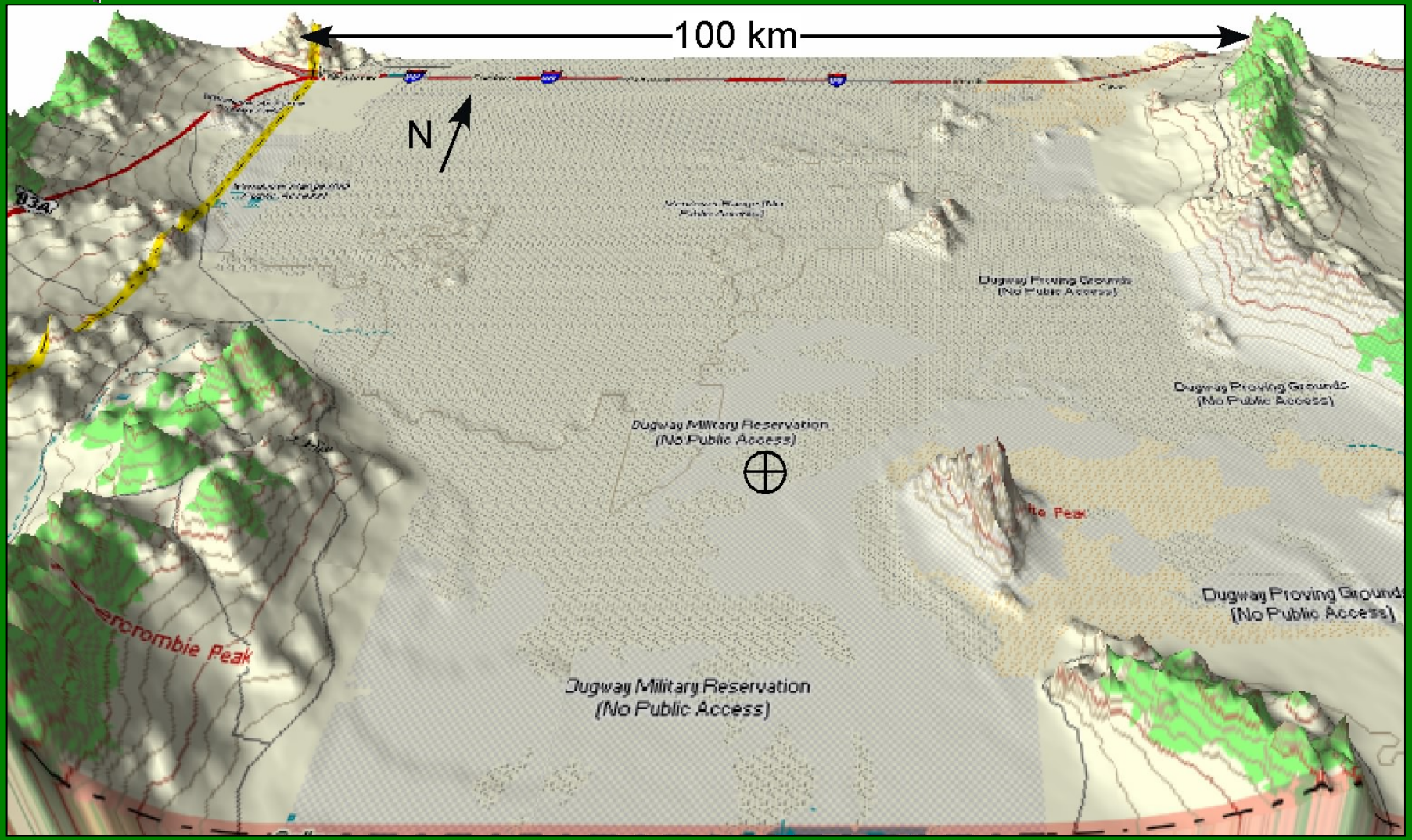
  time resolved and statistically converged near wall (y+≈3000) observations for u,v,w, ω_y, ω_z
- Benevolent Conditions
- stable winds – magnitude and directions
- neutral atmosphere
- good pre- and post-calibrations

In this presentation:

- The yield from Friday the 13th, 2003
- What was required to obtain these data

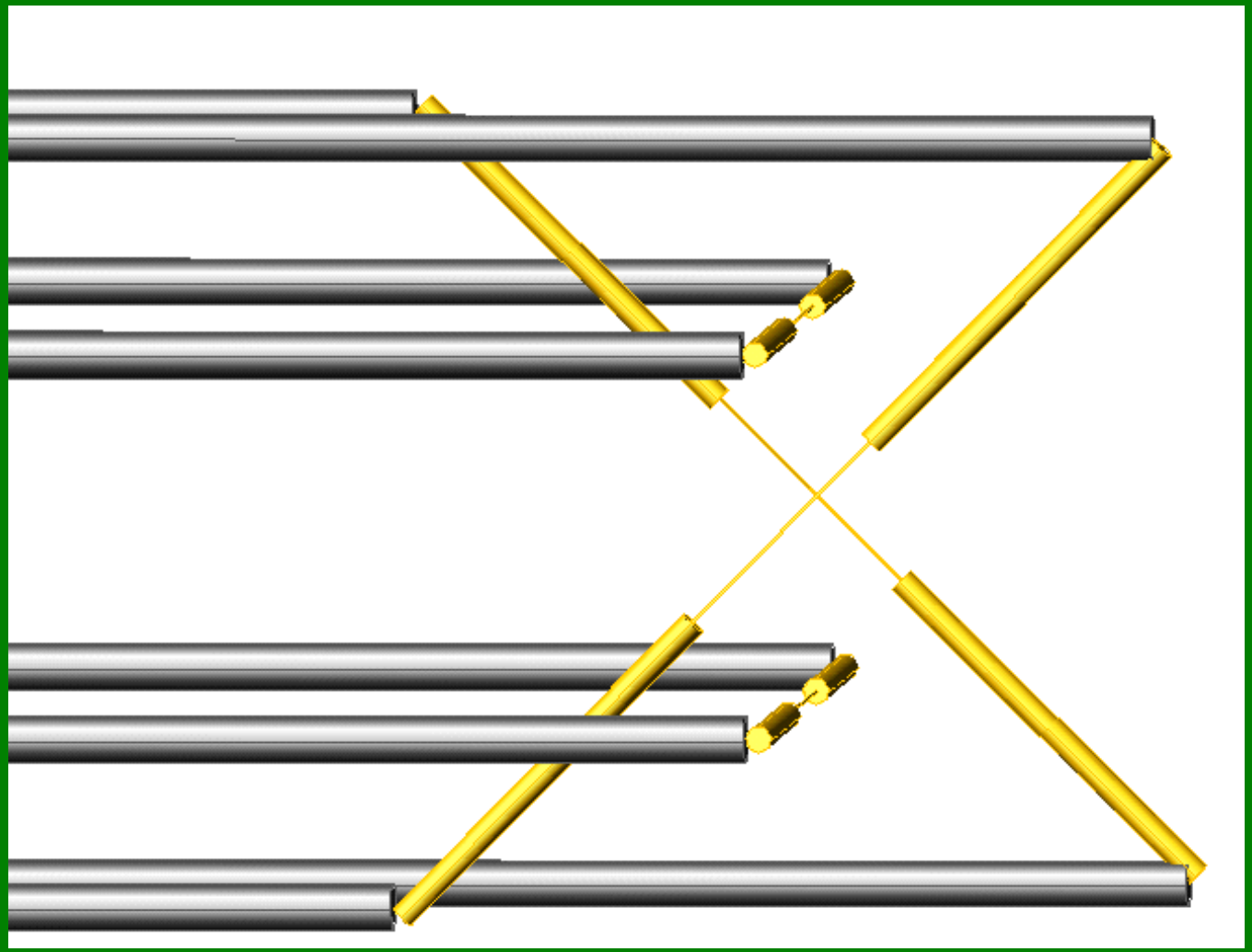
(The MSU team held out for the 13th – others had left – no independent wall shear stress values)

SLTEST Site Location

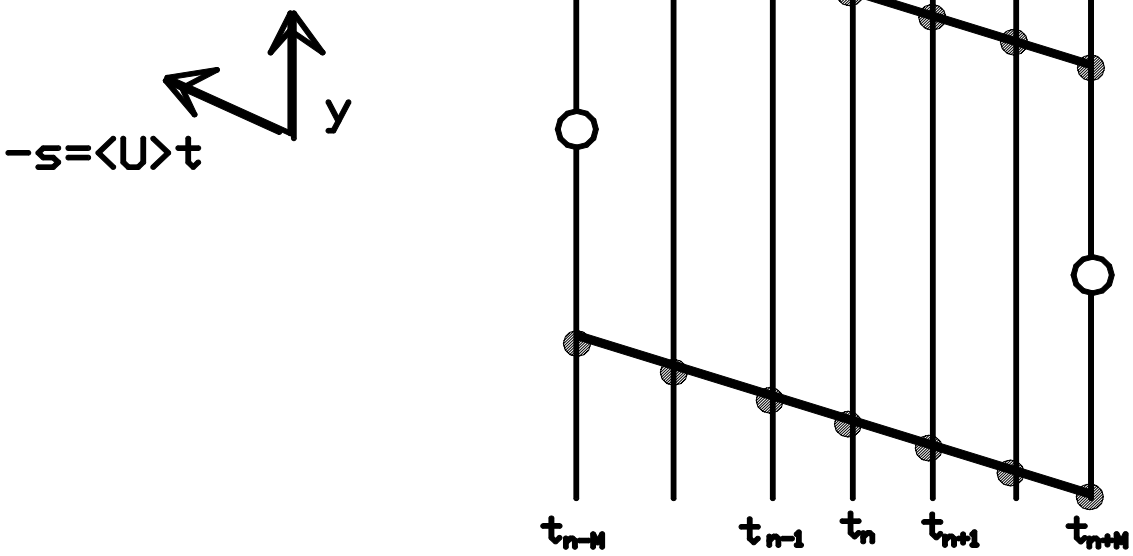


Mobile Data Cart

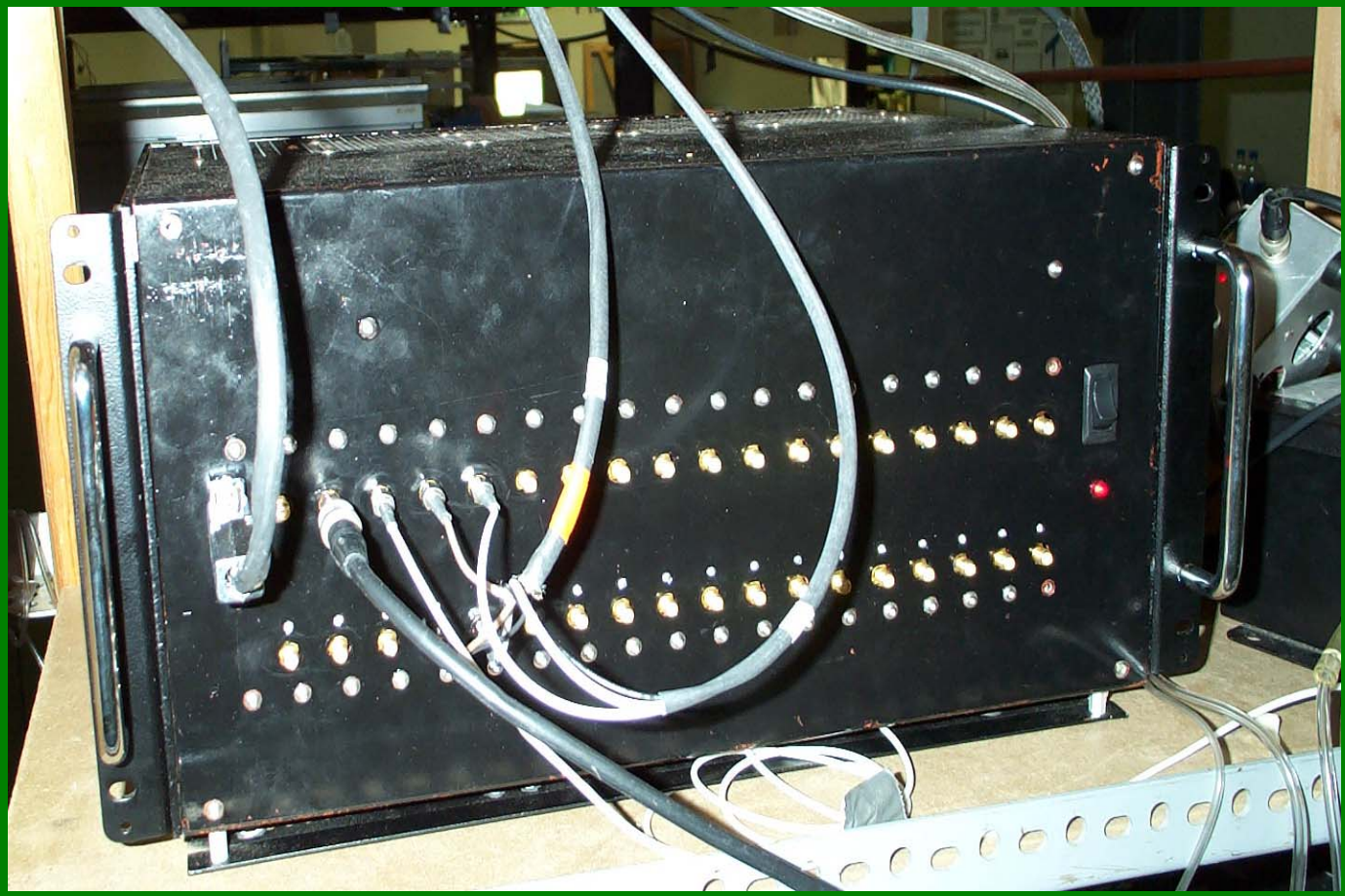
4 Sensor Vorticity Probe



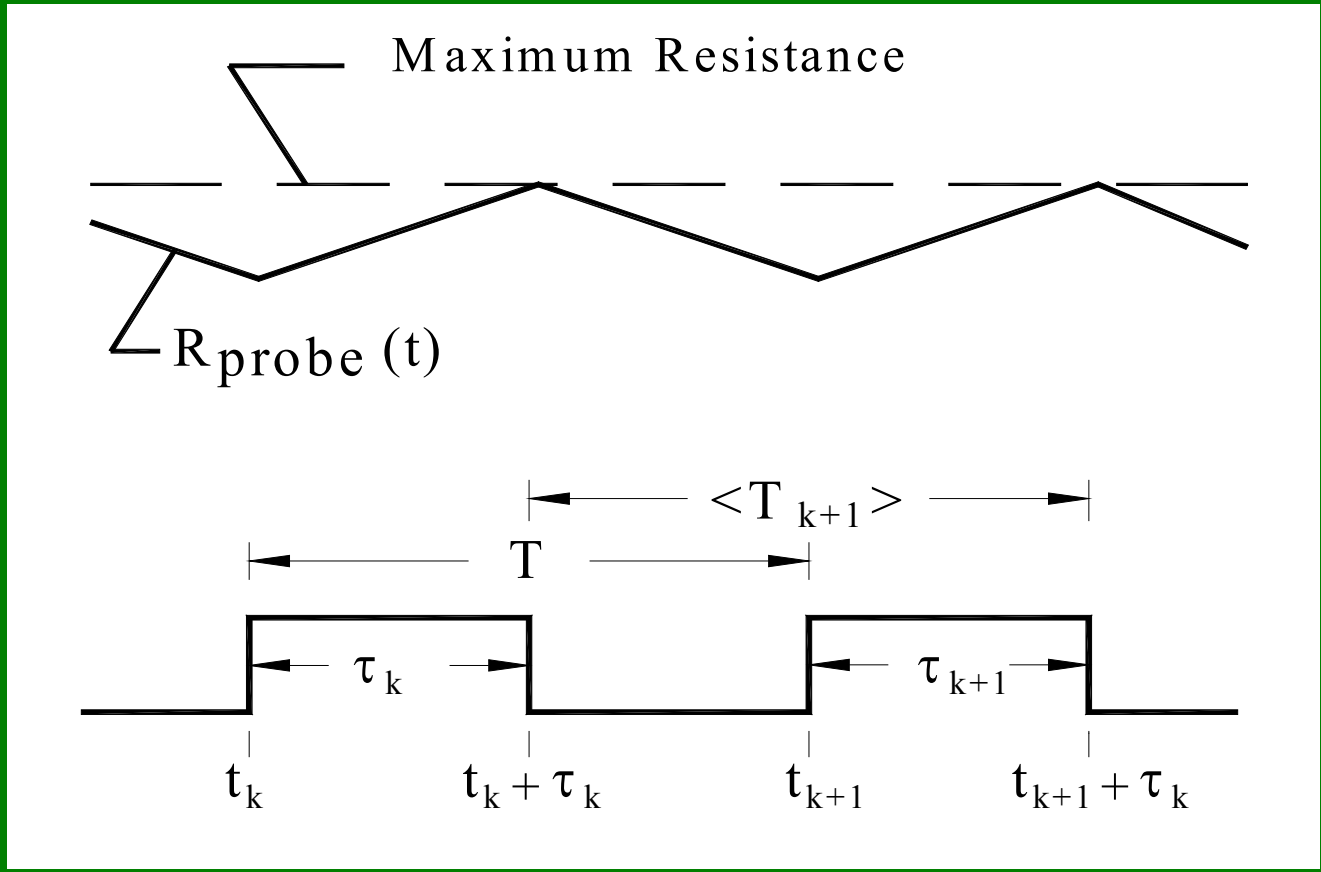
Microcirculation Domain



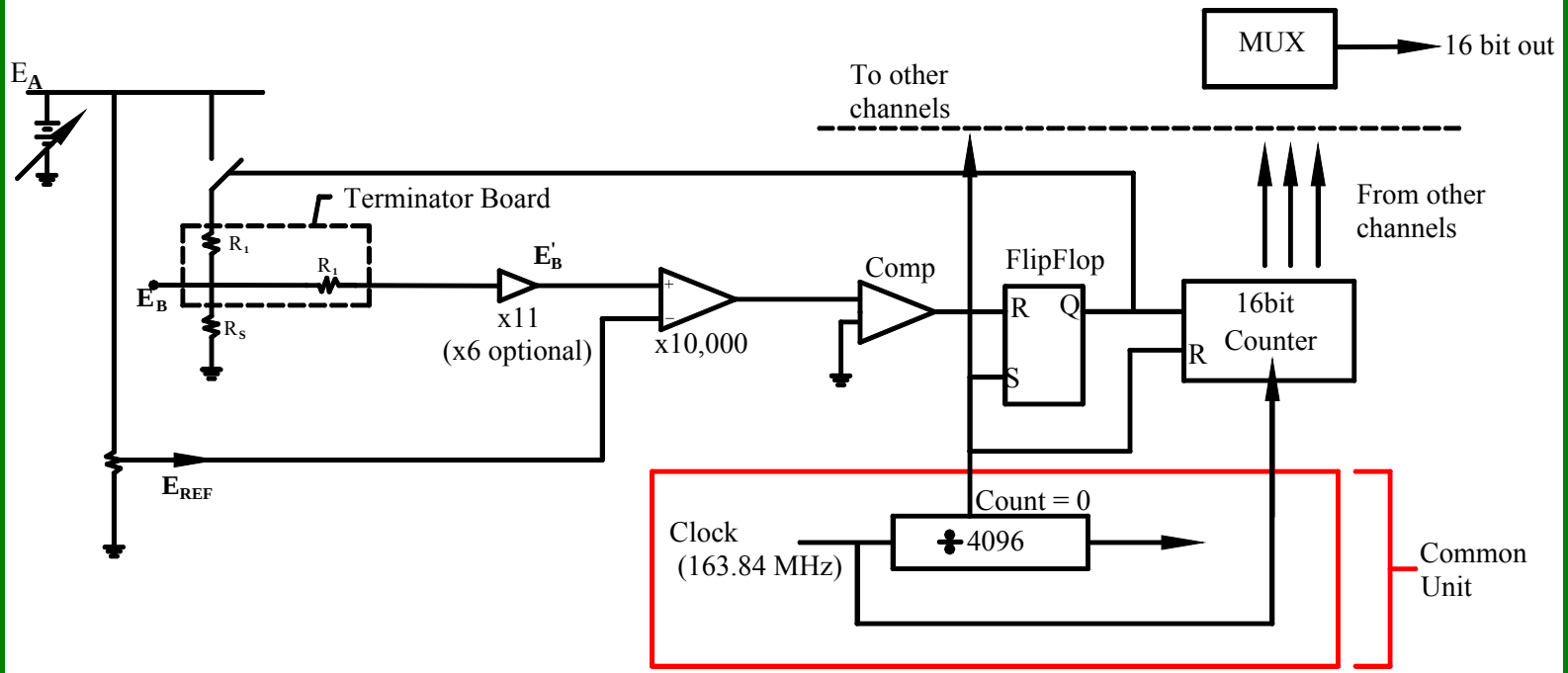
PWM-CTA



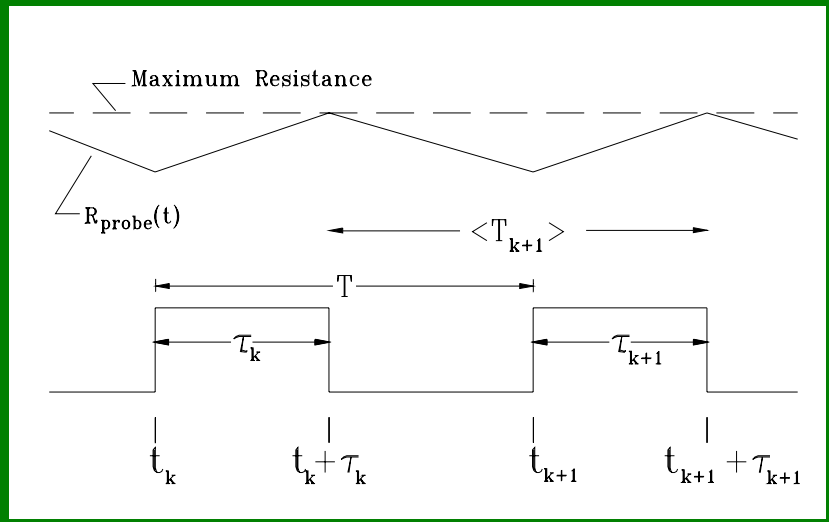
Timing Diagram for the PWM-CTA



Enabling Electronics



Governing Equations

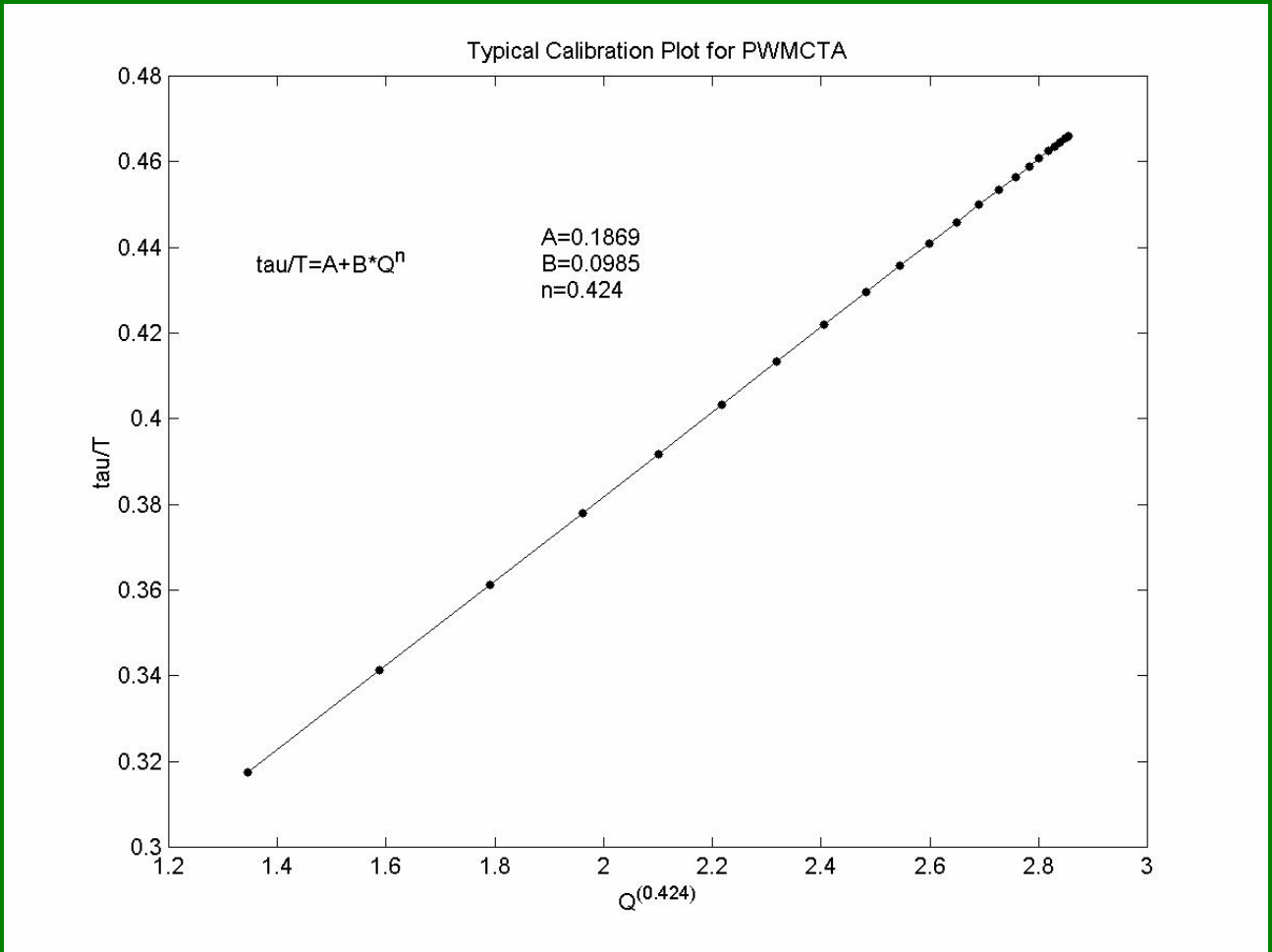


$$(1)\quad \int_{t_K}^{t_K+\tau_K} (I_S^2/R_S)\,dt = \int_{t_K}^{t_K+\tau_K} \left[\frac{E_A}{R_1+R_S(t)}\right]^2 R_S(t)\,dt = \int_{t_K}^{t_K+\tau_K} g(R_S;E_A,R_1)\,dt$$

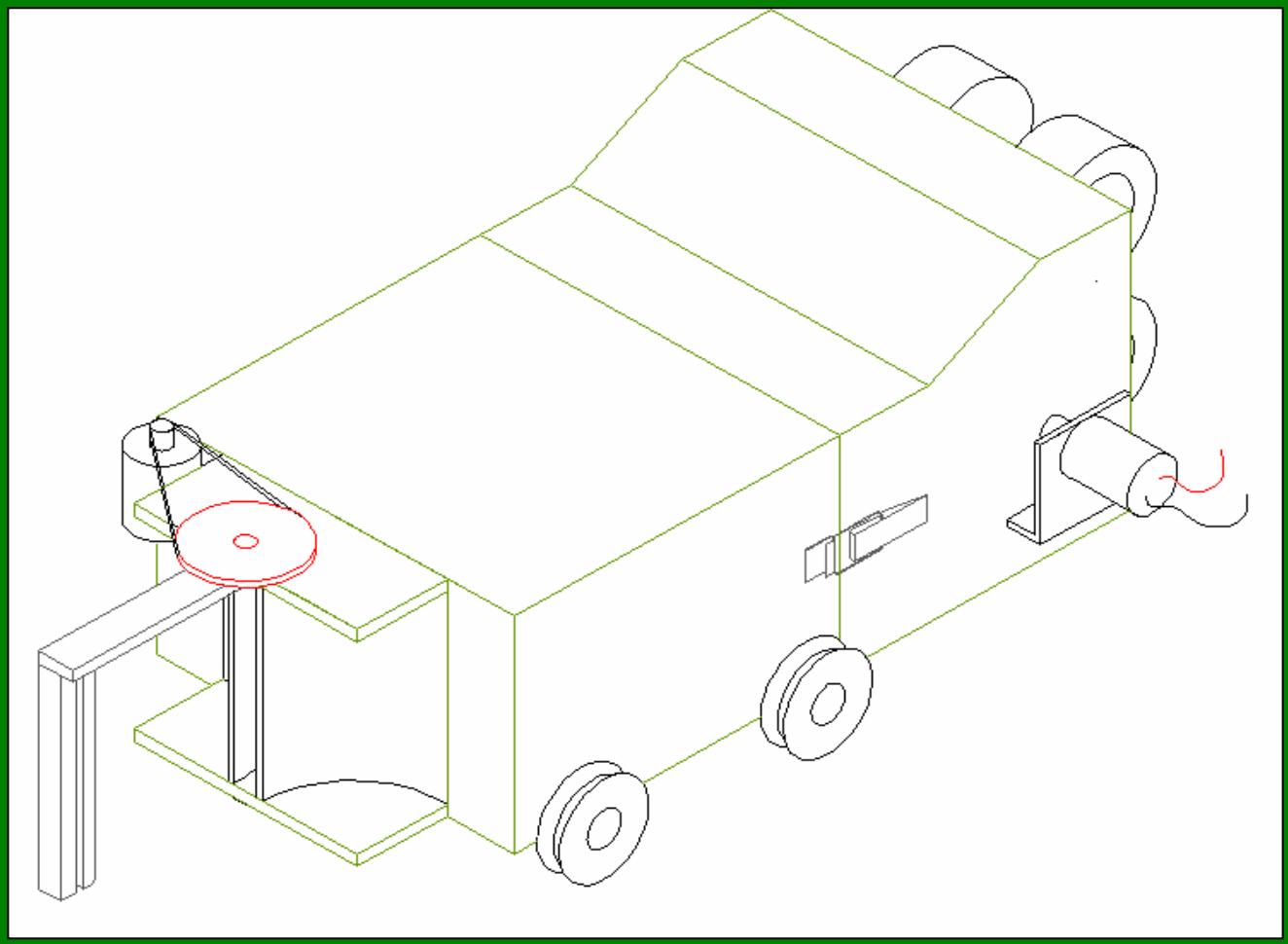
$$(2)\quad \int_{t_{K-1}+\tau_{K-1}}^{t_K+\tau_K} [A'+B'Q^n]\,dt = [A'+B'\langle V_K\rangle^n]\langle T_K\rangle$$

$$(3)\quad \frac{\tau_K}{\langle T_K\rangle} = A+B\langle V_K\rangle^n$$

Calibration Plot



Calibration Unit



Four 4-Sensor Vorticity Probes – SLTEST Site

Special features of the data processing

- ω_y probe $\rightarrow$ acceptance angles for ω_z probe
- Neutral atmosphere – near ground temperature measurements

Statistical Results (y=15cm)

$\bar{u} = 4.75$ m/s $\quad \tilde{u} = 0.83$ m/s $\quad \overline{u'v'} = -0.079$ m^2/s^2 $\quad \tilde{\omega}_y = 115$ 1/s

$\bar{v} = 0$ m/s $\quad \tilde{v} = 0.327$ m/s $\quad -\frac{\partial}{\partial y}\overline{u'v'} = -19.80$ m/s^2 $\quad \tilde{\omega}_z = 117$ 1/s

$\bar{w} = 0$ m/s $\quad \tilde{w} = 0.820$ m/s

$\varepsilon = 0.227\ m^2/s^3$ $\quad \eta = 0.36$ mm $\quad \lambda_u = 0.037$ m $\quad \lambda_v = 0.011$ m

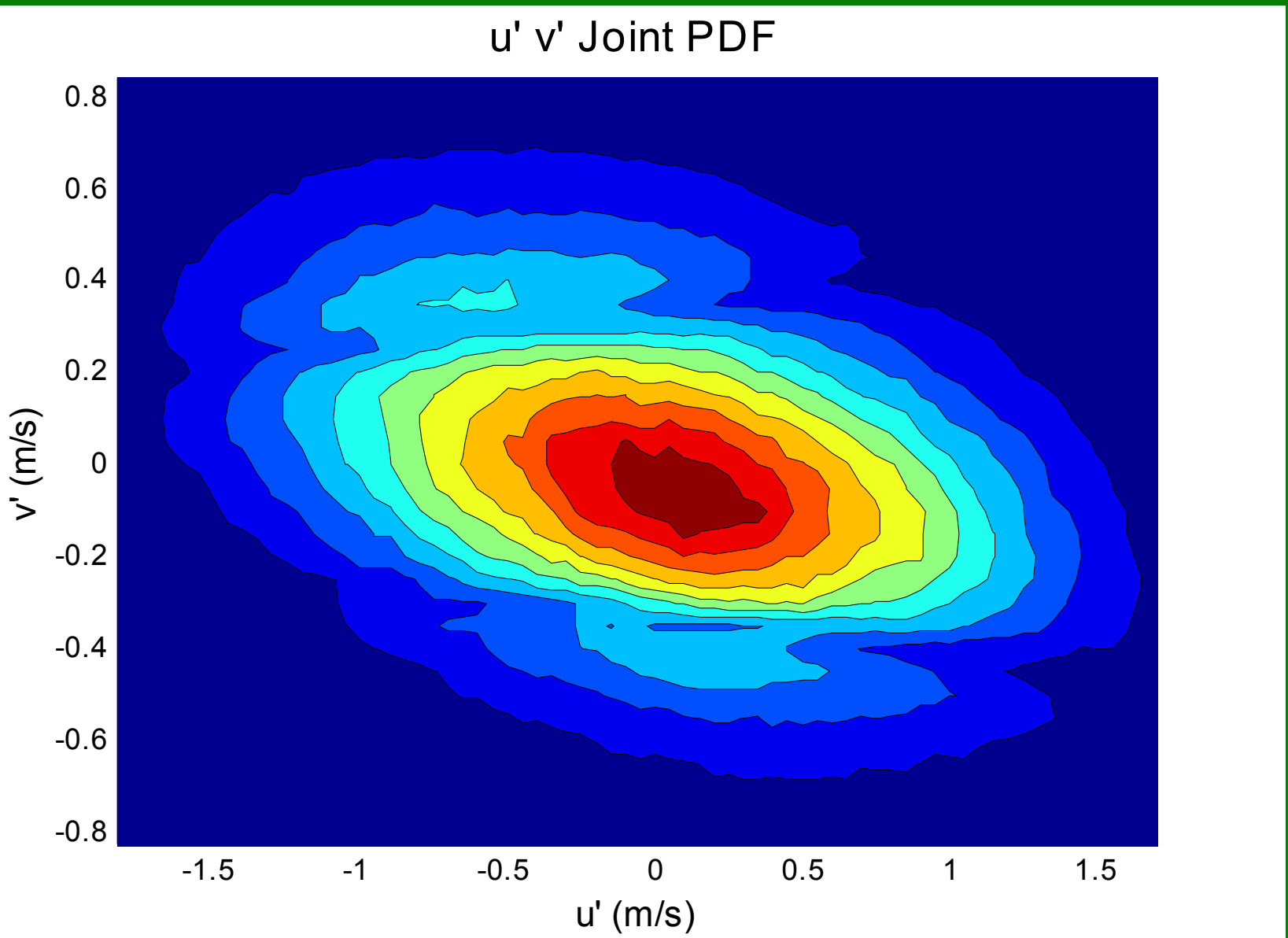
Statistical Results, Non-Dimensional

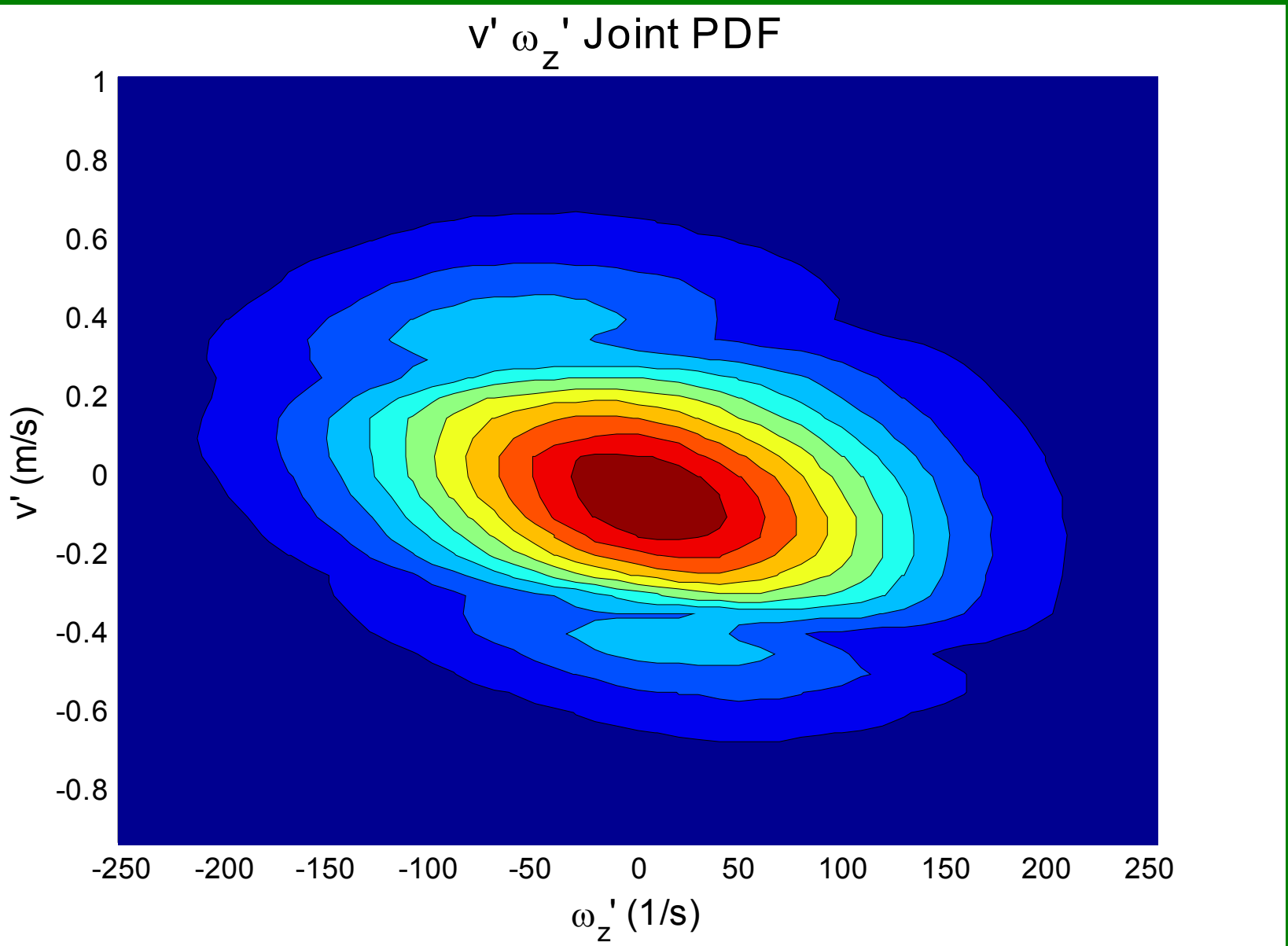
$$\overline{u'v'} \Rightarrow u_\tau^2; \quad y^+ = 2630$$

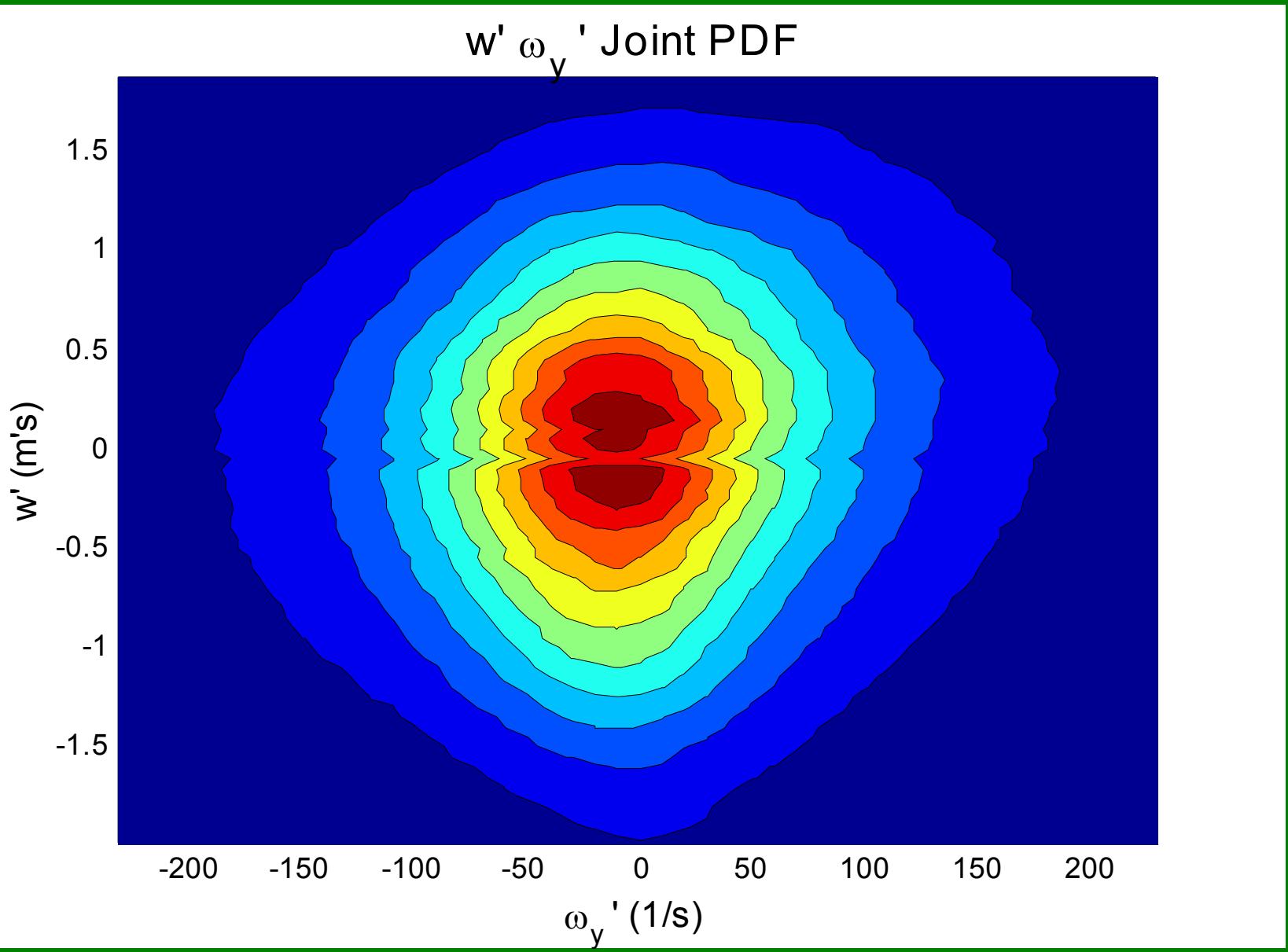
$$\frac{\bar{u}}{\bar{u}_\tau} = 16.9 \quad \frac{\tilde{u}}{u_\tau} = 2.95 \qquad \frac{w_y \lambda_v}{\tilde{u}} = 5.27 \quad \frac{w_y \nu}{u_\tau^2} = 0.024$$

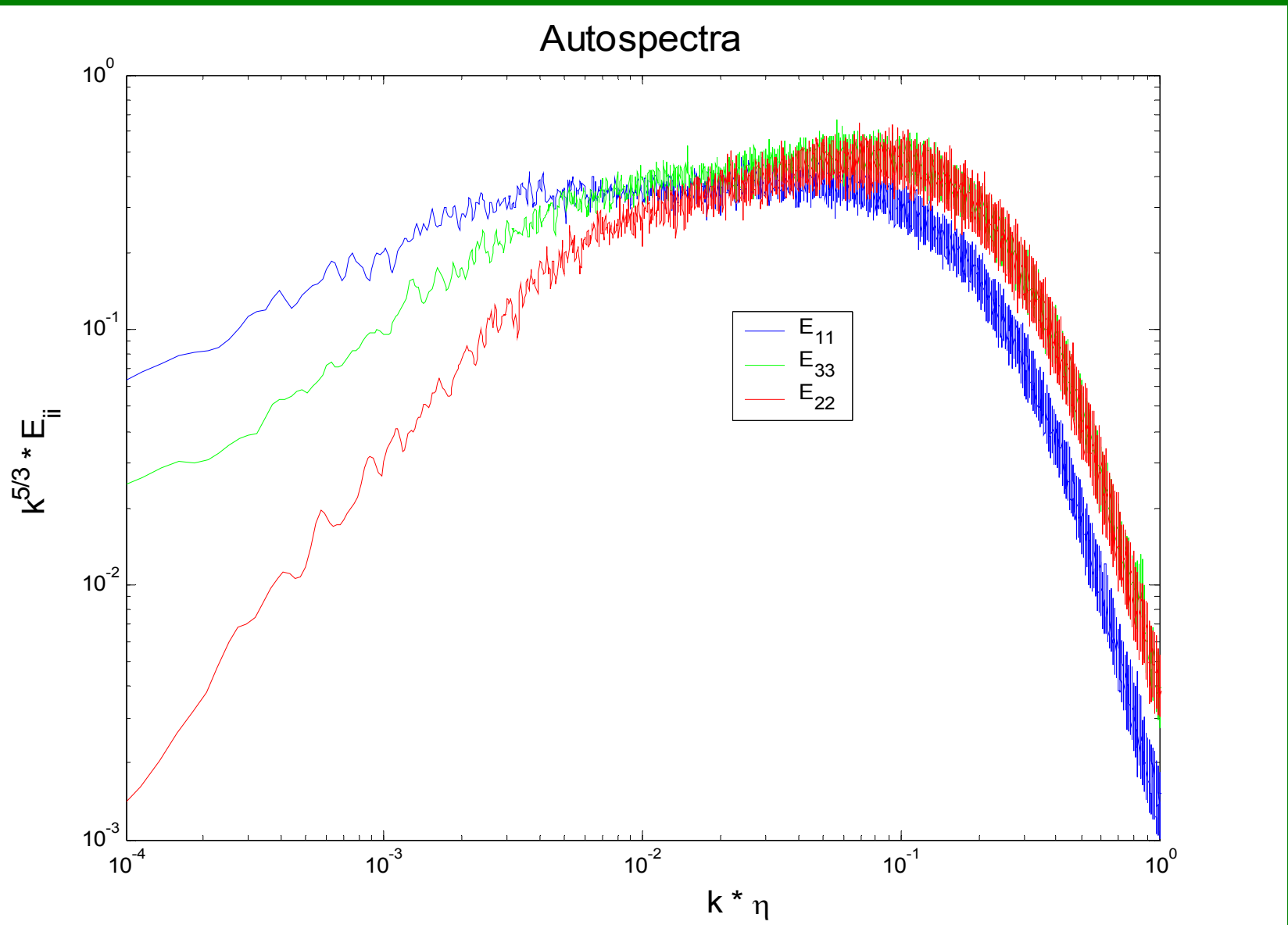
$$\frac{\tilde{v}}{u_\tau} = 1.16 \quad \frac{\tilde{w}}{u_\tau} = 2.92 \qquad \frac{\omega_z \lambda_v}{\tilde{u}} = 5.21 \quad \frac{\omega_z \nu}{u_\tau^2} = 0.023$$

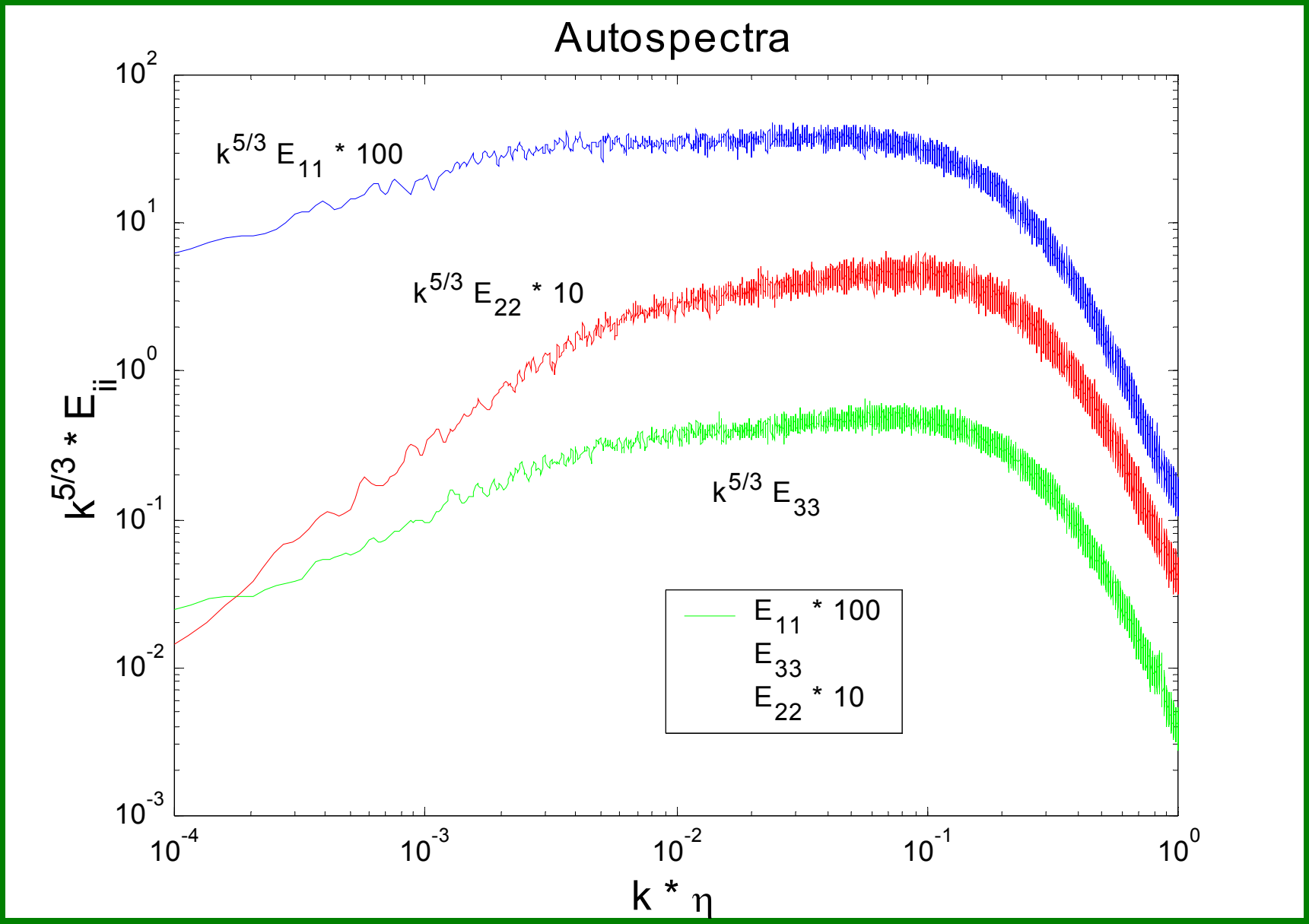
$$\frac{\overline{u'v'}}{\tilde{u}\tilde{v}} = -0.291$$

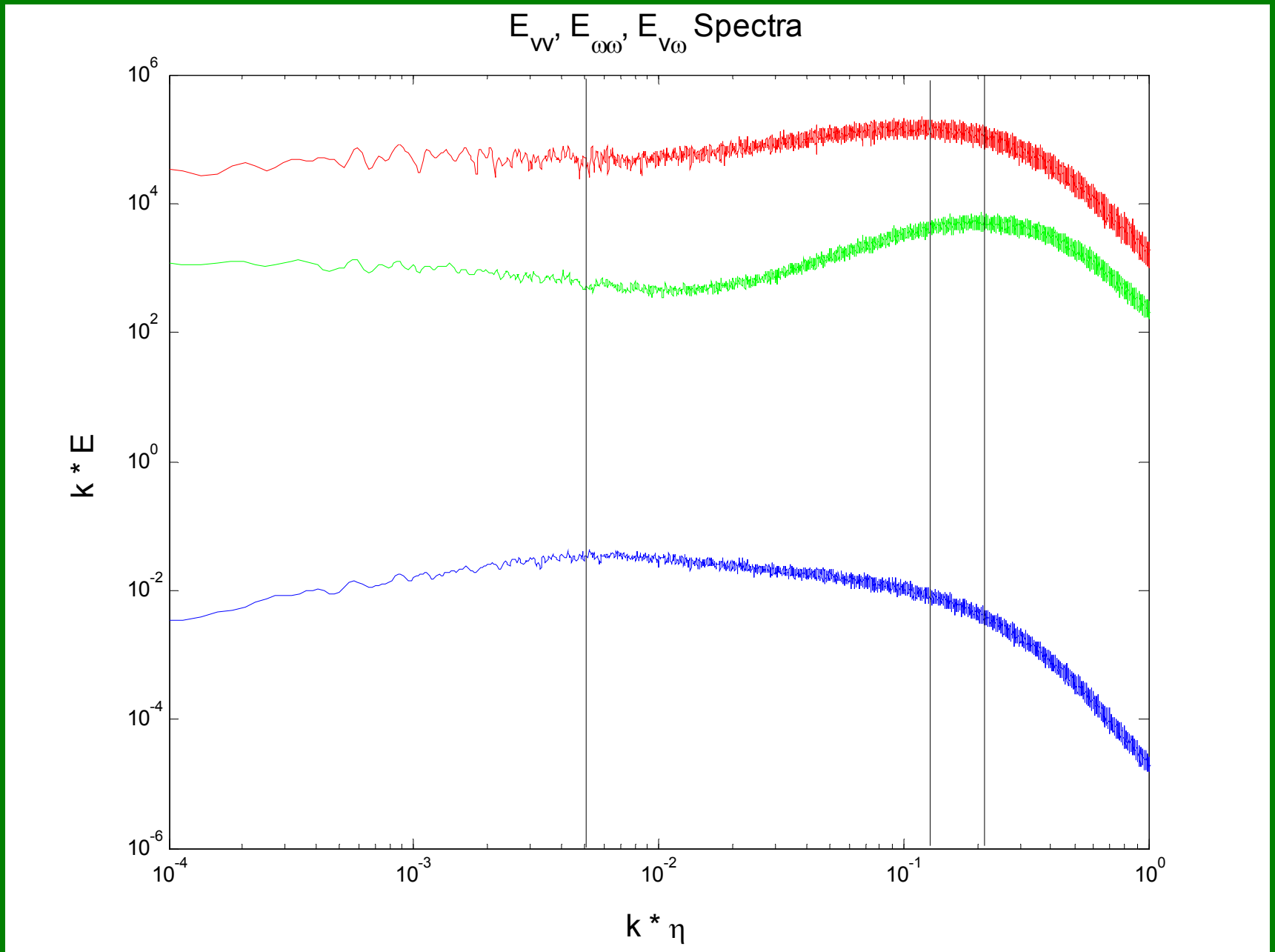

u' v' Joint PDF
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
v' (m/s)
-1.5
-1
-0.5
0
0.5
1
1.5
u' (m/s)

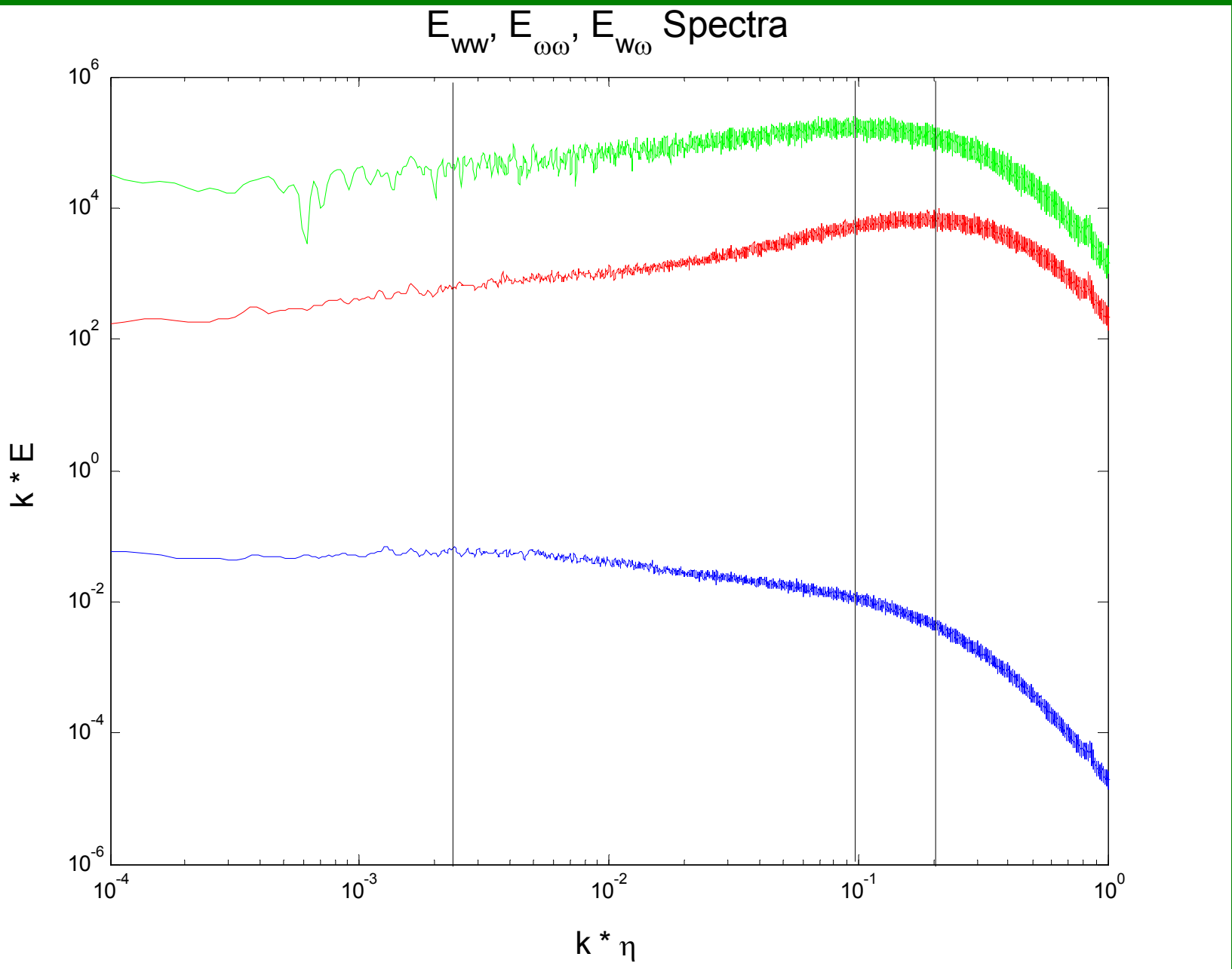

v' ω_z' Joint PDF
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
v' (m/s)
-250
-200
-150
-100
-50
0
50
100
150
200
250
ω_z' (1/s)


w' ω_y ' Joint PDF
1.5
1
0.5
0
-0.5
-1
-1.5
w' (m's)
-200
-150
-100
-50
0
50
100
150
200
ω_y ' (1/s)


Autospectra
10^0
10^{-1}
10^{-2}
10^{-3}
$k^{5/3} * E_{ii}$
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
k * η
E_{11}
E_{33}
E_{22}

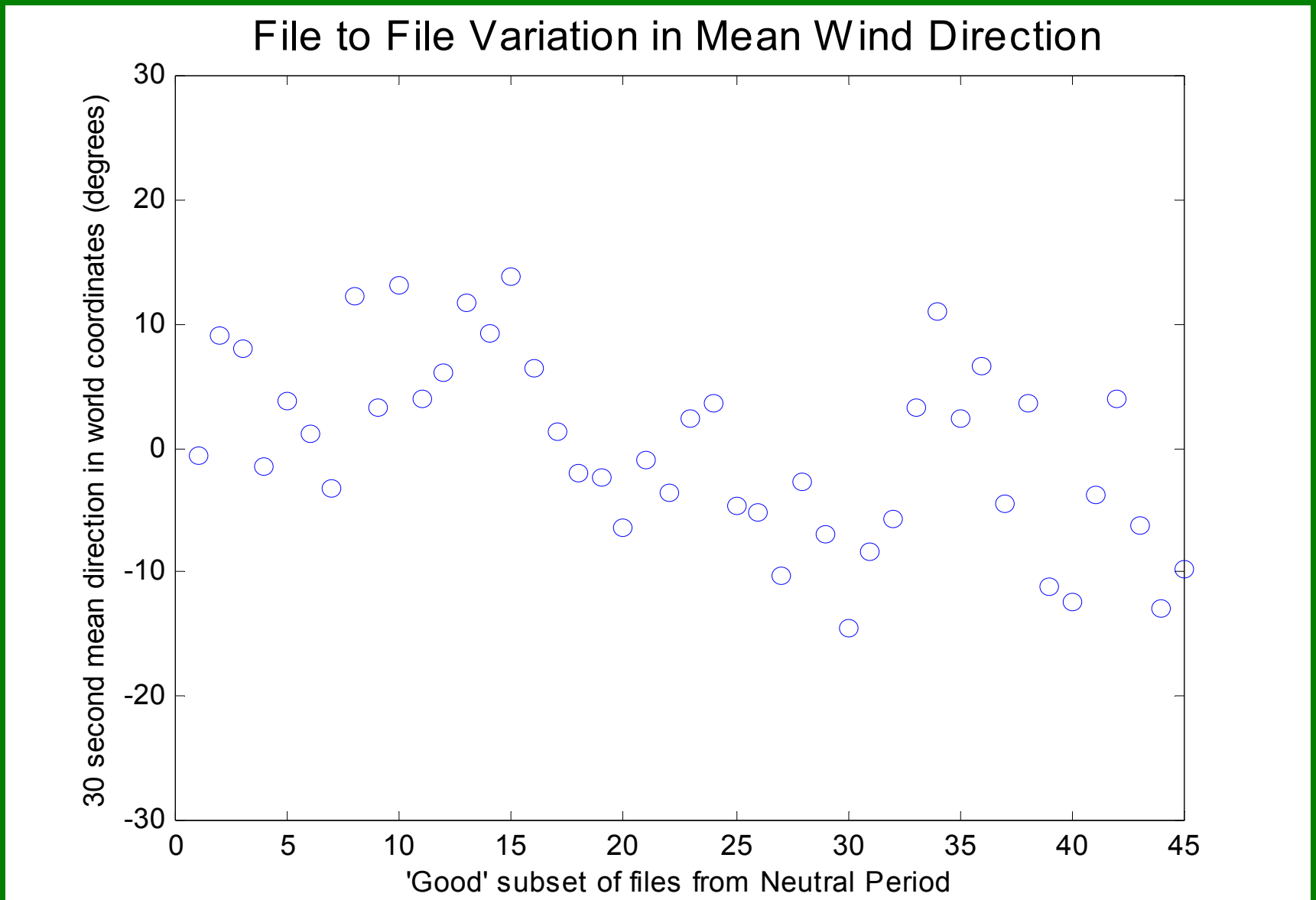

Autospectra
$k^{5/3} E_{11} * 100$
$k^{5/3} E_{22} * 10$
$k^{5/3} E_{33}$
$E_{11} * 100$
E_{33}
$E_{22} * 10$
$k^{5/3} * E_{ii}$
$k * \eta$
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}


E_{vv}, $E_{\omega\omega}$, $E_{v\omega}$ Spectra
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
k * E
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
k * η


E_{ww}, $E_{\omega\omega}$, $E_{w\omega}$ Spectra
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
k * E
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
k * η

Summary

- Summer 2003 has added substantially to the well resolved, very high R_θ, TBL data
- The statistical data are self-consistent with those data from prior experiments at the SLTEST site
- The spectral contributions, to the stress-gradient expression, confirm that the velocity-vorticity correlations are dominated by the small, but energetic, scales --- a message for LES


File to File Variation in Mean Wind Direction
30 second mean direction in world coordinates (degrees)
30
20
10
0
-10
-20
-30
0
5
10
15
20
25
30
35
40
45
'Good' subset of files from Neutral Period