LEGI
LABORATOIRE DES ECOULEMENTS GEOPHYSIQUES ET INDUSTRIELS

UBERTONE
ultrasonic measurements in liquids

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Turbulence Measurements with a New Two Components Ultrasonic Profiler

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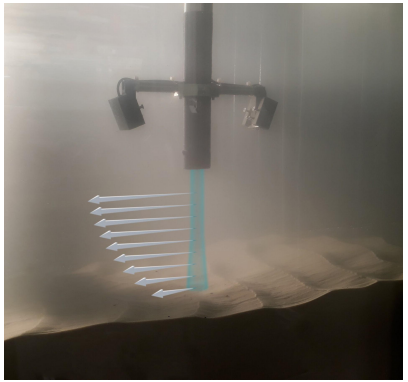
Situation

- Need suspended solids measurement for environmental monitoring and industries
- LEGI: sediment transport monitoring in the lab
- UBERTONE: ultrasonic measurement in liquids

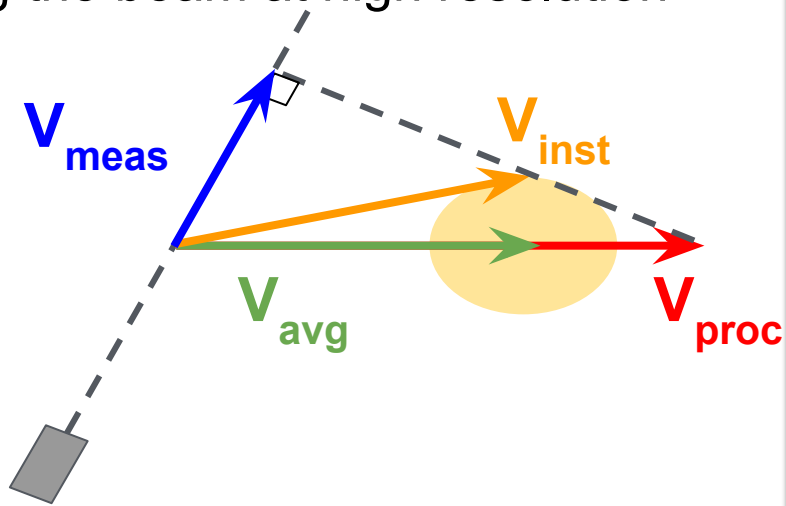


Goal

- Hydroacoustic inversion tool
  → concentration and grain size information
- Acoustic device

Ultrasonic Velocity Profiler

- UVP or UDV
- Pulsed Doppler : velocity profile along the beam at high resolution
- Accuracy : better than 0.34%
- needs **particles** / microbubbles
- clear and **opaque** liquids
- projected velocity on the beam axis
  → **1C mean** velocity profiling
  uncertainty on flow direction
  ⇒ strong error on processed velocity



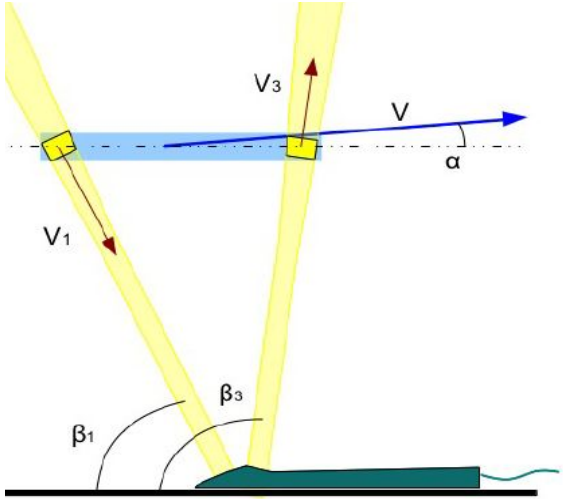
Furuichi, N. (2013). Fundamental uncertainty analysis of flowrate measurement using the ultrasonic Doppler velocity profile method. *Flow Measurement and Instrumentation, 33, 202-211.*

What about turbulent flow?

- UVP with multiple divergent beams
  = multi-monostatic configuration
  → **2-3C/1D mean** velocity profiling

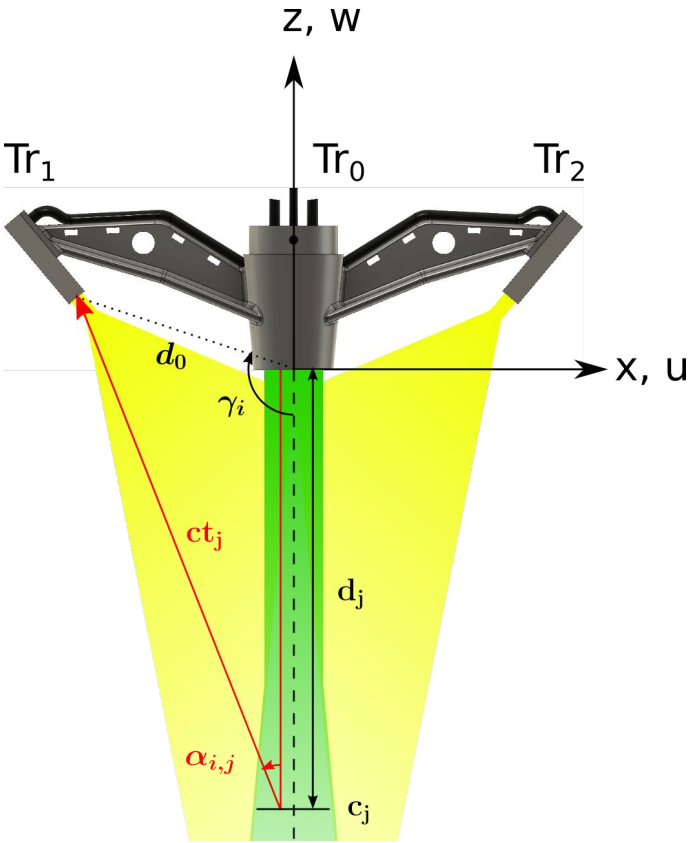
- UVP with beams grid
  = multi-monostatic configuration
  → **2C/2D mean** velocity profiling

- **ADVP** (Acoustic Doppler Velocity Profiler)
  = multi-bistatic configuration
  → **2-3C/1D quasi-instantaneous** velocity profiling



2C Bistatic Velocity Profile

- 3 transducers →
  2 components **at the same time** in a profile along the beam
- Wide angle transducer : full profile of 2C velocity
- No side lobes effect



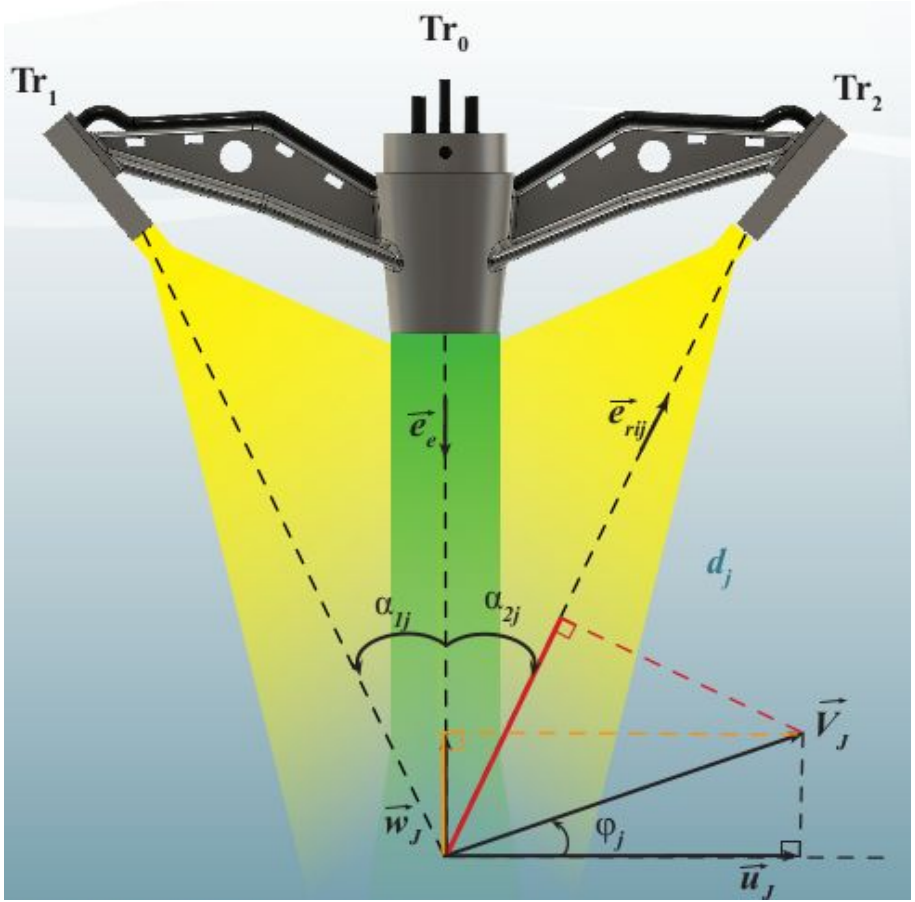
Hurther, D. et al. (2011). A multi-frequency Acoustic Concentration and Velocity Profiler (ACVP) for boundary layer measurements of fine-scale flow and sediment transport processes. *Coastal Engineering, 58, 594–605.*

2C Bistatic Velocity Profile

$$V_{i,j} = \frac{c f_{d,i}}{f_0} = \vec{V_j} \cdot (\vec{e_{rij}} - \vec{e_e})$$
$$= V_j \left(\sin\left(\varphi_j - \alpha_{ij}\right) + \sin\varphi_j\right)$$

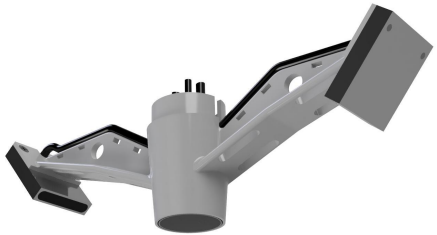
$$u_j = \frac{V_{1j} - V_{2j}}{2\sin(\alpha_j)}$$

$$w_j = -\frac{V_{1j} + V_{2j}}{2\left(1 + \cos(\alpha_j)\right)}$$



2018

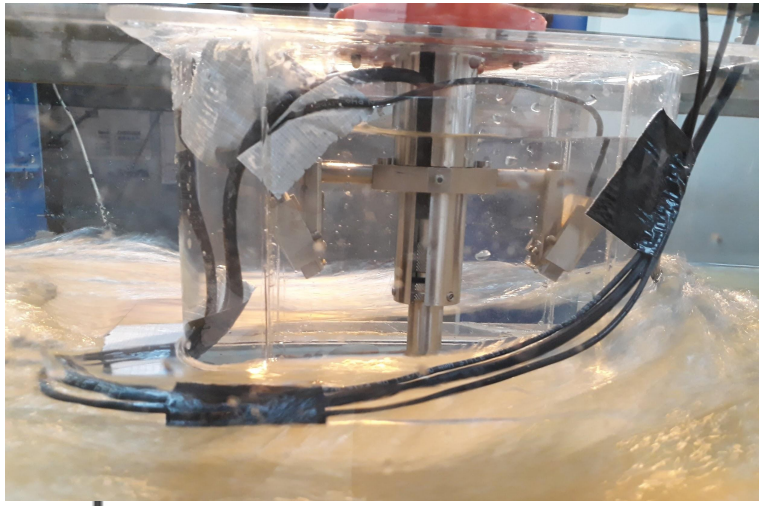
Acoustic Multi-Bistatic Profiler **UB-Lab 2C**

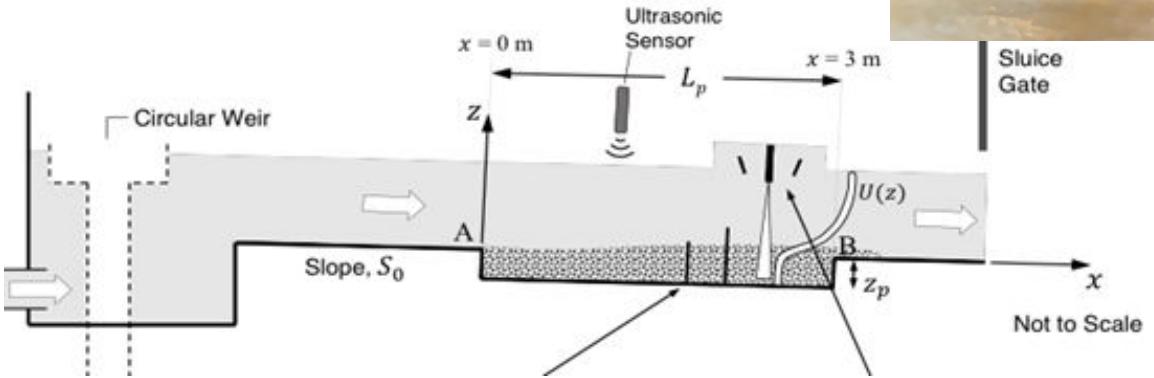


Emitting frequency	0.8 to 1.2 MHz
Spatial resolution	1.4 to 20 mm
Cells number	100
Transducers	1 Emitter + 2x2 Recievers
Temperature	1 input
Velocity accuracy	0.2 to 1 %
Sampling rate	100 Hz
Trigger	IN/OUT
Weight	1.5 kg
Consumption	4 W

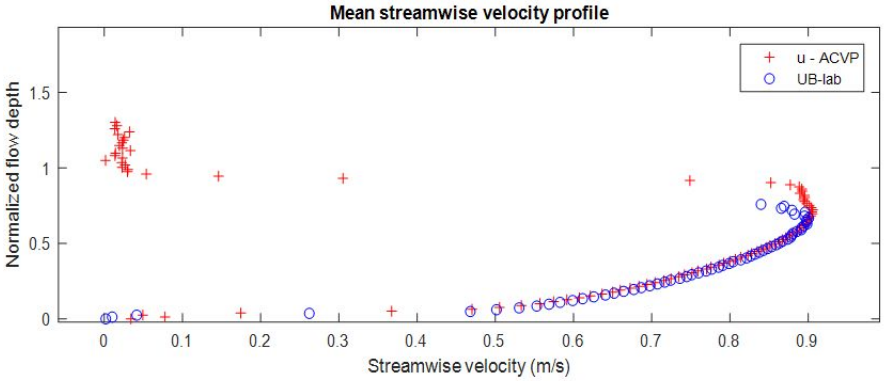
2C measurement in a flume

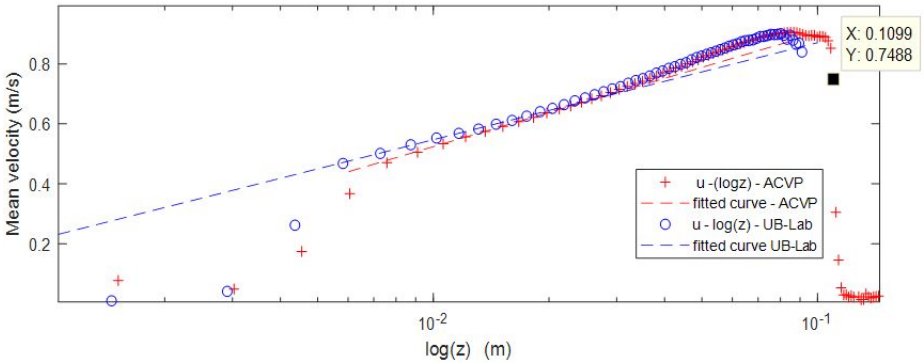
- UB-Lab 2C
- In a flume with sediment pit at the LEGI in Grenoble
- Reference measurement (not simultaneously) with ACVP





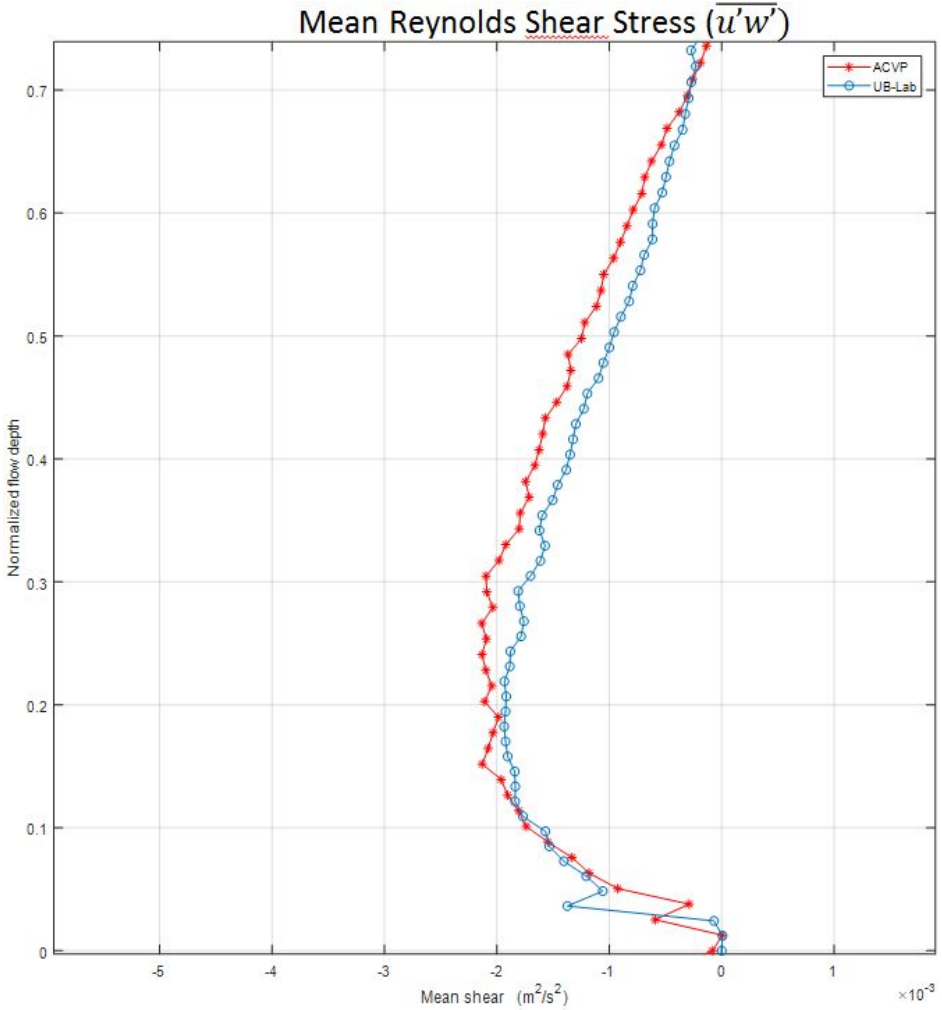
2C velocity profile





$$u = \frac{u*}{k} \ln\left(\frac{z}{z_o}\right)$$

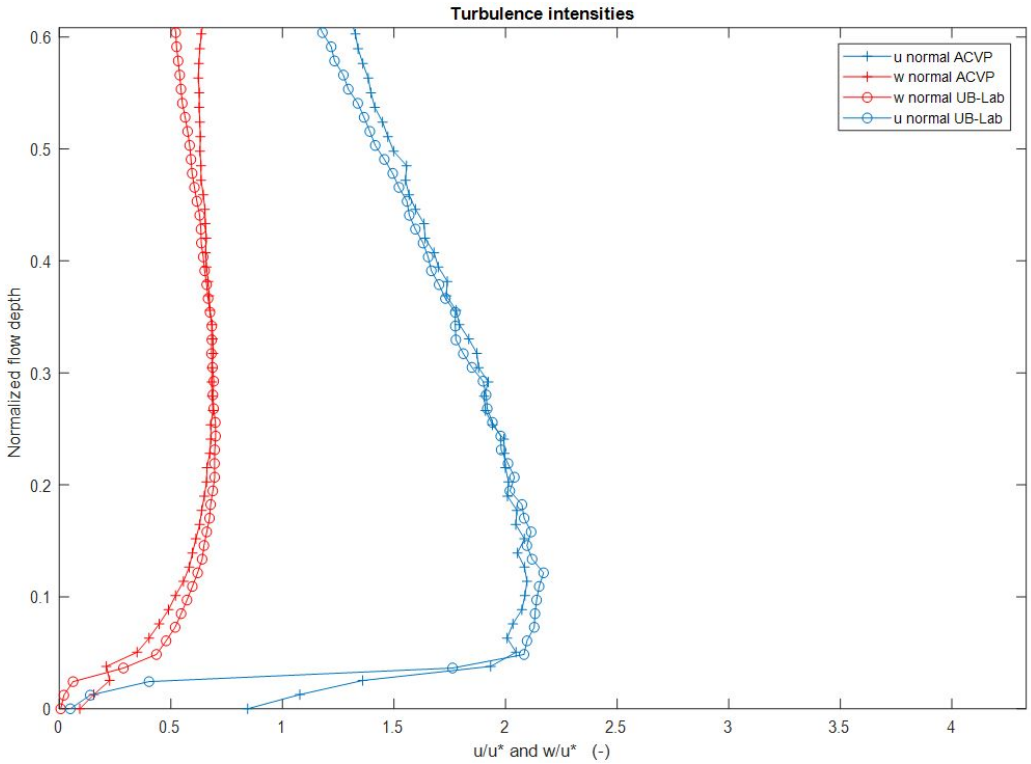
	FRICTION VELOCITY
	u*(m/s)
ACVP	0,060
UB-Lab 2C	0,057



Reynolds Shear Stress

- Higher friction velocity and higher shear stress for ACVP
  → higher flow rate
- 0 shear point not at z/Hf = 1
  ⇒ disturbance of the free surface flow due to sensor intrusion

Turbulence Intensities



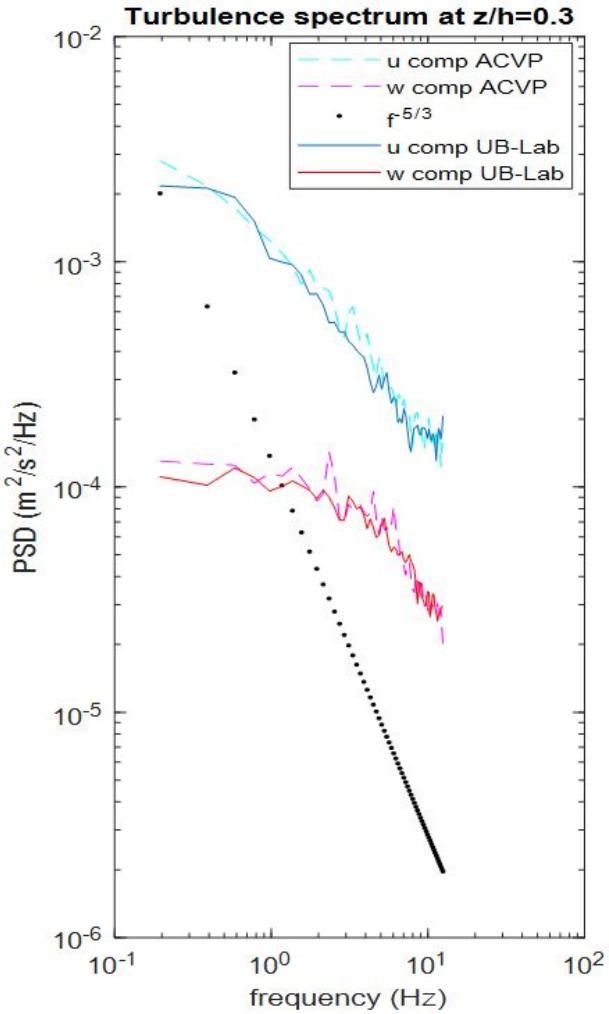
$$u_{rms} = \sqrt{\overline{u'^2}}$$

$$w_{rms} = \sqrt{\overline{w'^2}}$$

- Good agreement of the system in both profiles u_{rms} and w_{rms}
- *Nezu & Nakagawa (1993)*

$$\frac{u_{rms}}{u_*} = 2.3\exp(-C_u z)$$

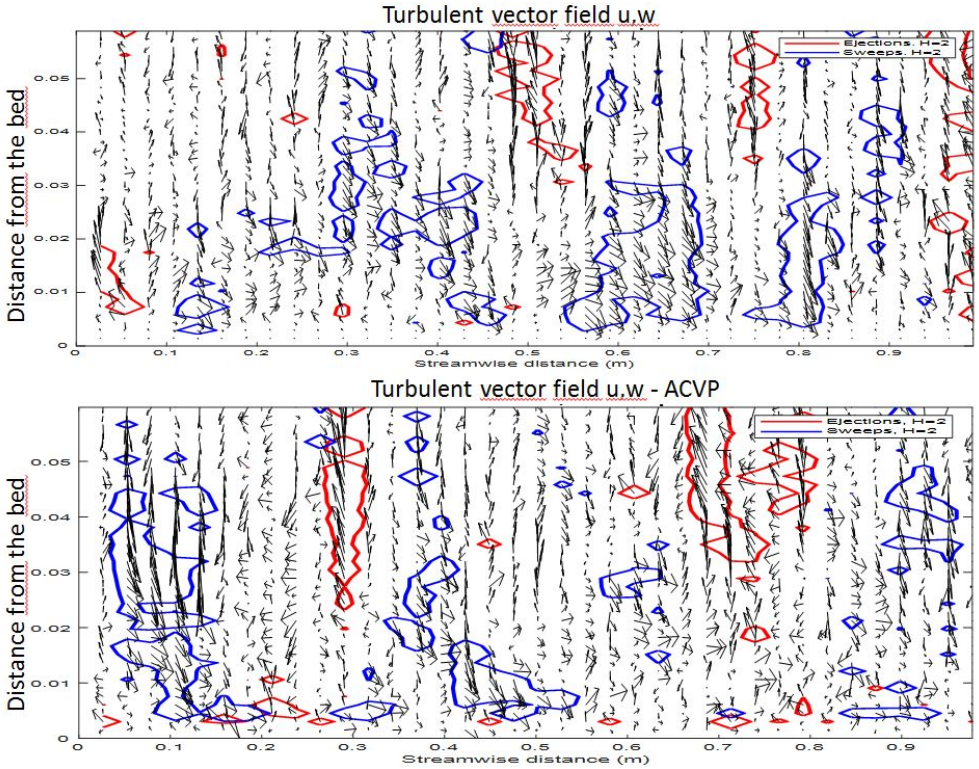
$$\frac{w_{rms}}{u_*} = 1.27\exp(-C_w z)$$



Mean Turbulence Spectra

- Magnitude and shape of the Spectra are similar in both systems, for u and w
- Agreement with -5/3 slope confirms Kolmogorov (1941) turbulence cascading theory

Time resolved turbulence measurements



- Agreement between measurements of large scale turbulent flow structures: similar size, orientation and duration.
- True for both **Ejections** (red) and **Sweeps** (blue)

Conclusion

- Good agreement between the commercial UB-Lab 2C and the ACVP prototype of the LEGI
- And with previous measurement campaigns and literature

- **UB-Lab 2C** - instantaneous 2C-velocity profiles
- Next/ongoing:
  - comparing with LDA
  - measuring in pipe through a plastic wall

Thank you for your attention

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