Observations of the bora-wind turbulence using the hot-wire anemometer

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I. INTRODUCTION

- BORA: a strong downslope windstorm that blows at the E Adriatic coast from the NE quadrant

- Smith (1987): Hydraulic nature of the mean bora flow

- The mean wind speed may reach 30 m s^{-1}

- Due to the gustiness wind speed maxima my surpass 60 m s^{-1}

- OBJECTIVE:

  To estimate the *TKE* dissipation rate, ε

  ➔ “cheapest” way to do it is using ultrasonic anemometer data and the Inertial Dissipation Method (IDM):

$$S_u(k) = \alpha \varepsilon^{\frac{2}{3}} k^{\frac{-5}{3}} \quad \text{➔ Taylor's hypothesis ➔} \quad \varepsilon = \frac{2\pi}{\overline{U}} \left[\frac{f^{5/3} S_u(f)}{\alpha} \right]^{3/2}$$

- How reliable is this approach for bora?

- The hot-wire anemometer (HWA) ➔ direct method for estimation of ε:

$$\epsilon = 15\nu\overline{\left(\frac{\partial u}{\partial x}\right)^2}$$

- Taylor's hypothesis + Heskestad-Lumley correction for the streamwise derivative:

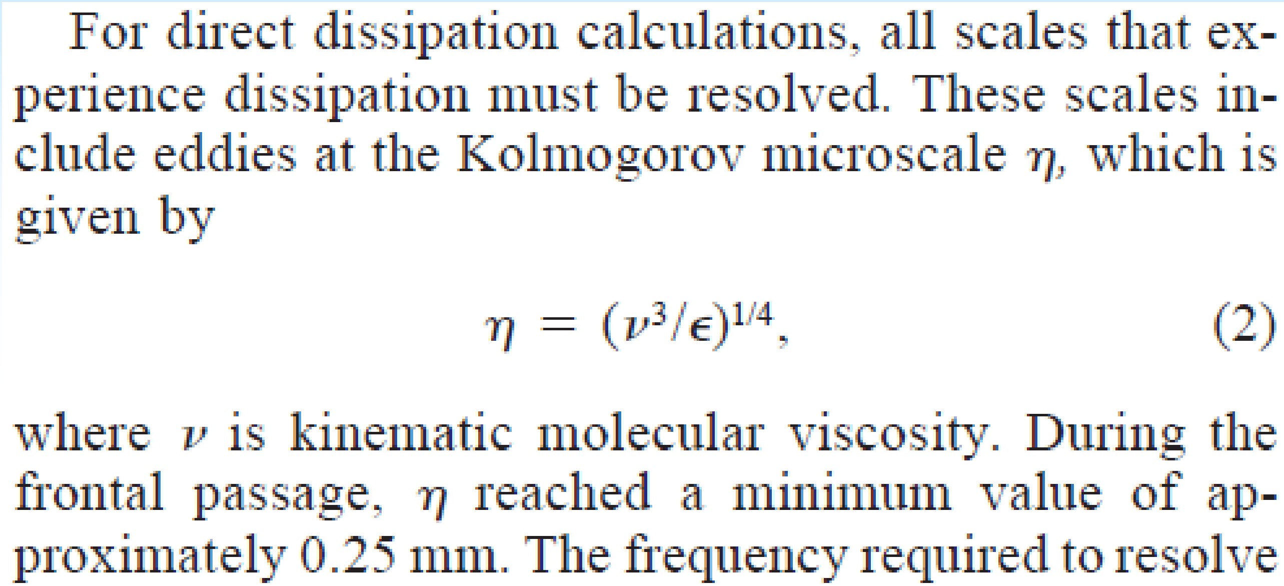
$$\epsilon = \frac{15\nu}{U^2}\overline{\left(\frac{\partial u}{\partial t}\right)^2}\left(1 + \frac{\overline{u^2}}{U^2} + 2\frac{\overline{v^2} + \overline{w^2}}{U^2}\right)^{-1}$$

$\nu = 1.5\cdot10^{-5}\ \mathrm{m^2\ s^{-1}}$......kinematic viscosity

- How fast do we need to sample the bora wind speed with the HWA? ➔ ➔ Kolmogorov's microscale η ➔ size of the dissipative eddies:

$$f_K = \frac{U}{2\pi\eta}$$ ....Kolmogorov's frequency ➔ Nyquist frequency

- Piper and Lundquist (2004):


For direct dissipation calculations, all scales that experience dissipation must be resolved. These scales include eddies at the Kolmogorov microscale η, which is given by

$$\eta = (\nu^3/\epsilon)^{1/4}, \qquad (2)$$

where ν is kinematic molecular viscosity. During the frontal passage, η reached a minimum value of approximately 0.25 mm. The frequency required to resolve

- How did they calculate η? ➔ No information about ε (not yet)!

- If we take their value of η = 0.25 mm and extreme mean bora wind speed of 30 m s^{-1} :

$$f_K = \frac{U}{2\pi\eta}$$ ➔ $f_K \approx$ 20 000 Hz ➔ $f_S \approx$ 40 000 Hz

- Our ultimate goal ➔ to sample bora with $f_S \approx$ 50 000 Hz

II. INSTRUMENTS, LOCATION AND DATA

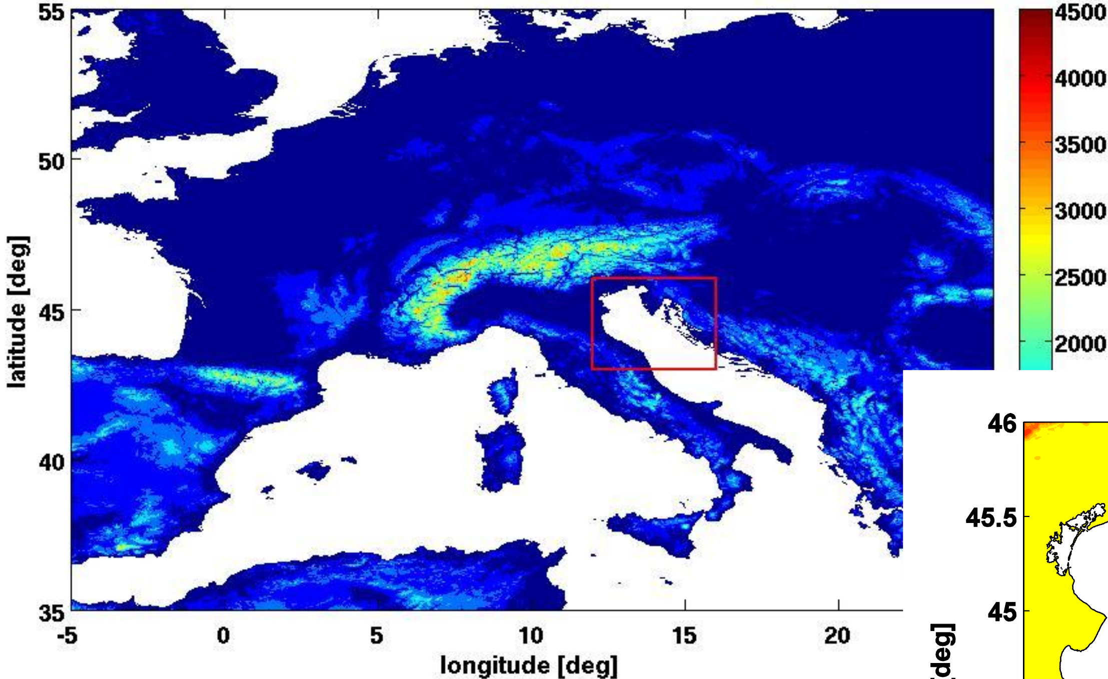
- HWA: Dantec Dynamics multichannel CTA (Constant Temperature Anemometer) system

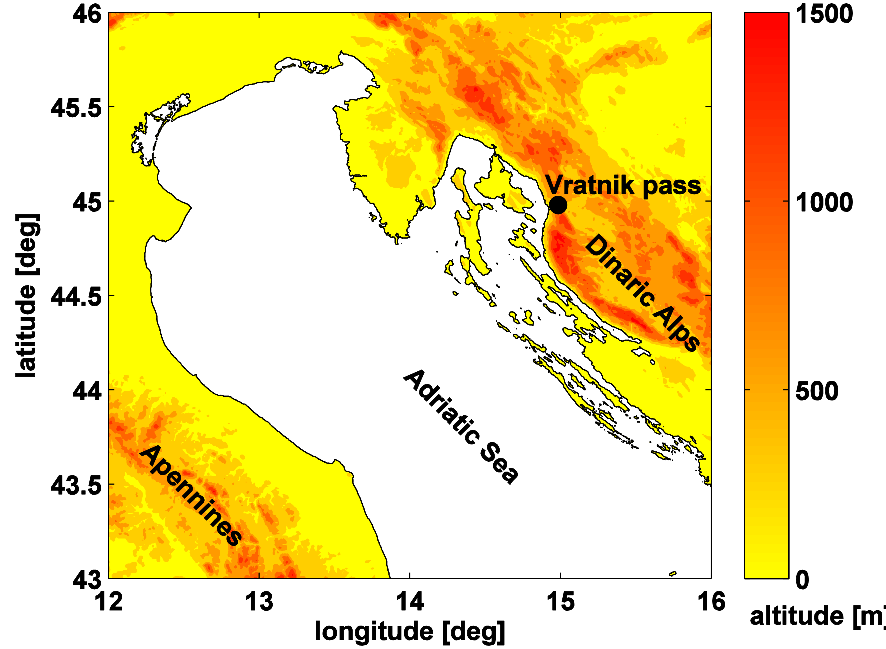
- The original software can continuously record only $8 \cdot 10^6$ samples ➔ 160 s intervals with $f_S \approx 50\ 000$ Hz ➔ problem!

- Guys from the Faculty of Electrical Engineering (FEE guys) wrote a new software ➔ problem solved!

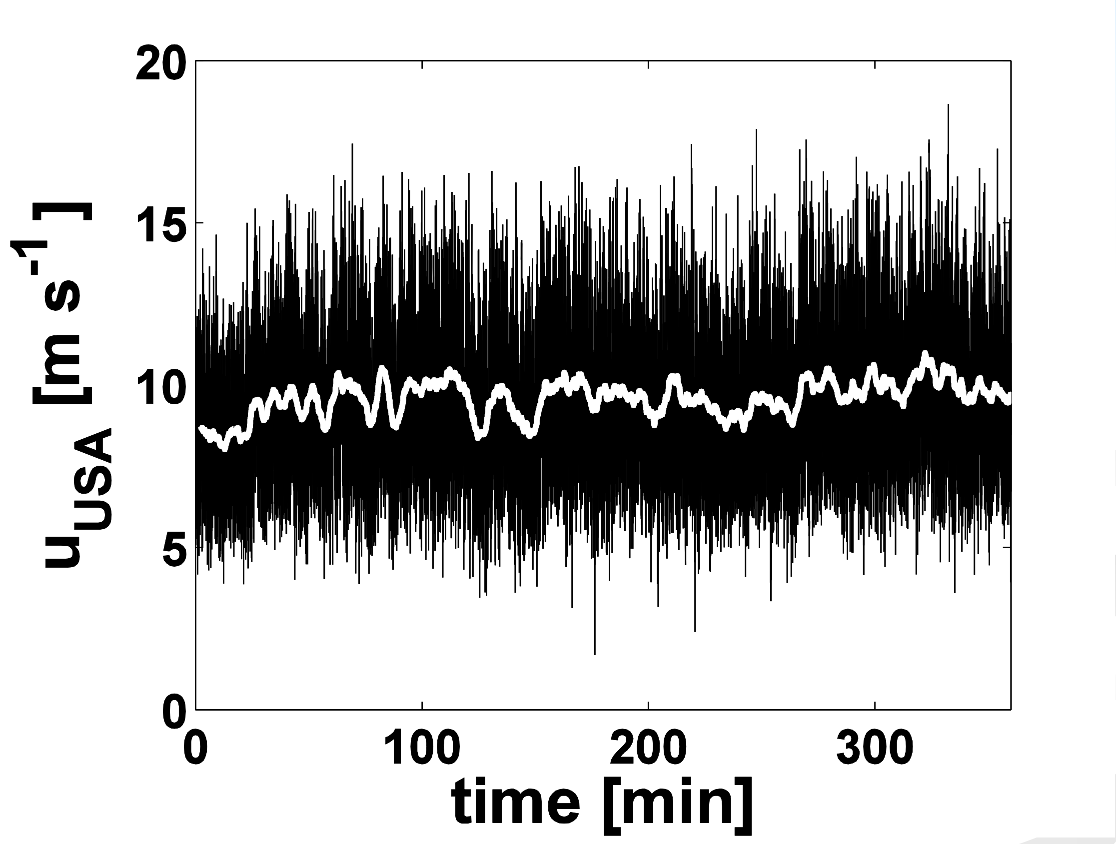
- The original DAQ card cannot register changes in the hot wire voltage if the $f_S > 10\ 000$ Hz ➔ $f_K = 5\ 000$ Hz ➔ U_{max} below 10 m s^{-1} ➔
  ➔ weak to moderate bora

- Gill WindMaster Pro ultrasonic anemometer


latitude [deg]
longitude [deg]
55
50
45
40
35
-5
0
5
10
15
20
4500
4000
3500
3000
2500
2000

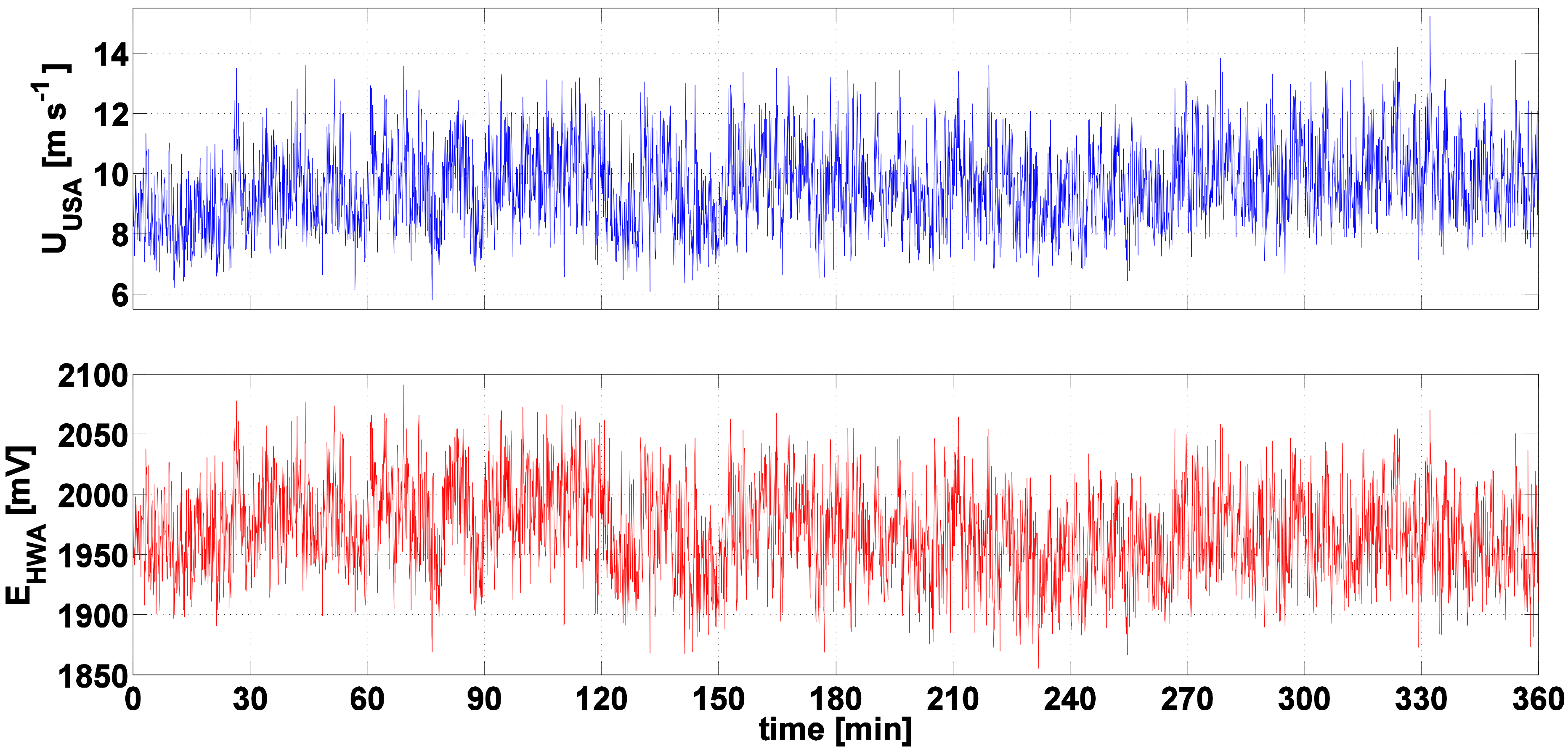

Vratnik pass
Dinaric Alps
Adriatic Sea
Apennines
latitude [deg]
longitude [deg]
altitude [m]
46
45.5
45
44.5
44
43.5
43
12
13
14
15
16
1500
1000
500
0


Senj



20
15
10
5
0
0
100
200
300
u_USA [m s^-1]
time [min]

5-s averages



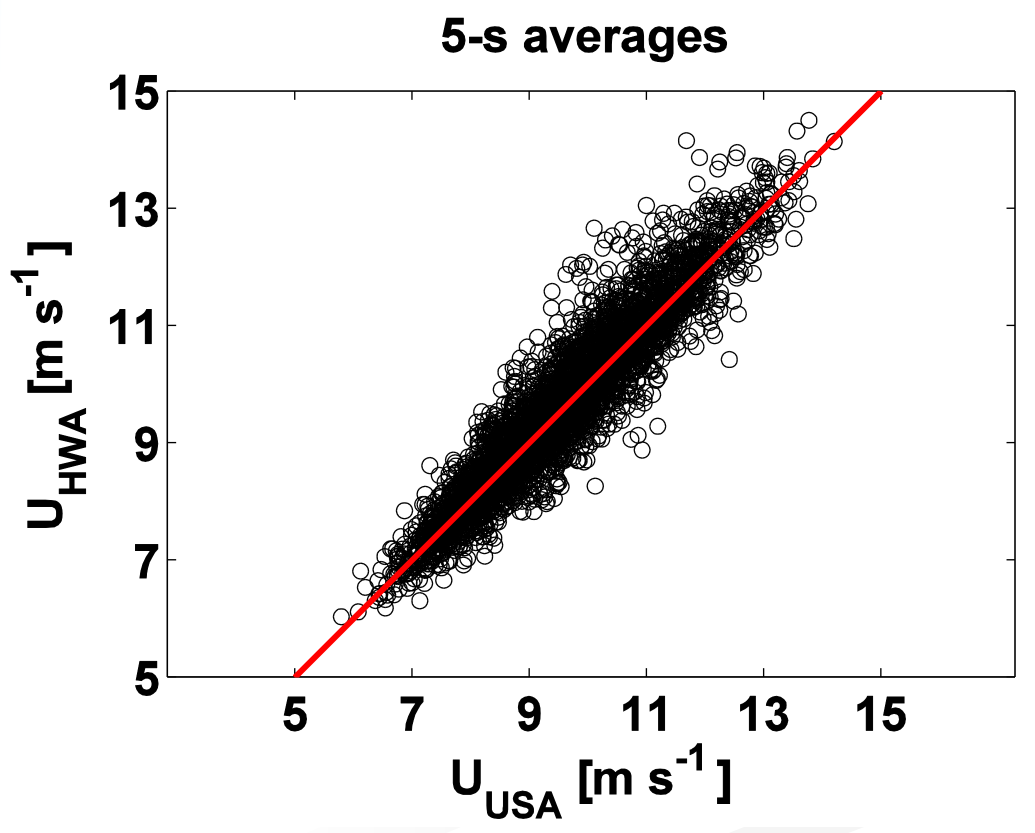
U_USA [m s^-1]
14
12
10
8
6
E_HWA [mV]
2100
2050
2000
1950
1900
1850
0
30
60
90
120
150
180
210
240
270
300
330
360
time [min]

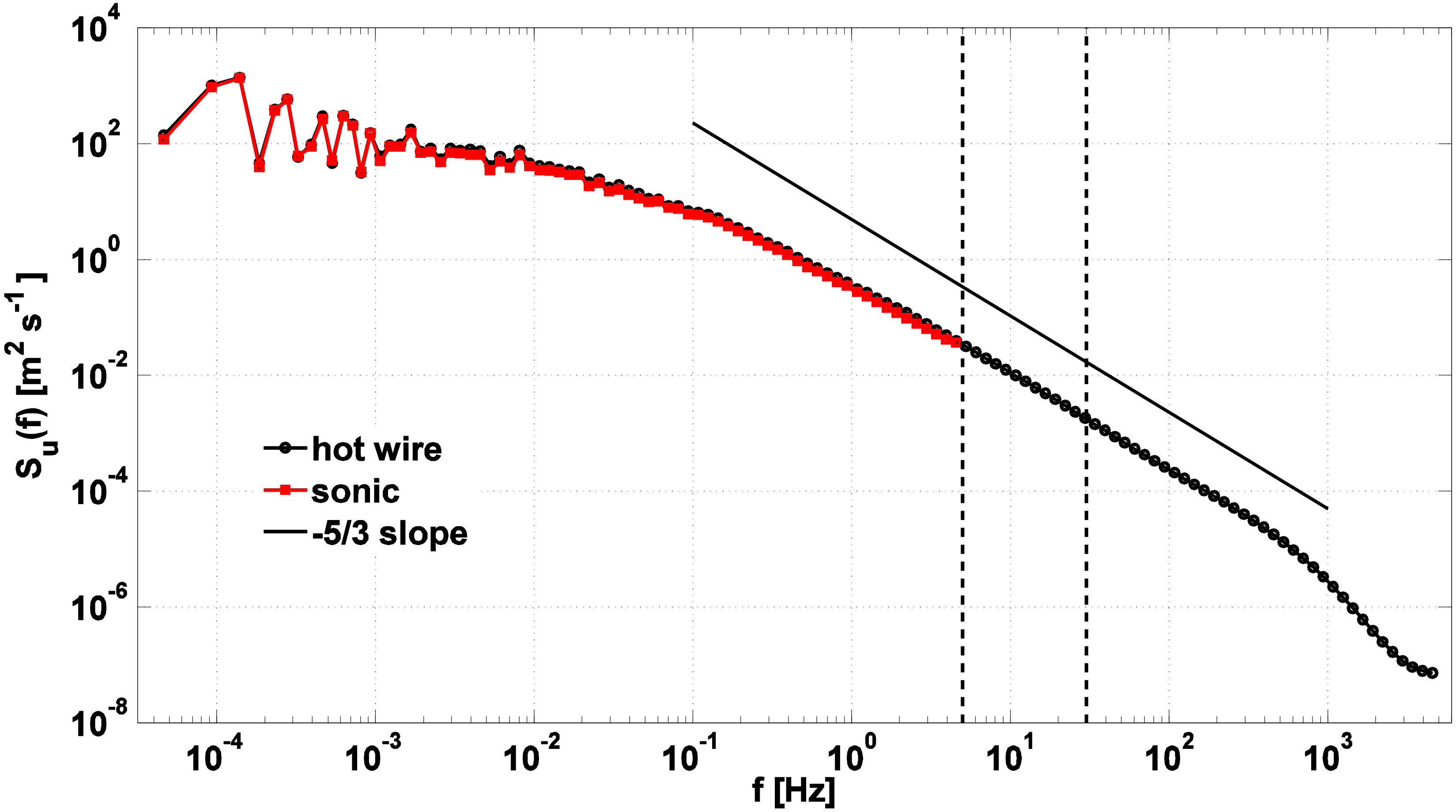
III. ANALYSIS AND RESULTS

- In situ calibration of E_{HWA} to U_{USA} on 5-s intervals using King's law:

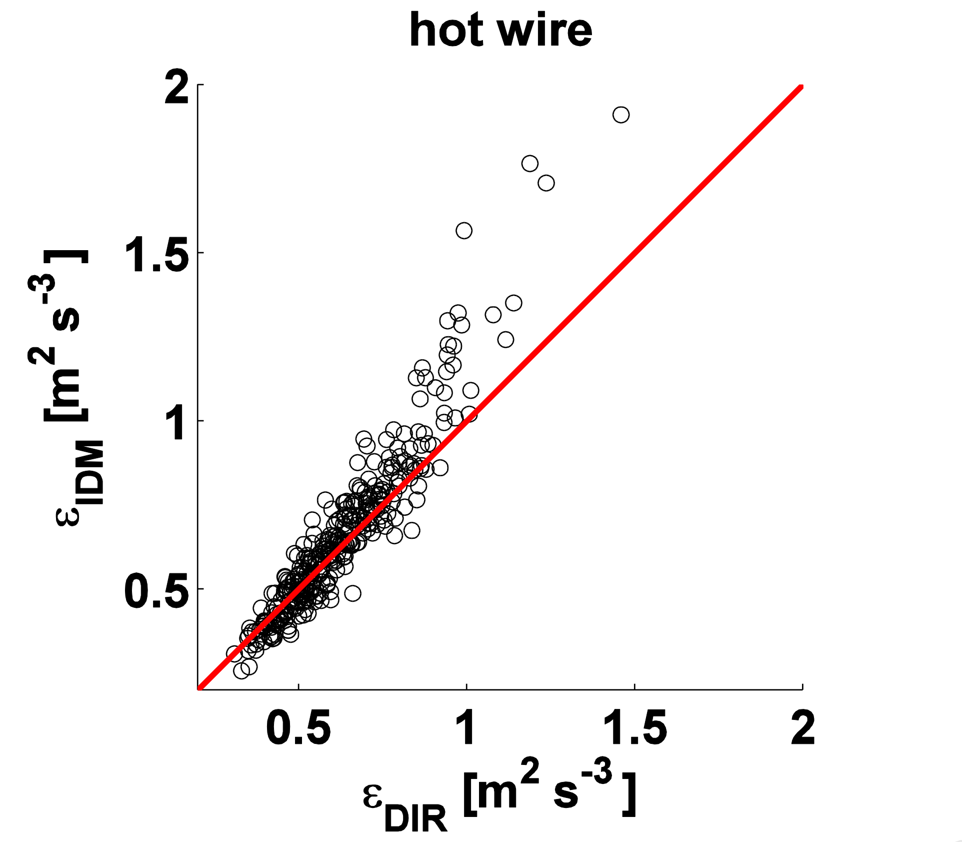
$$E^2 = a + bU^n$$

$n = 0.45$





10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
$S_u(f)$ [m^2 s^{-1}]
hot wire
sonic
-5/3 slope
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
f [Hz]



hot wire
2
1.5
1
0.5
0.5
1
1.5
2
ε_{IDM} [m^2 s^{-3}]
ε_{DIR} [m^2 s^{-3}]

V. SUMMARY

- Indications that IDM might be useful for bora

- Higher sampling rate is needed to cover greater wind speeds ➔

  ➔ FEE guys provided a better DAQ card and we have measured bora using $f_S \approx 50\,000$ Hz

Discussion is opened!