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MECÂNICA DOS FLUIDOS AMBIENTAL I

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Impact evaluation – methods

= predictions about expected effects, based on:

Field experiments

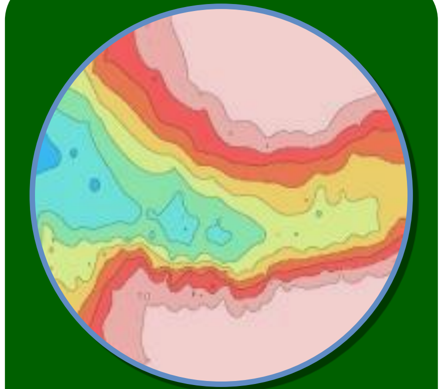
- rhodamine dye tests (Perth SWRO)

Laboratory experiments

- effluent toxicity tests (Carlsbad)

Analogies & judgement

- similar desalination projects



Computer models

- hydrodynamic modelling

Picture: Western Australian, (Crisp et. Al 2007)

Picture: Voutchkov & Dietrich 2007

Todos métodos requerem

1. Entendimento dos processos e fenômenos (descrição qualitativa)
2. Descrição quantitativa (física / modelagem)
3. Solução (matemática)
4. Interpretação

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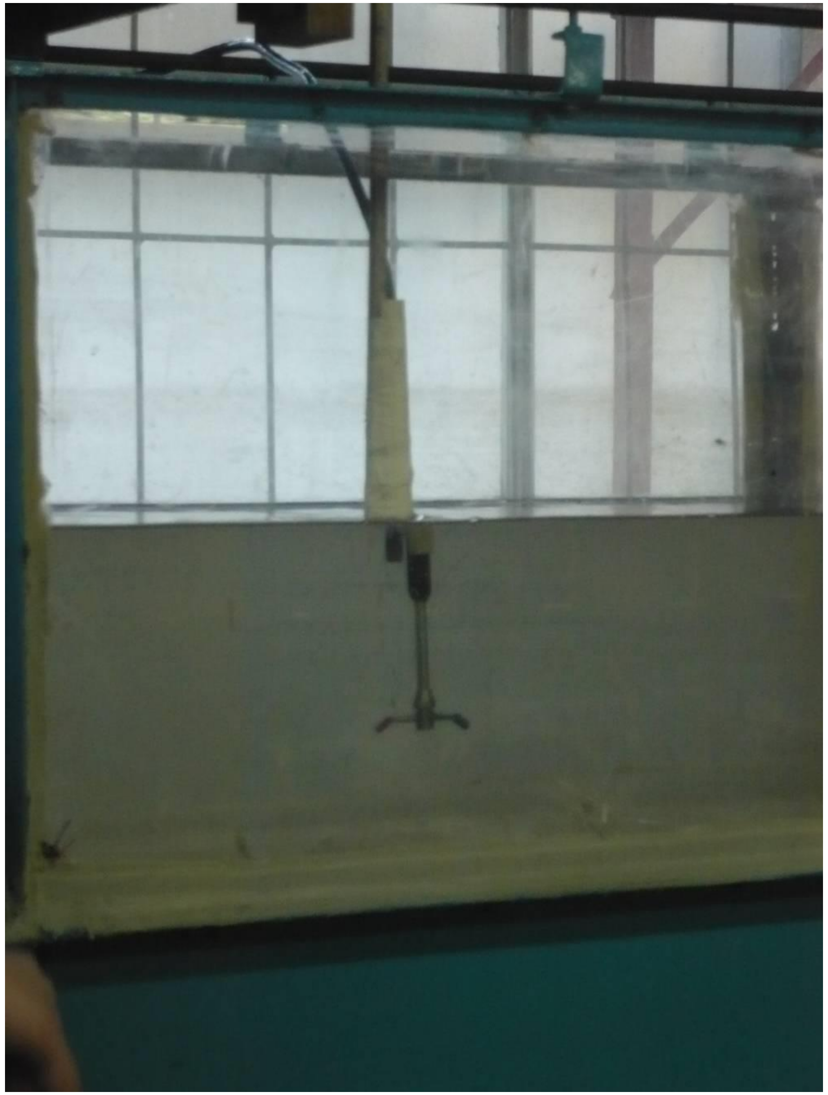
Laboratorio didático de mecânica dos fluidos

Medições de velocidades com ADV (Acoustic Doppler Velocimeter)



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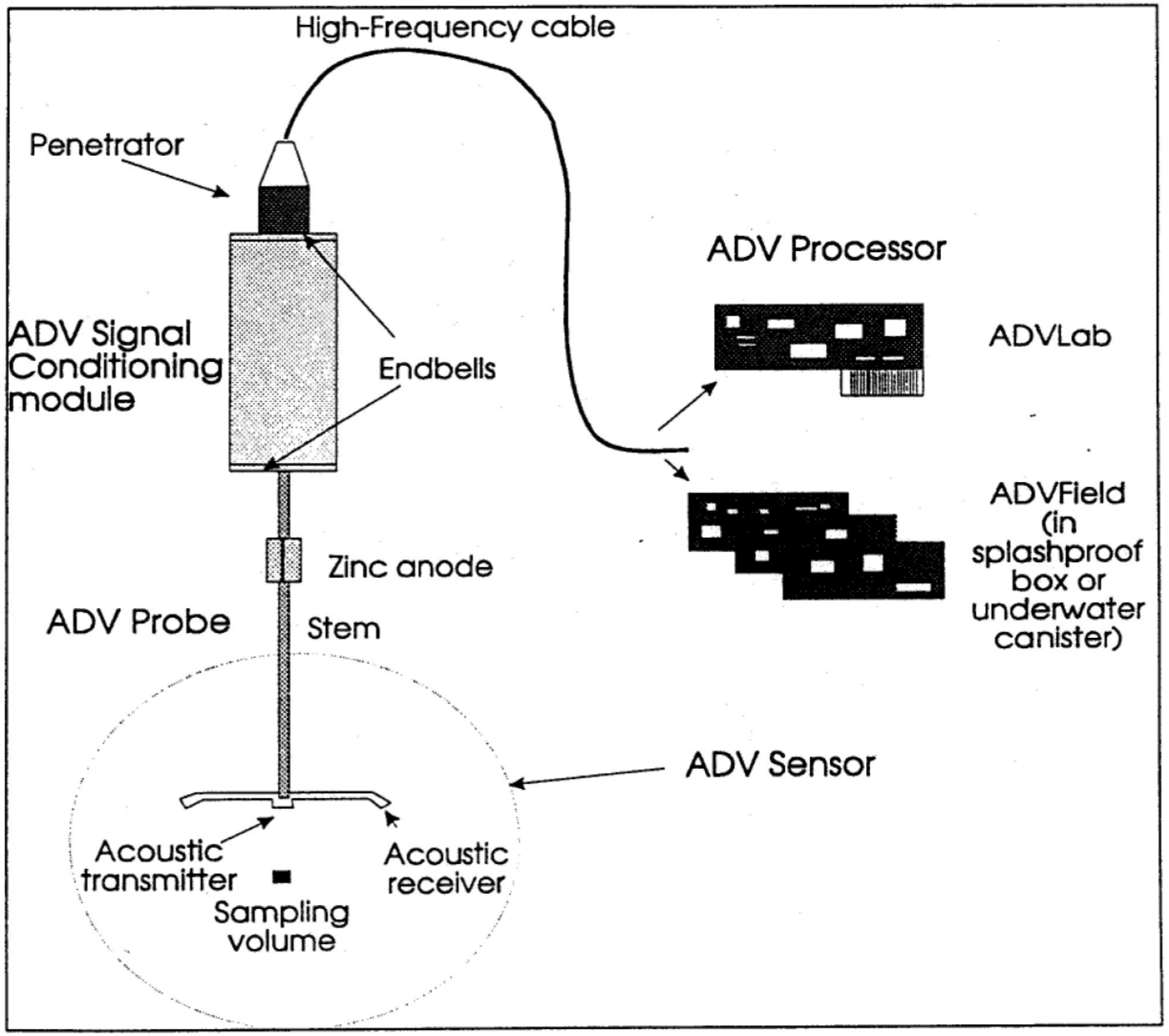

Fonte: www.sontek.com

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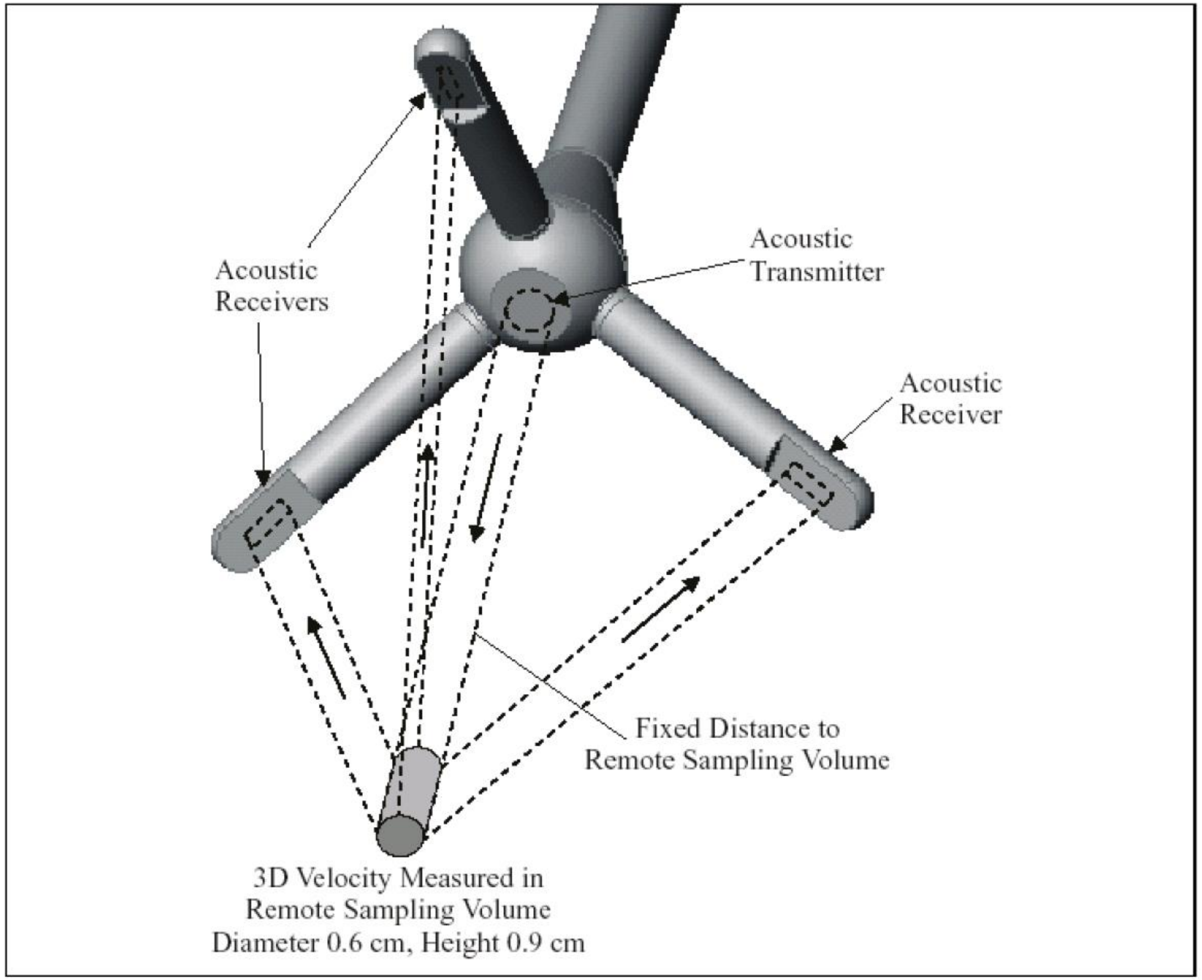

Fonte: www.sontek.com

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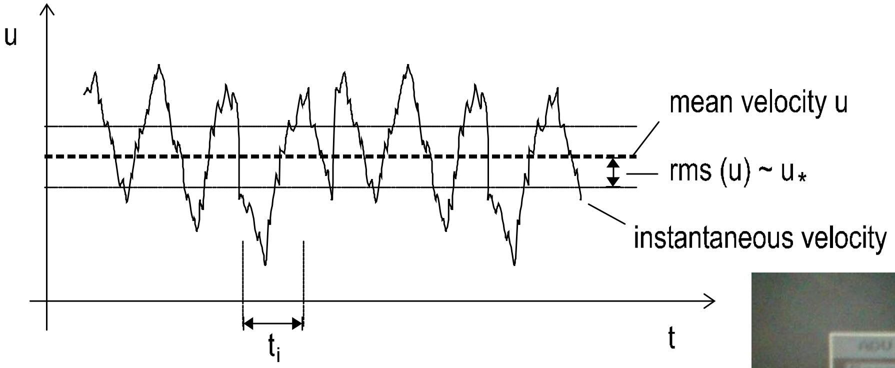

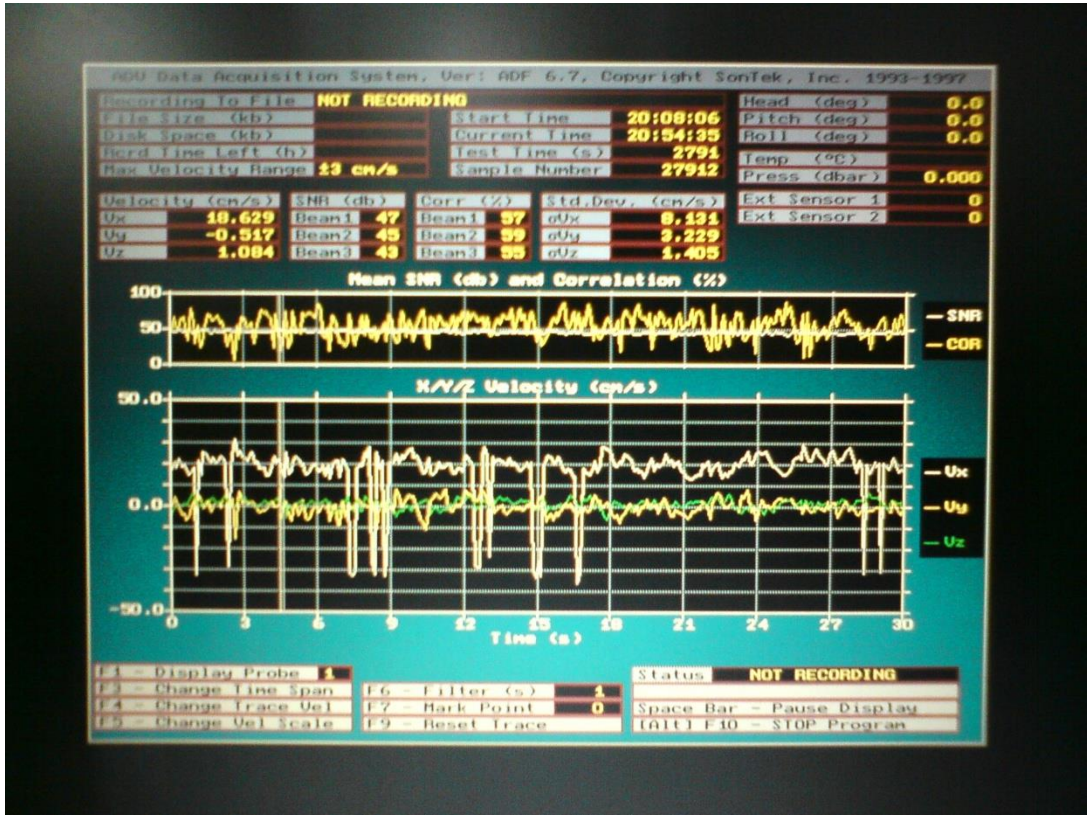

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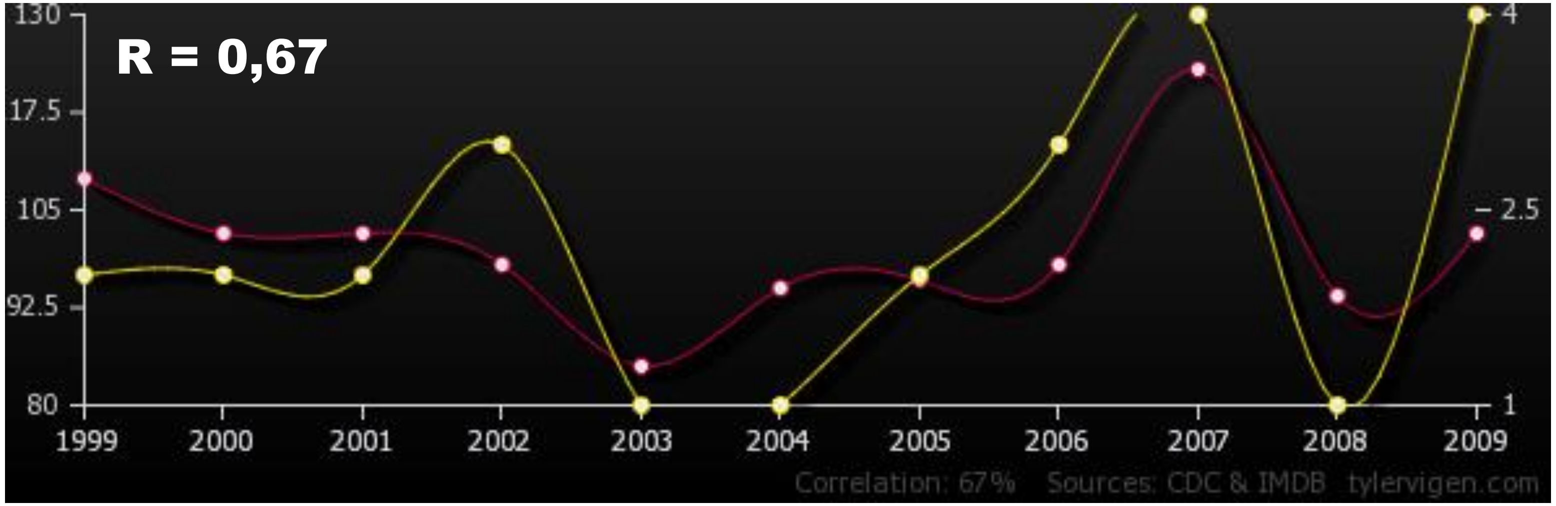
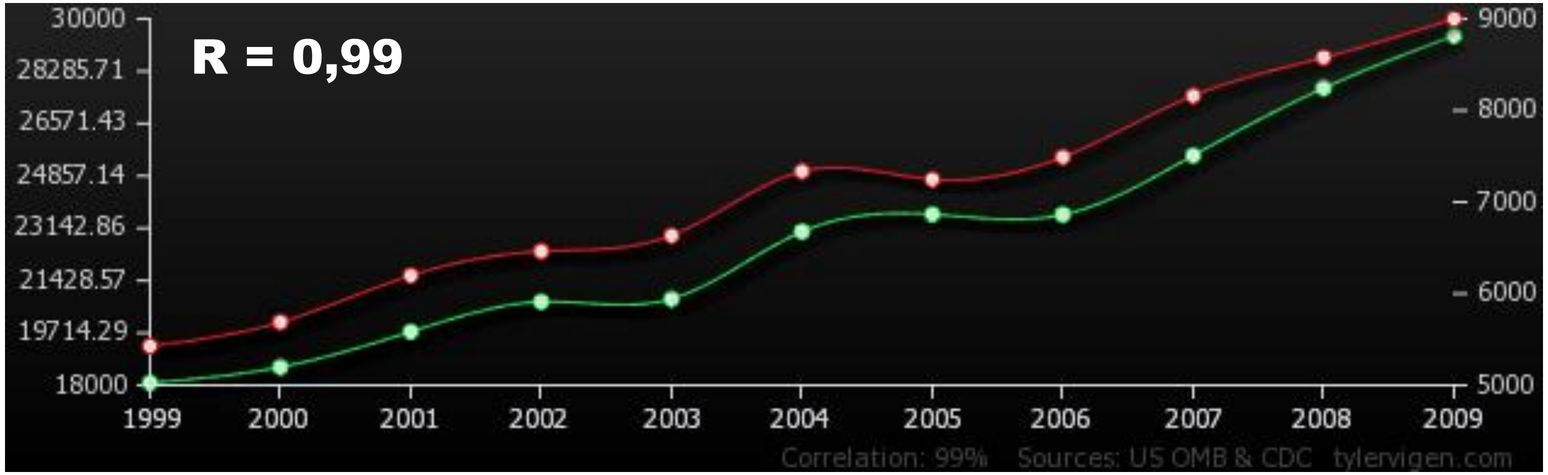
Perguntas a fazer





Source: http://www.tylervigen.com/

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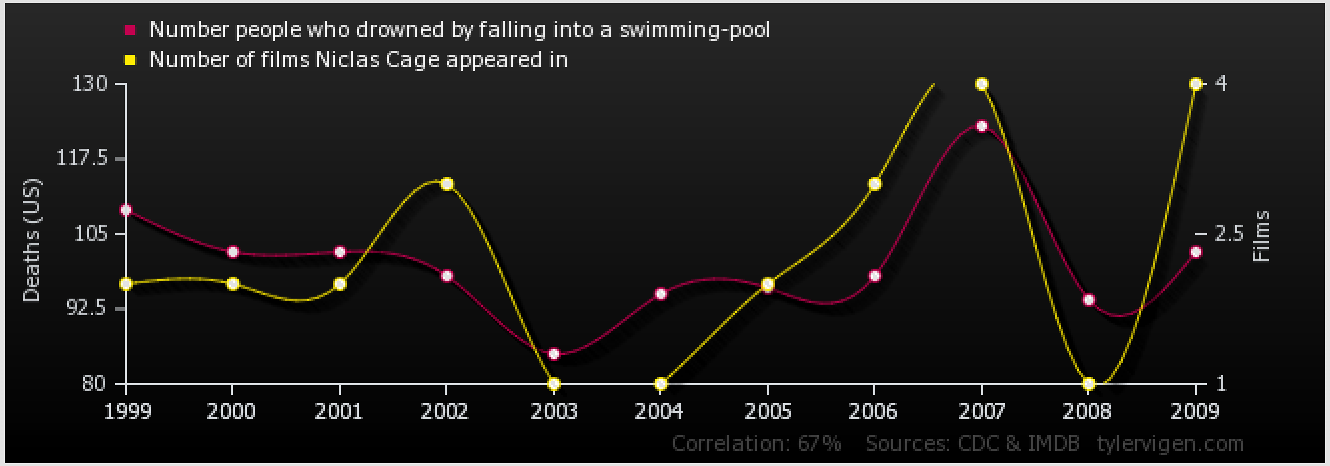
Caso 1

Number people who drowned by falling into a swimming-pool

correlates with

Number of films Nicolas Cage appeared in



Upload this chart to imgur

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number people who drowned by falling into a swimming-pool *Deaths (US) (CDC)*	109	102	102	98	85	95	96	98	123	94	102
Number of films Nicolas Cage appeared in *Films (IMDB)*	2	2	2	3	1	1	2	3	4	1	4

Correlation: 0.666004

Source: http://www.tylervigen.com/

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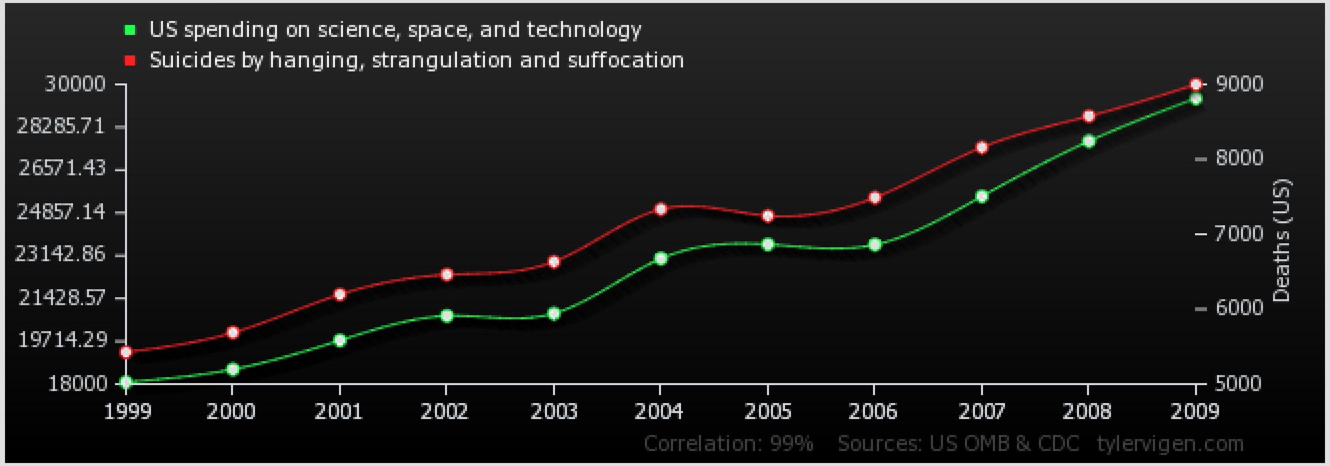
US spending on science, space, and technology

correlates with

Suicides by hanging, strangulation and suffocation



Upload this chart to imgur

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
US spending on science, space, and technology *Millions of todays dollars (US OMB)*	18,079	18,594	19,753	20,734	20,831	23,029	23,597	23,584	25,525	27,731	29,449
Suicides by hanging, strangulation and suffocation *Deaths (US) (CDC)*	5,427	5,688	6,198	6,462	6,635	7,336	7,248	7,491	8,161	8,578	9,000

Correlation: 0.992082

Source: http://www.tylervigen.com/

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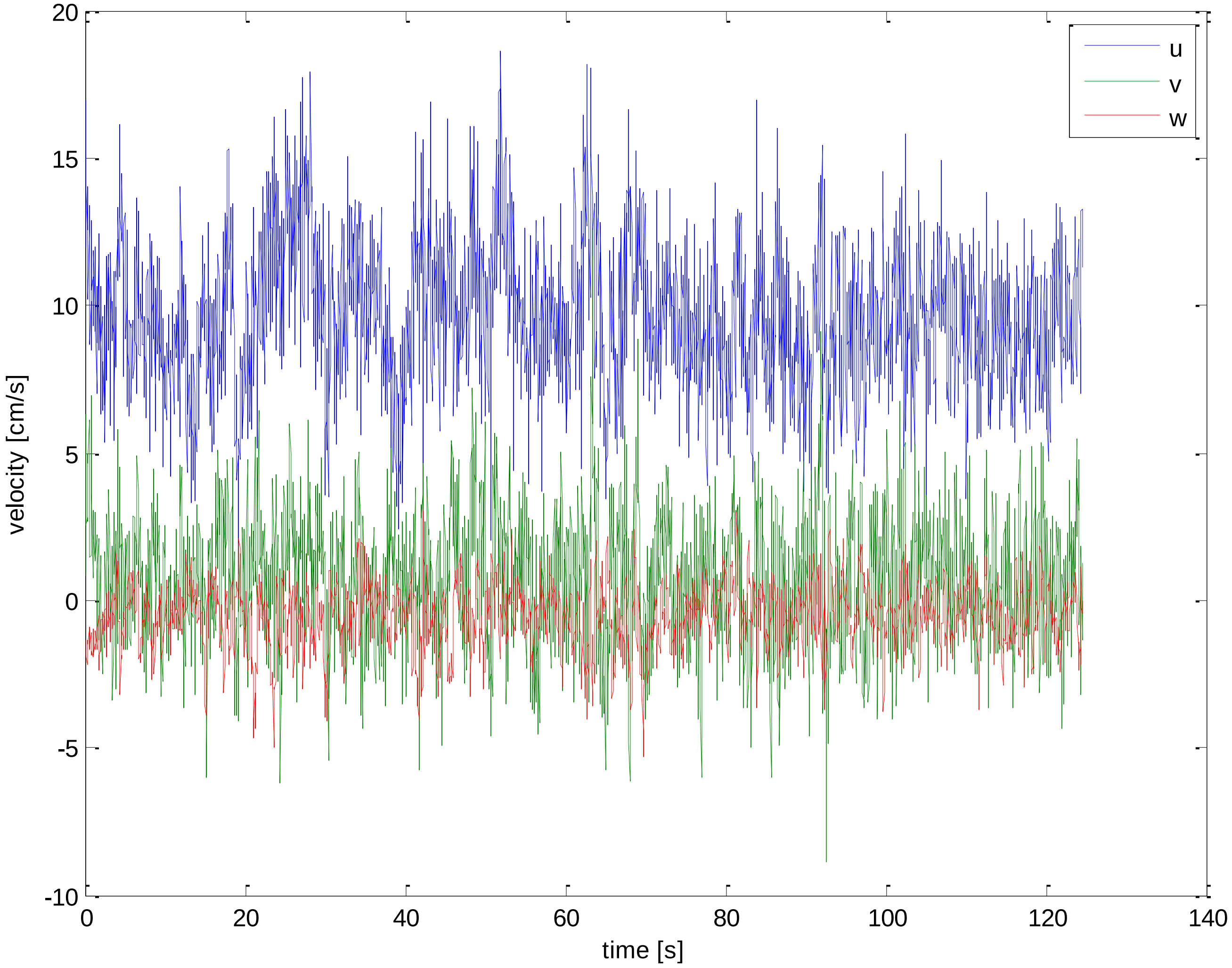
Series temporais



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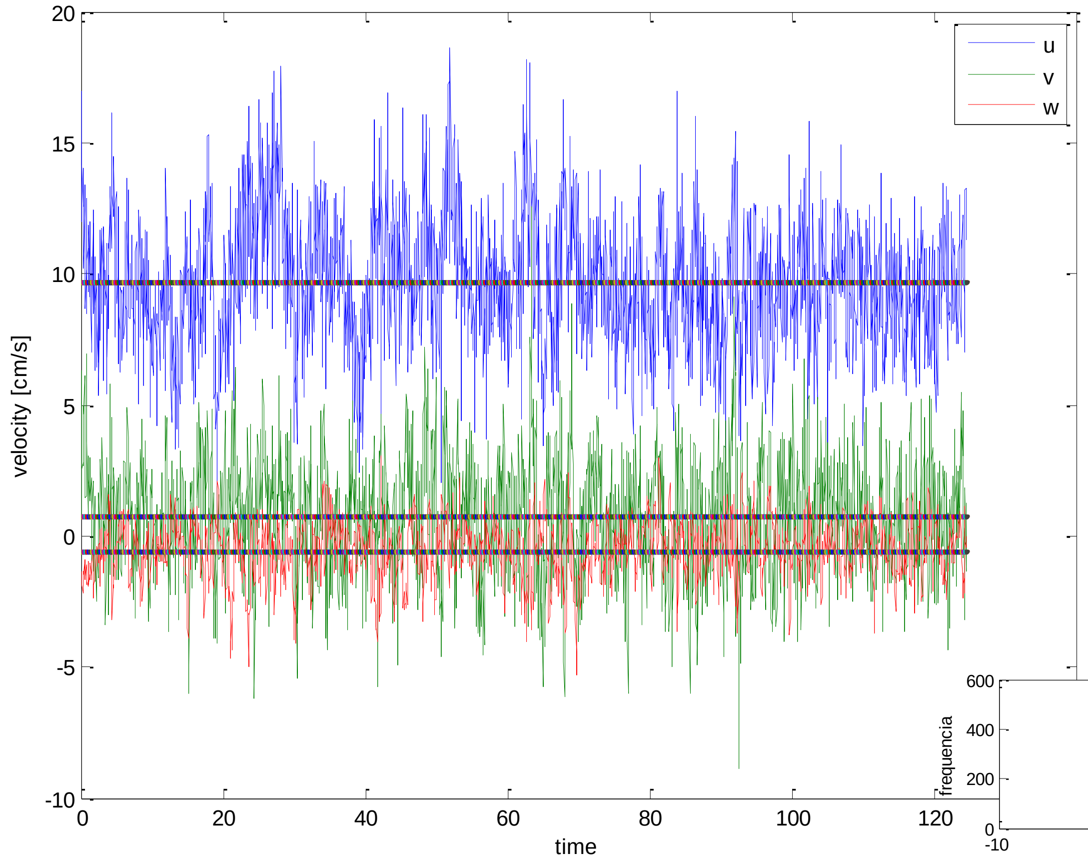
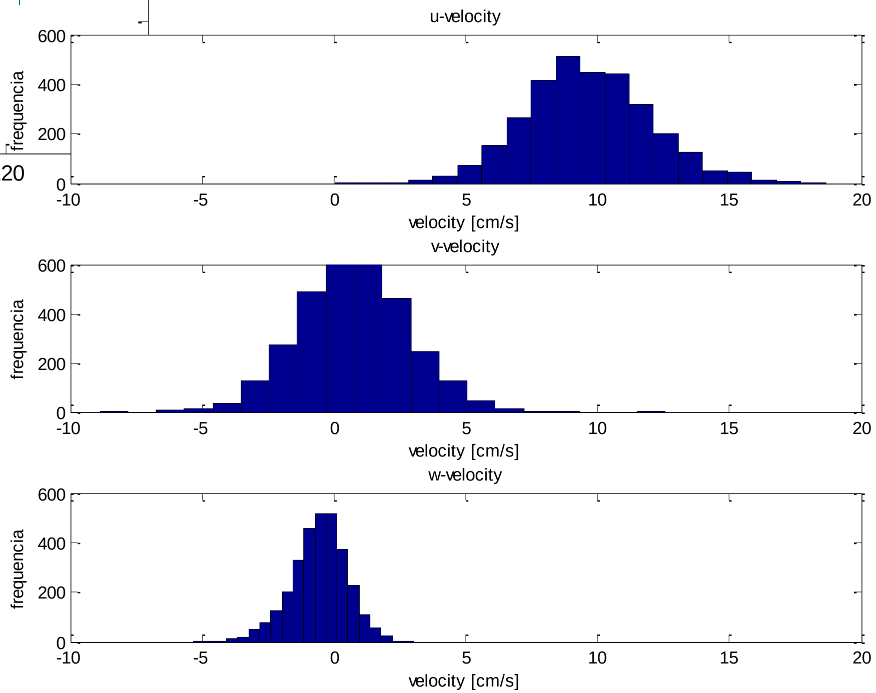
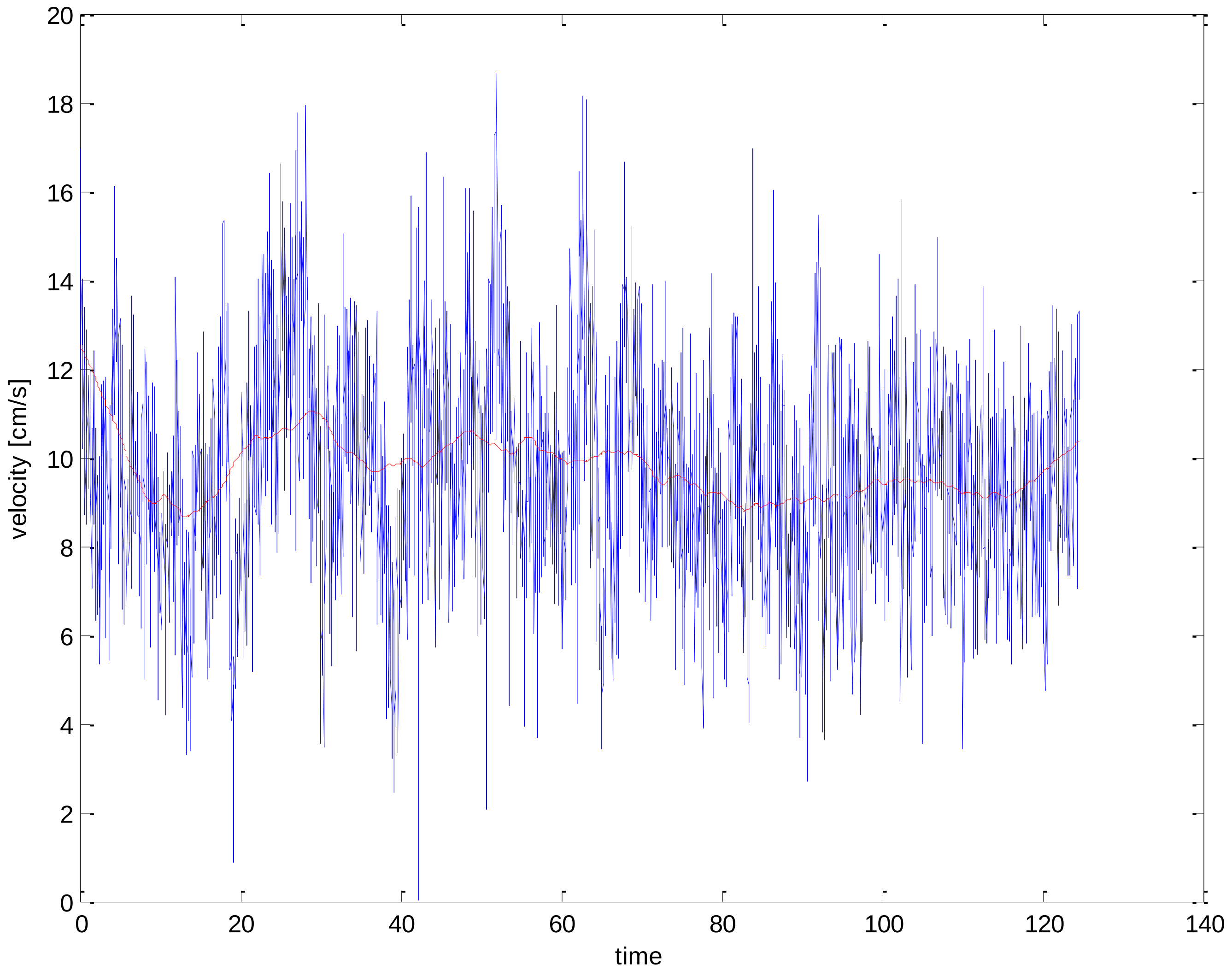
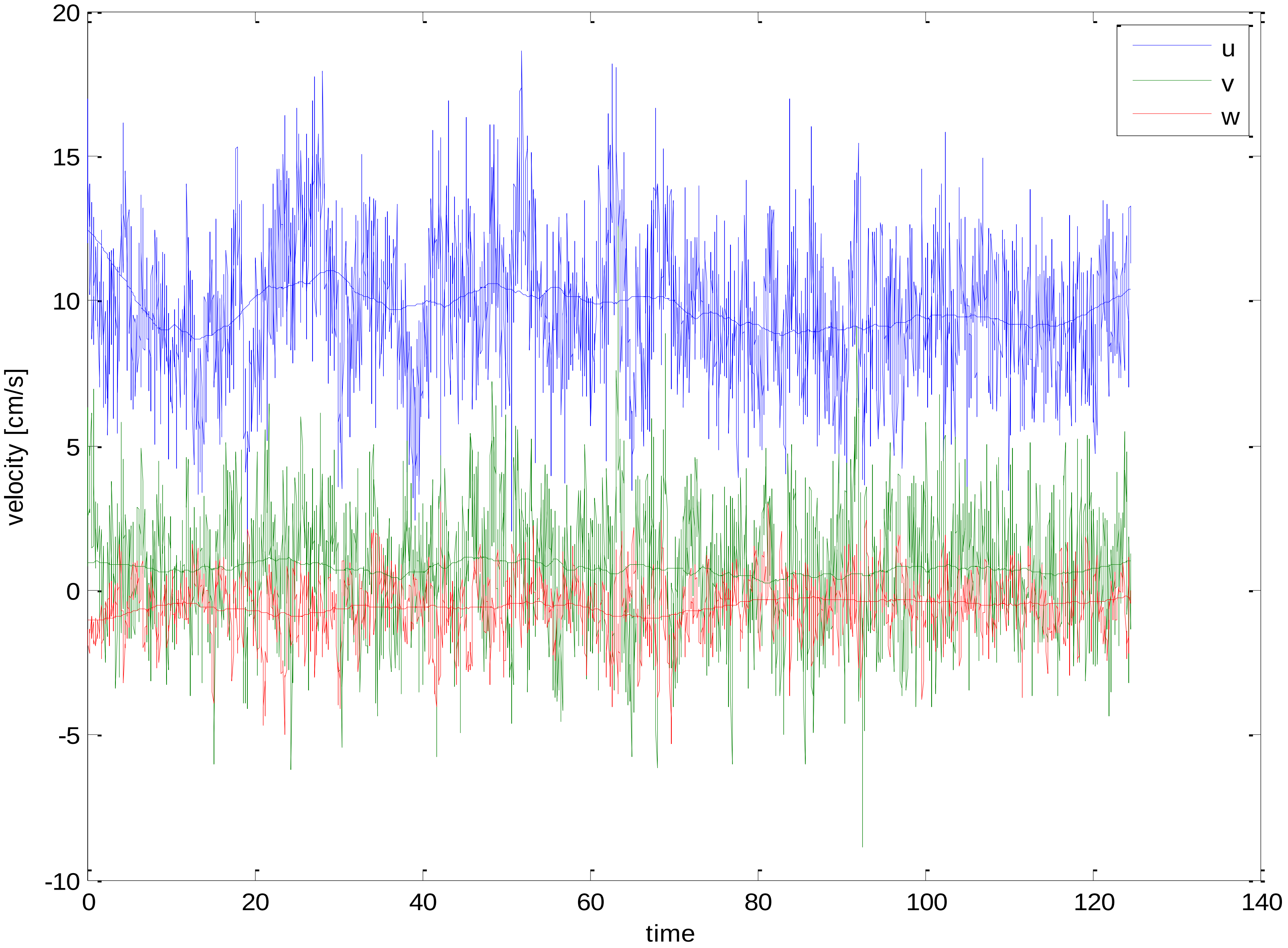




Direction	Mean [cm/s]	std	median	varianca
u	9.6614	2.3859	9.5500	5.6925
v	0.7440	2.0750	0.7300	4.3058
w	-0.5636	1.0668	-0.5000	1.1381


20
18
16
14
12
10
8
6
4
2
0
velocity [cm/s]
0
20
40
60
80
100
120
140
time


20
15
10
5
0
-5
-10
velocity [cm/s]
0
20
40
60
80
100
120
140
time
u
v
w

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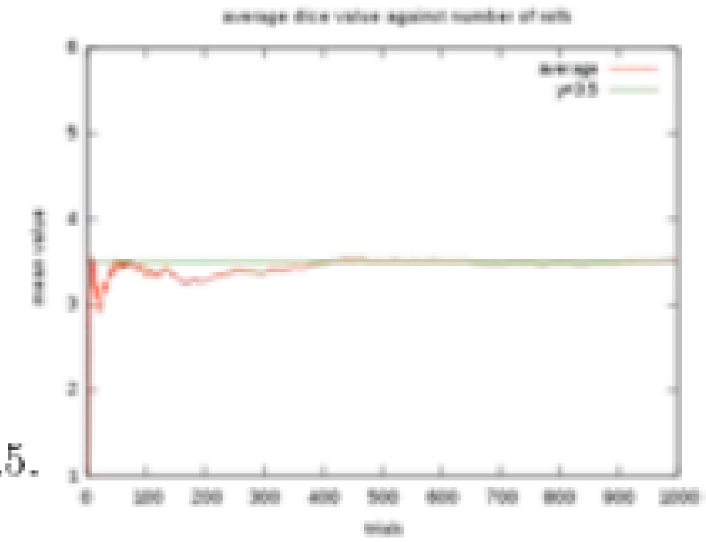
- Expected value (mean)

$$\mathrm{E}[X] = \mu.$$

$$\mathrm{E}[X] = \frac{x_1 p_1 + x_2 p_2 + \cdots + x_k p_k}{p_1 + p_2 + \cdots + p_k}.$$

Dice example :

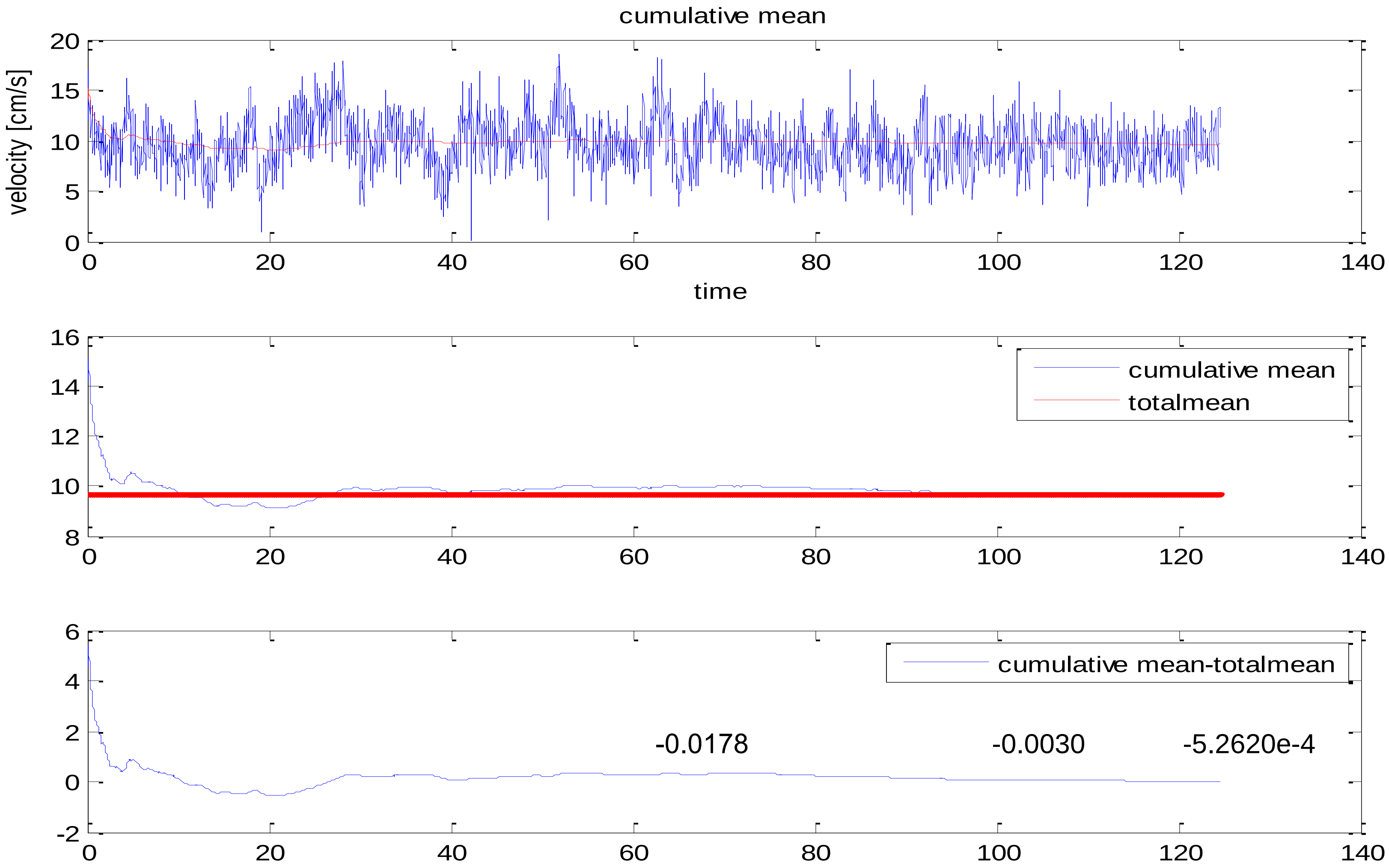
$$\mathrm{E}[X] = 1 \cdot \frac{1}{6} + 2 \cdot \frac{1}{6} + 3 \cdot \frac{1}{6} + 4 \cdot \frac{1}{6} + 5 \cdot \frac{1}{6} + 6 \cdot \frac{1}{6} = 3.5.$$



- Standard deviation

$$\sigma = \sqrt{\mathrm{E}[(X - \mu)^2]} = \sqrt{\mathrm{E}[X^2] - (\mathrm{E}[X])^2}.$$

Source:
Wernher Brevis, University of Sheffield


cumulative mean
velocity [cm/s]
time
cumulative mean
totalmean
cumulative mean-totalmean
-0.0178
-0.0030
-5.2620e-4

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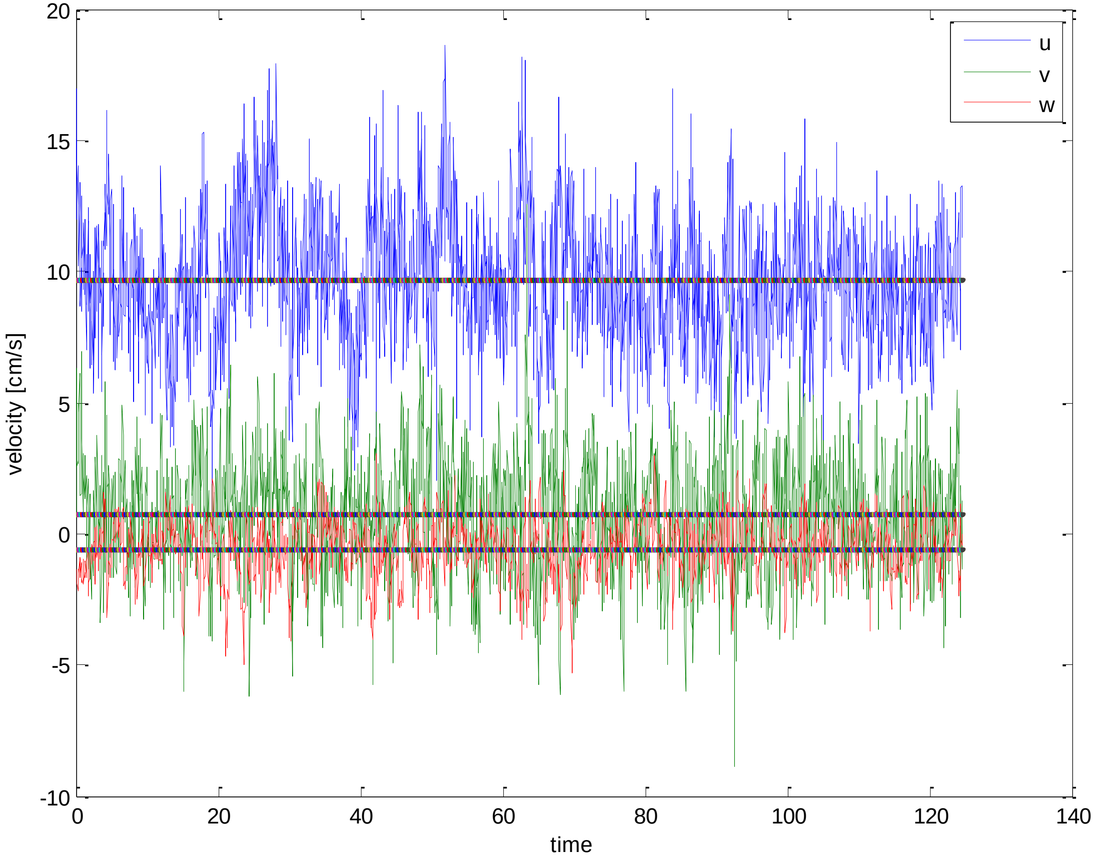

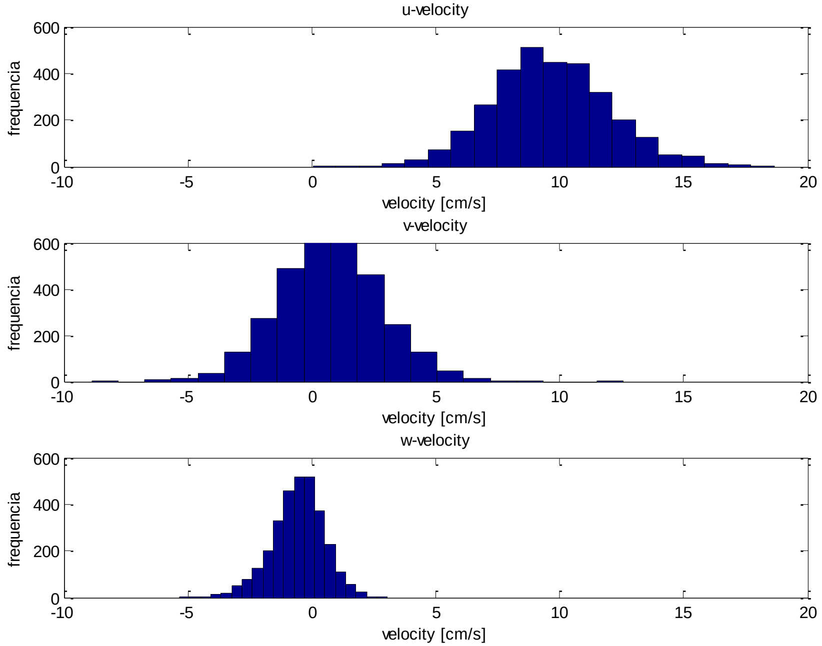

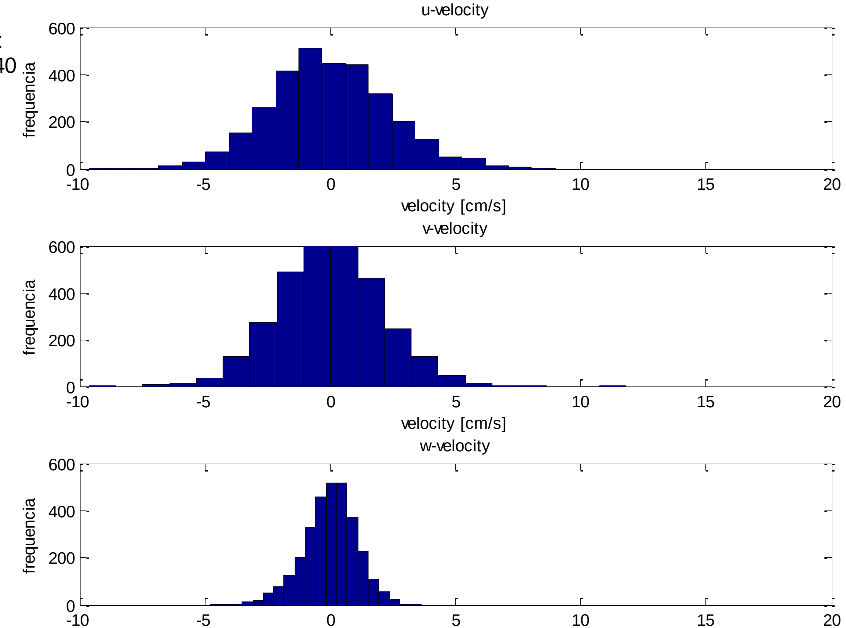

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w-mean	0	1.0668	0.0636	1.1381

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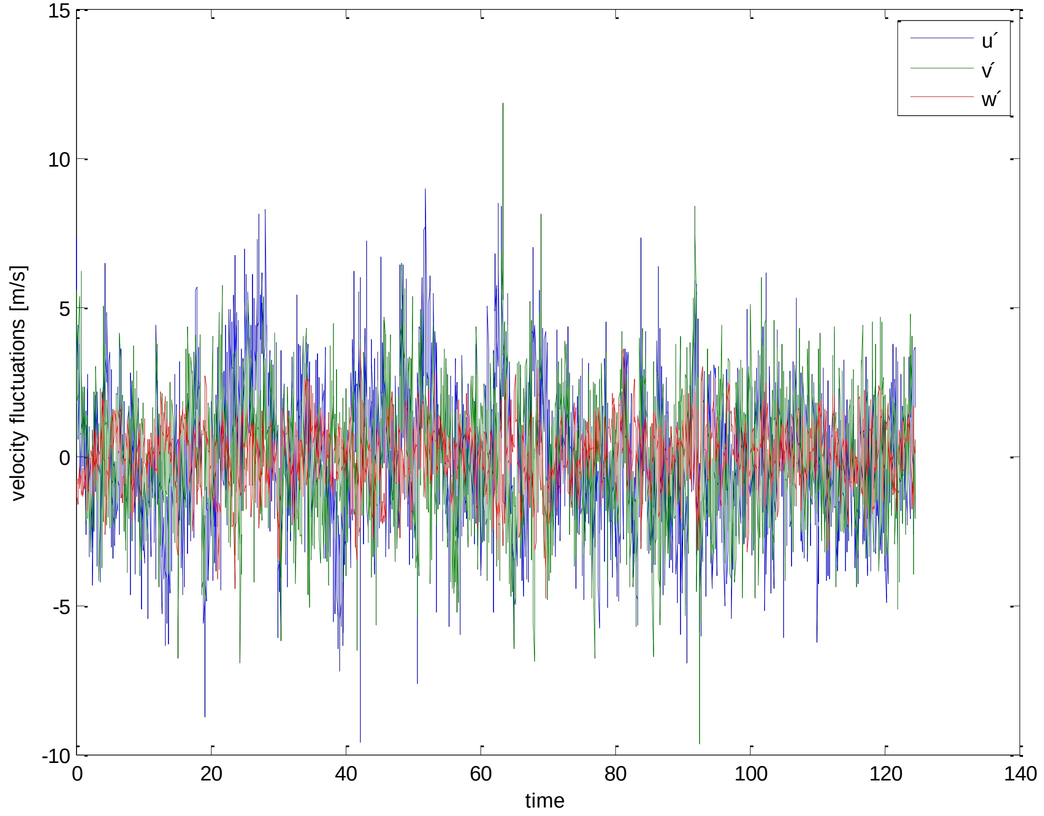
Flutuacoes



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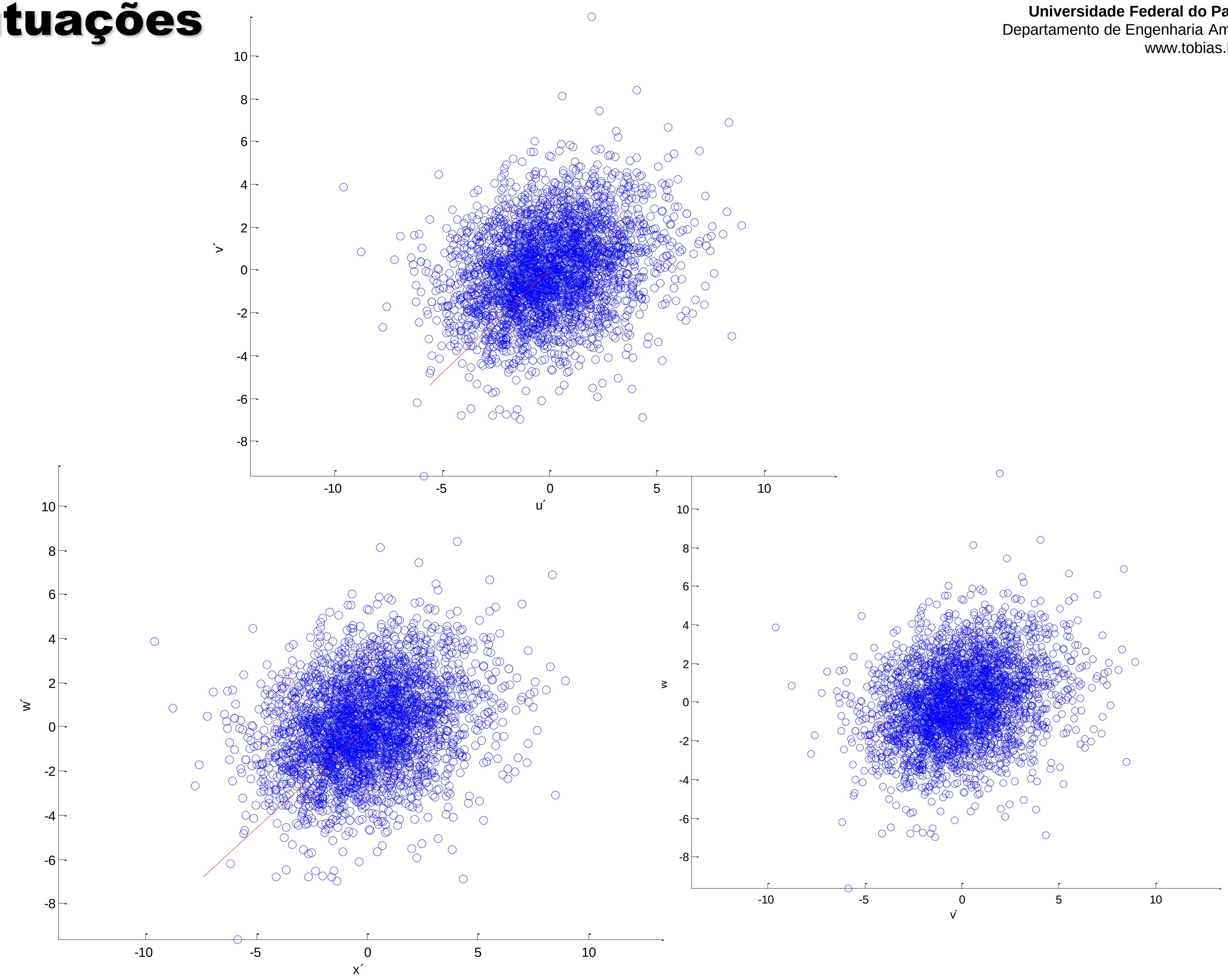
Flutuações



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Causa

- Vórtices no escoamento com estruturas dominantes/coerentes
- Flutuações = Oscilações?
- → Analise estatística usando series e transformadas de Fourier

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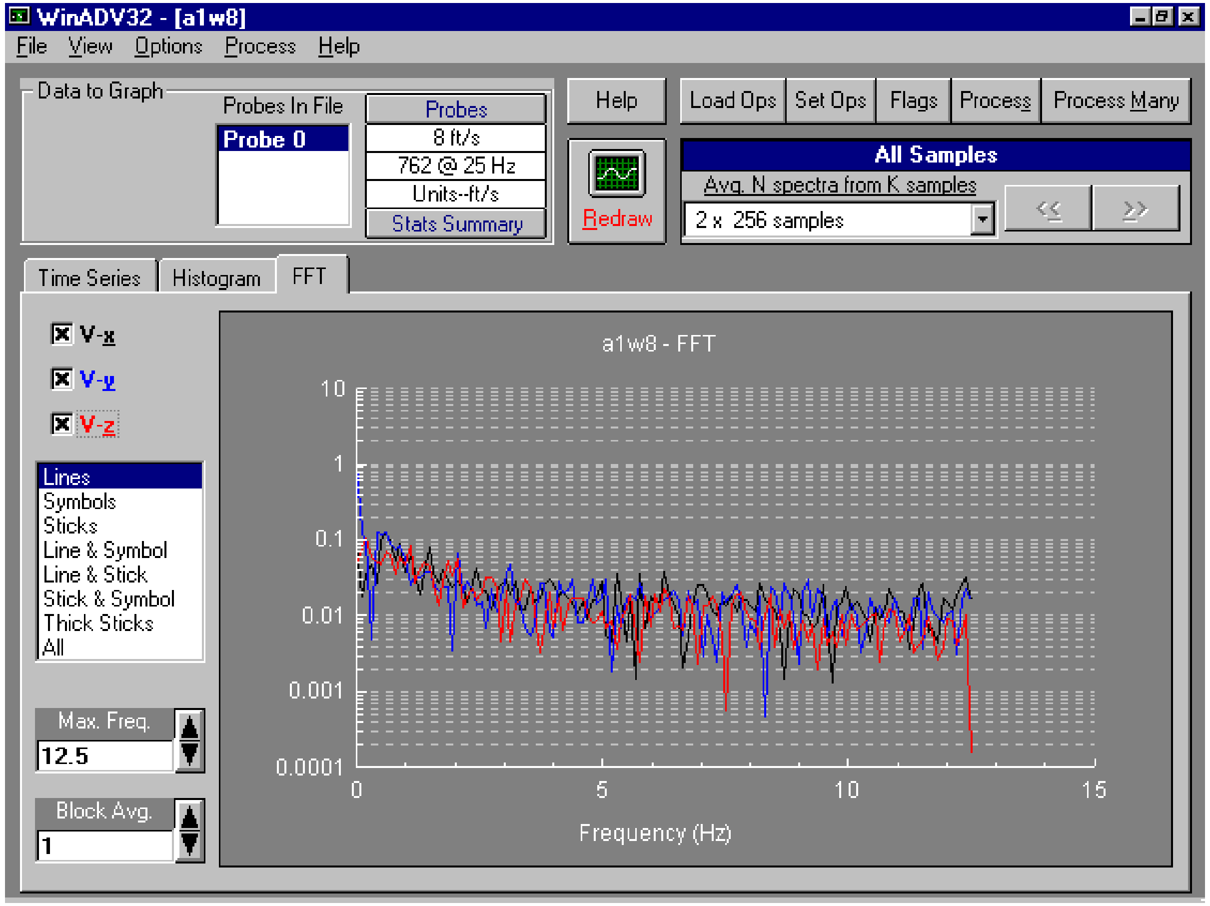

Fonte: http://**www.usbr.gov/**pmts/hydraulics_lab/twahl/winadv/wadv-ex.html

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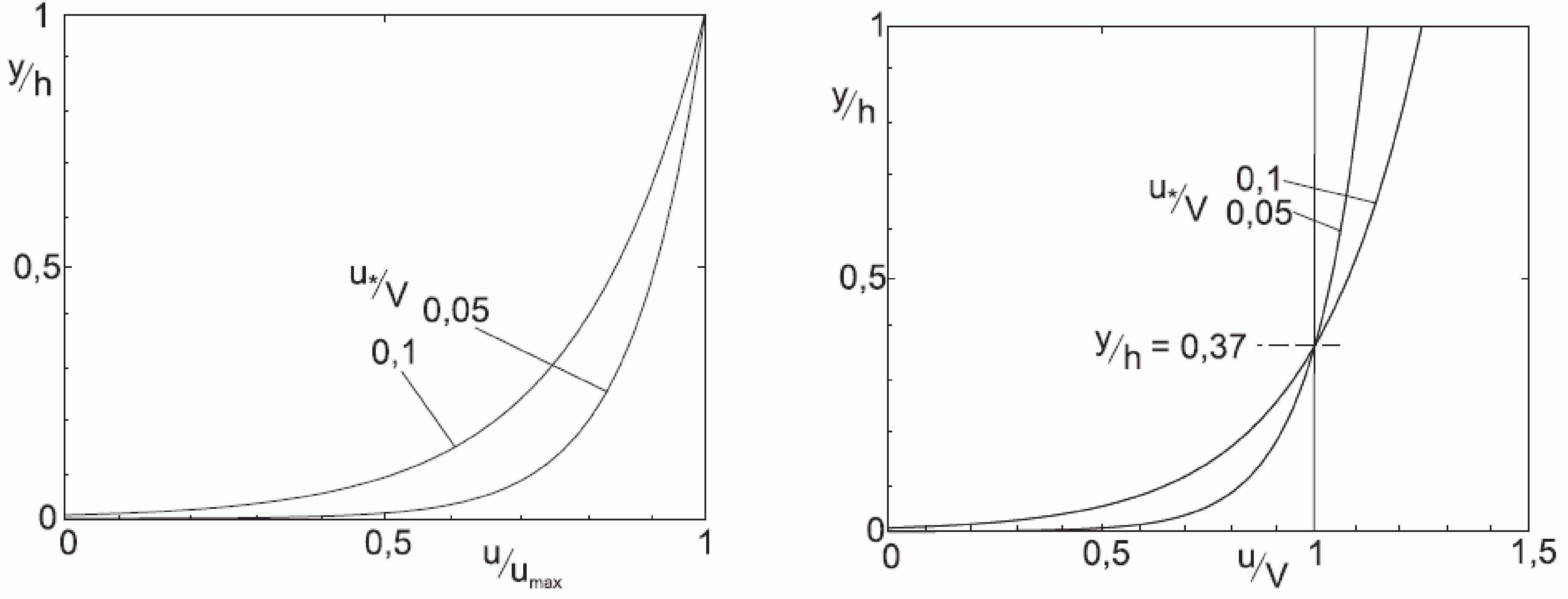
Perfil de velocidade



(a) Normalisiert mit $u_{\max}$

(b) Normalisiert mit V

Abb. 2.3: Logarithmisches Profil für turbulente breite Gerinneströmungen (vereinfachte Gl. (2.11)) normiert durch (a) maximale Geshwindigkeit $u_{\max}$ und (b) mittlere Geschwindigkeit V, in Abhängigkeit vom Turbulenzparameter u_*/V.

Fonte: Jirka e Lang, 2009

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Flutuações turbulentas

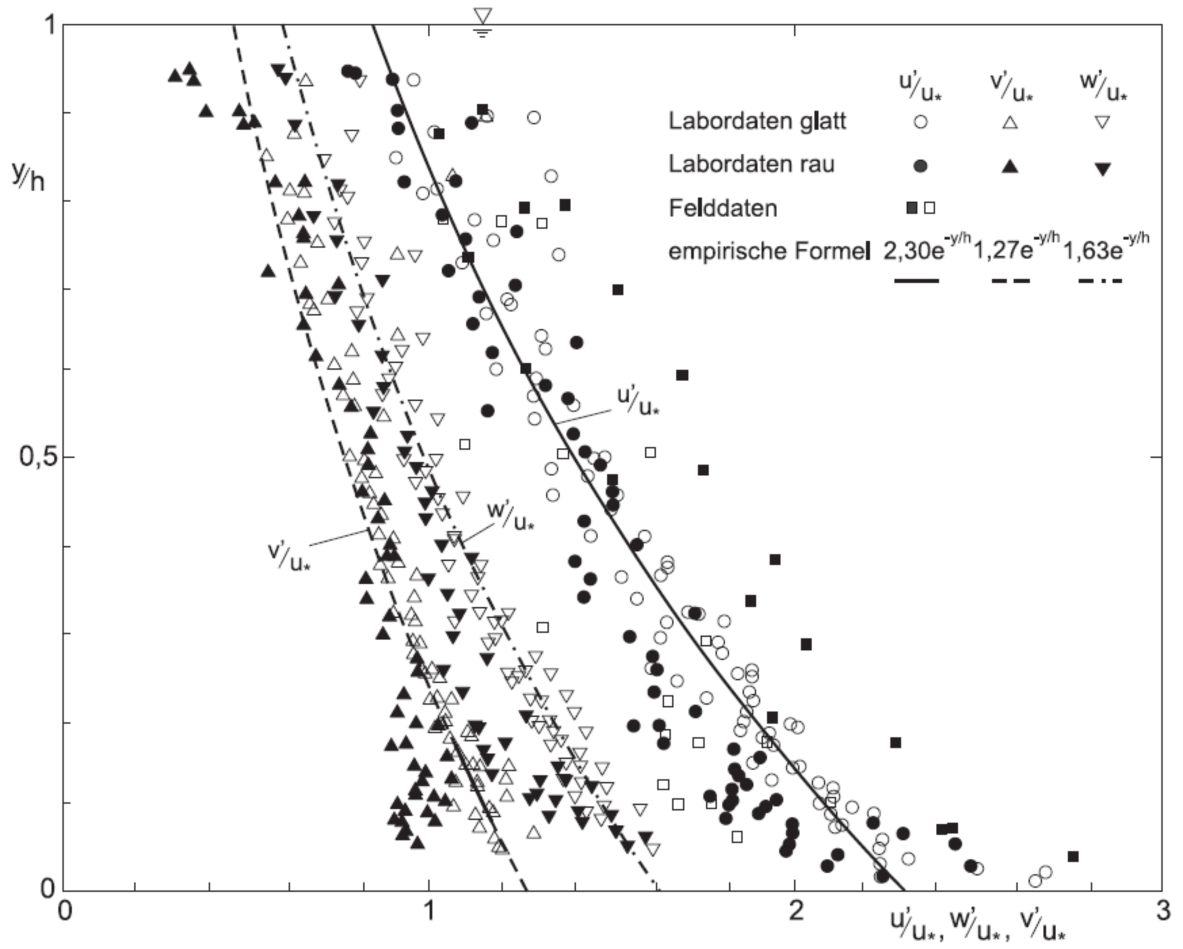

Abb. 2.4: Profile der Fluktuationsgeschwindigkeiten u', v' und w' normiert durch die Reibungsgeschwindigkeit u_* in turbulenten Gerinneströmungen (Daten nach Nezu und Nakagawa, 1993)

Jirka and Lang, 2009

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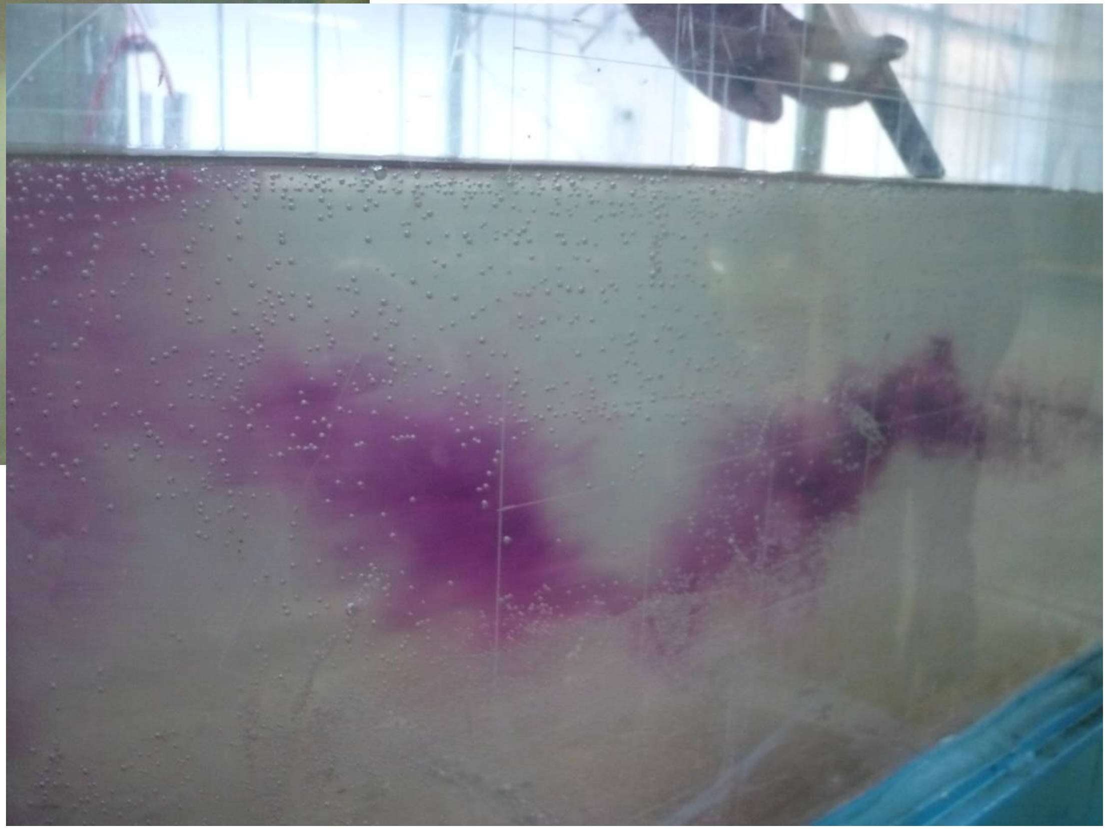
Visualização do escoamento e processos de mistura



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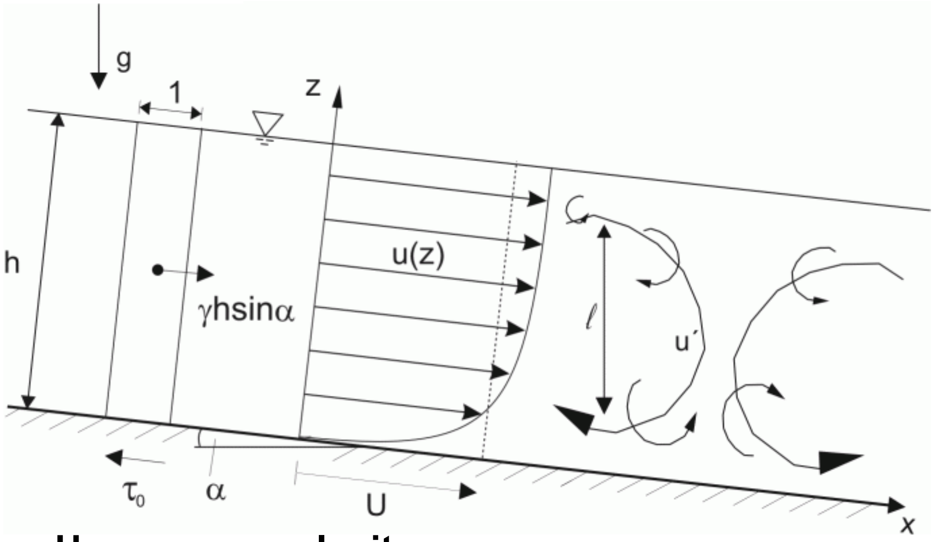
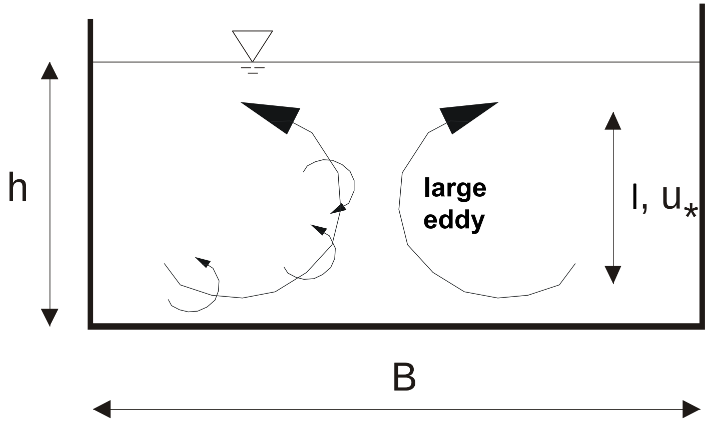
B) Turbulent Diffusion in river



U = average velocity



large river B/h > (5 - 10)

- Eddy generation due to roughness:

$\boldsymbol{\tau_0}$ = ρghsin$\alpha \approx \rho$ghI

I = slope $\approx$ sinα

$$\sqrt{\frac{\tau_0}{\rho}} = u_* = \sqrt{ghI}$$

$\mathbf{u_*}$ = $\sqrt{ghI}$, Friction velocity,

typical u_* = (0,05 – 0,1)U

- Turbulent eddy spectrum:

u´ = eddy velocity

l $\approx$ **h** = eddy size

- Duffusion analogy ($D_m \sim \lambda_m u_m$):

E $\approx$ h u_* turbulent Diffusivity [m²/s]
E = 0,1(+/-50%) u_* h for rivers

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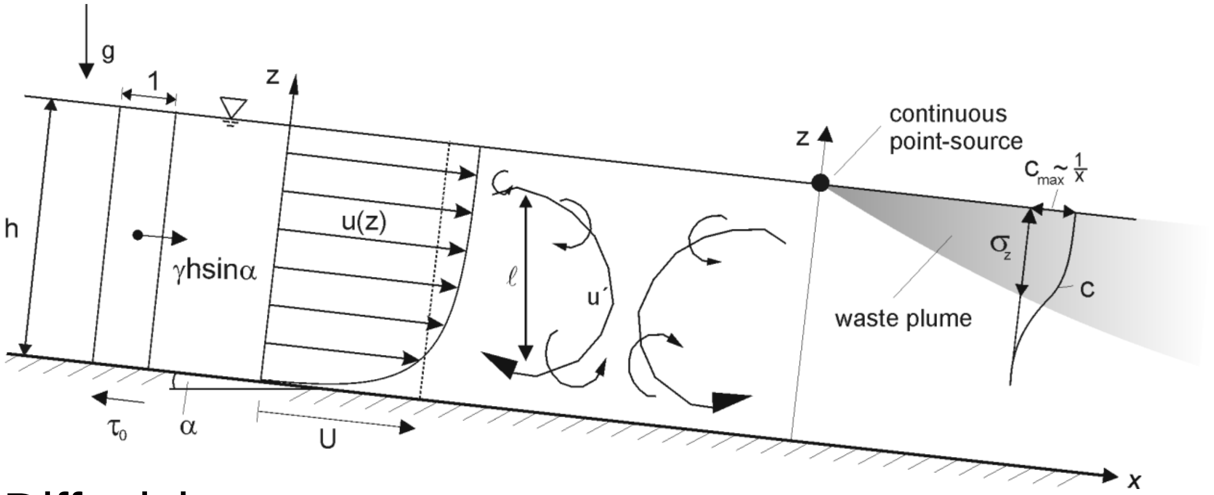
Vertical mixing (Advection + Diffusion)



- vertical Diffusivity: $E_z = \alpha_z u_* h$ $\alpha_z = 0{,}07$ +/- 50%
- vertical distribution: $\sigma_z = \sqrt{2E_z t} = \sqrt{2E_z \frac{x}{U}}$ **t = $\frac{x}{U}$ = „flowtime" (Advection)**
- Vertical passive mixing (method-of-images)

Mixing if $\sigma_z \approx h$, then $x = x_{MV}$

→ independent of velocity

→ morphology dominates!

$$x_{MV} \approx \frac{h^2 U}{2E} = \frac{h^2 U}{2(0{,}07 \underbrace{u_*}_{0{,}10U} h)} \approx 70h$$

0,10U

<u>Bsp. 1:</u> Rhein near Karlsruhe
B = 250m, h = 3m, U = 3m/s
x_{MV} = 70x3 = 210m ~fast!

<u>Bsp. 2:</u> Small river in Schwarzwald (Murg)
B = 5m, h = 0,5m
x_{MV} = 70x0,5 = 35m ~fast!

vertical mixing is fast process!

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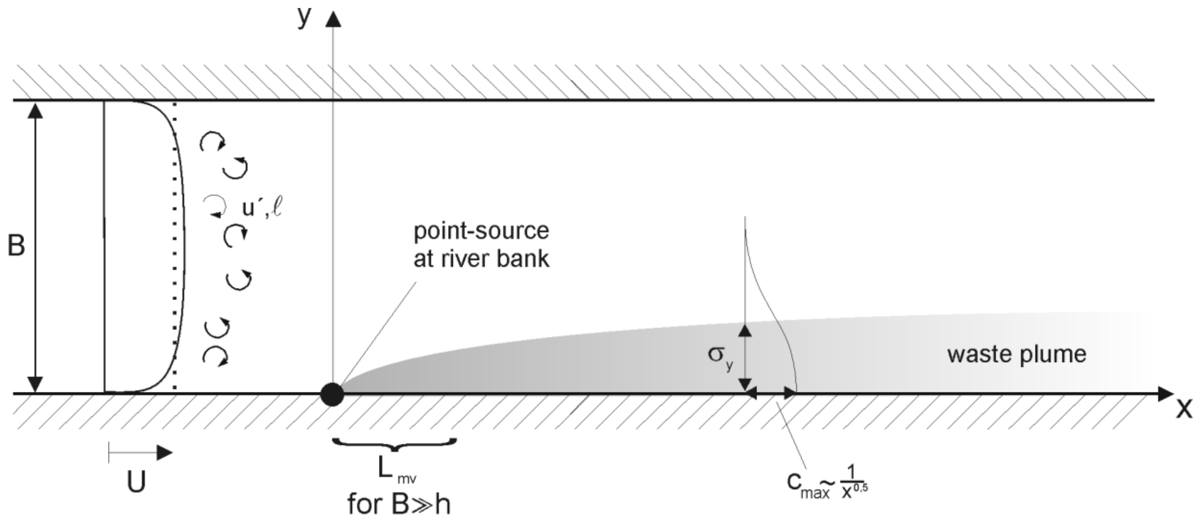
Lateral mixing (Advection + Diffusion)



- Horizontal Diffusivity: $E_y = \alpha_y u_* h$ α_z = 0,5 +/- 50%
  moderate heterogeneities
- Horizontal distribution: $\sigma_y = \sqrt{2E_y \frac{x}{U}}$
- Horizontal mixing (river bank)

Lateral mixing if $\sigma_y \approx B$, $x = x_{ML}$
→ independent of velocity
→ morphology dominates!

$$x_{ML} \approx \frac{B^2U}{2E} = \frac{B^2U}{2(0{,}5u_*h)} \approx 10\frac{B^2}{h}$$

0,10U

<u>Bsp. 1:</u> Rhein near Karlsruhe
$x_{ML} \approx 10x250^2/3$
= 208.000m ≈ 200km slow!

Bsp. 2: small river in Schwarzwald (Murg)
$x_{ML} \approx 10x5^2/0{,}5$
= 500m = 0,5km

lateral mixing is slow process!

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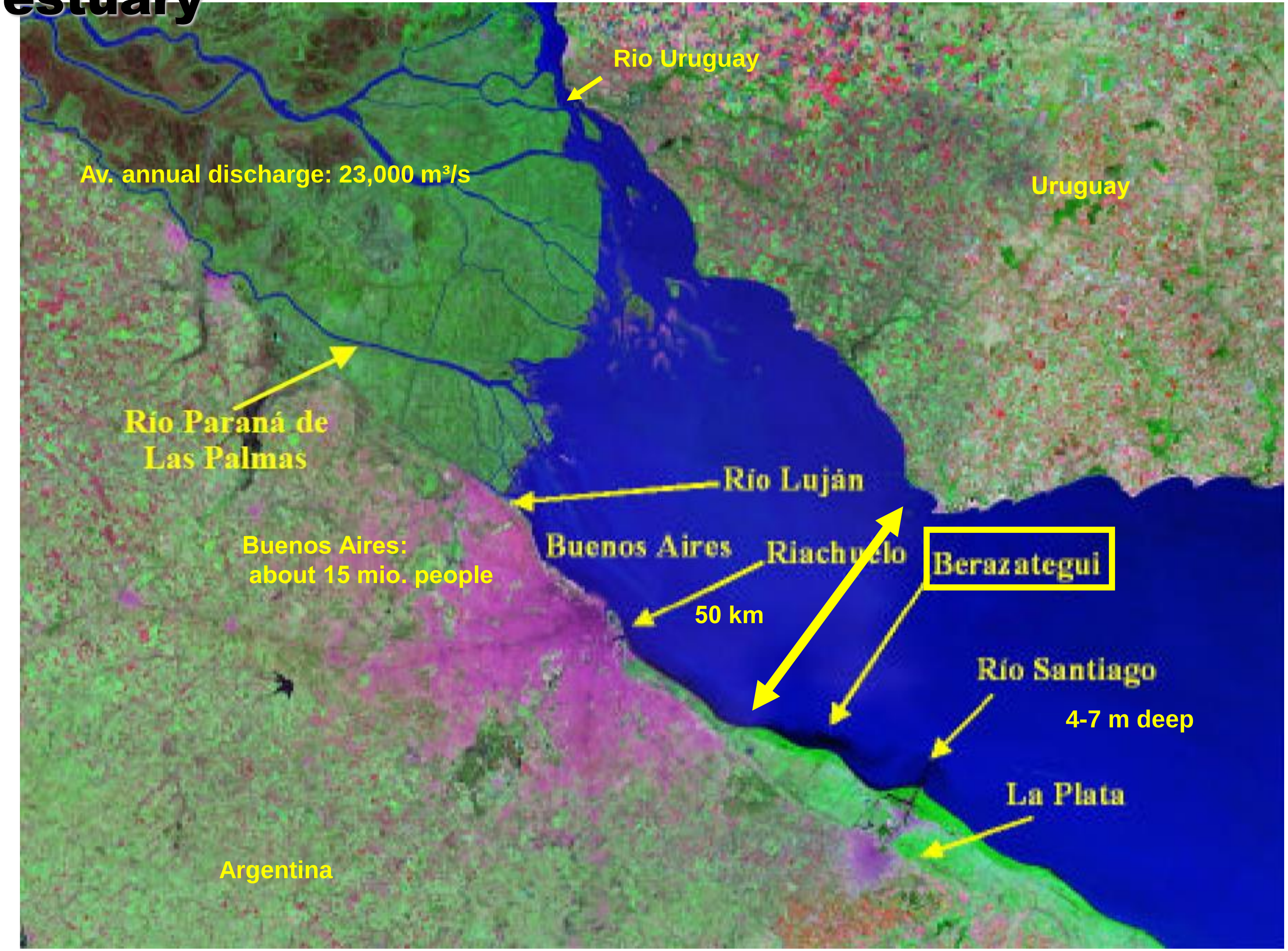
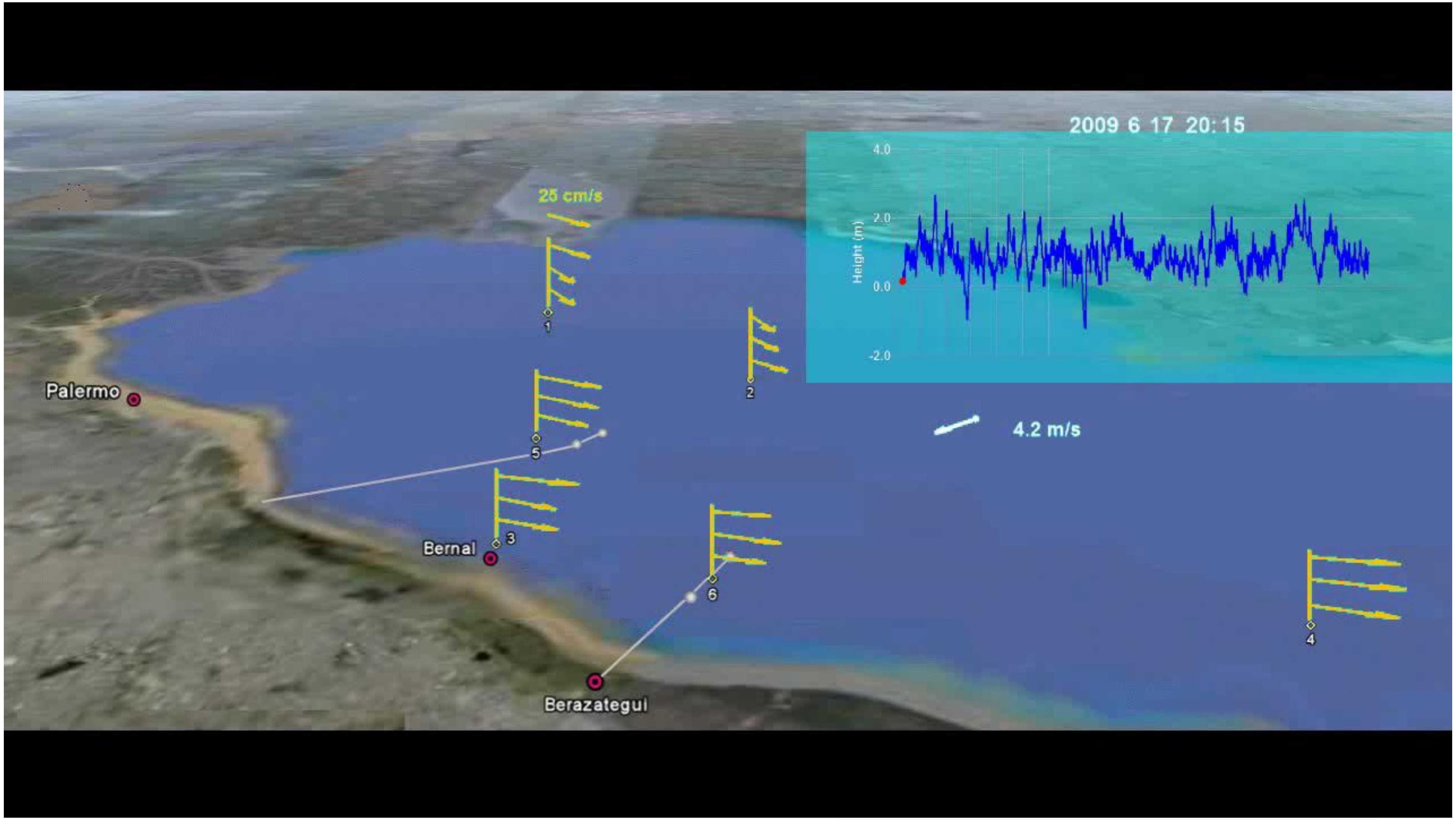
Rio de la Plata estuary



ADCP e vento



Courtesy: Phil Roberts, Georgia Tech

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Polar Scatter Diagrams of Currents

Courtesy: Phil Roberts, Georgia Tech

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GPS Drifter

Courtesy: Phil Roberts, Georgia Tech

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Drifter Experiment Riachuelo

Courtesy: Phil Roberts, Georgia Tech

Mathematical Model Domains

Courtesy: Phil Roberts, Georgia Tech

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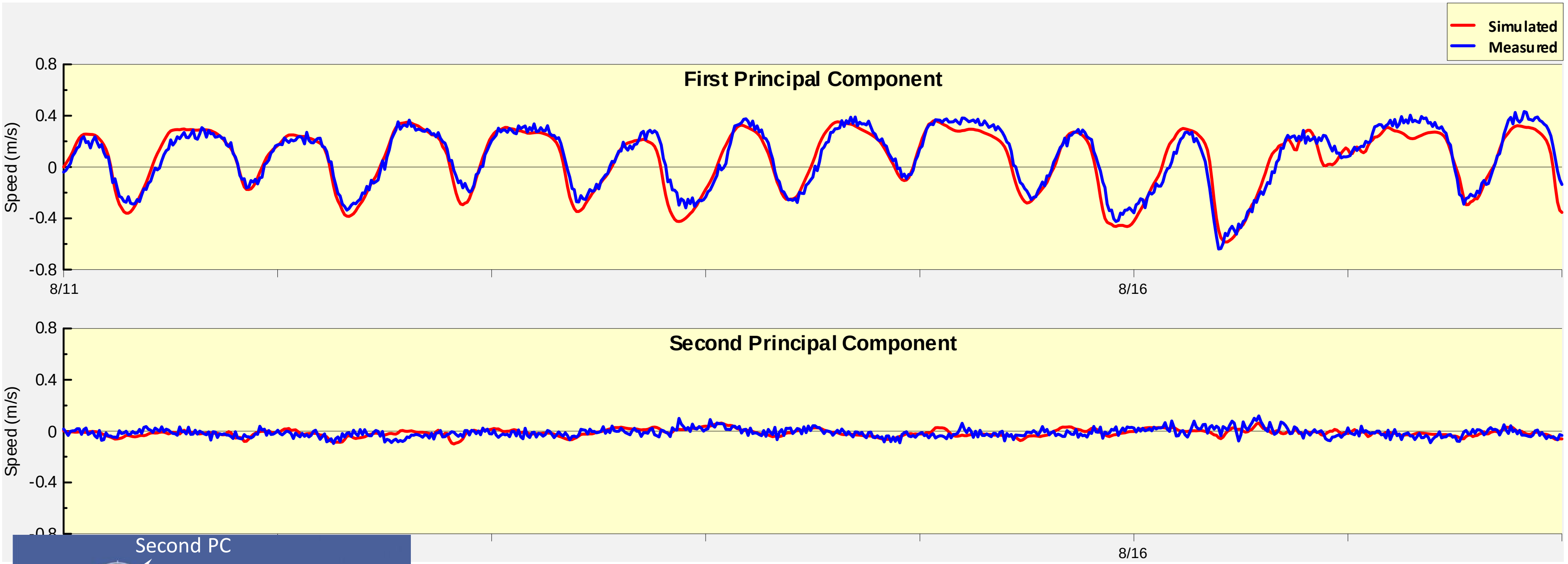
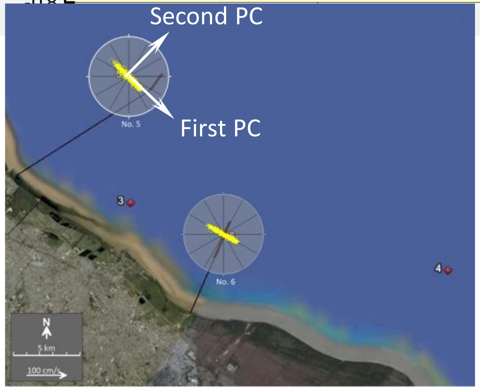
Model Comparisons with ADCP5





Courtesy: Phil Roberts, Georgia Tech

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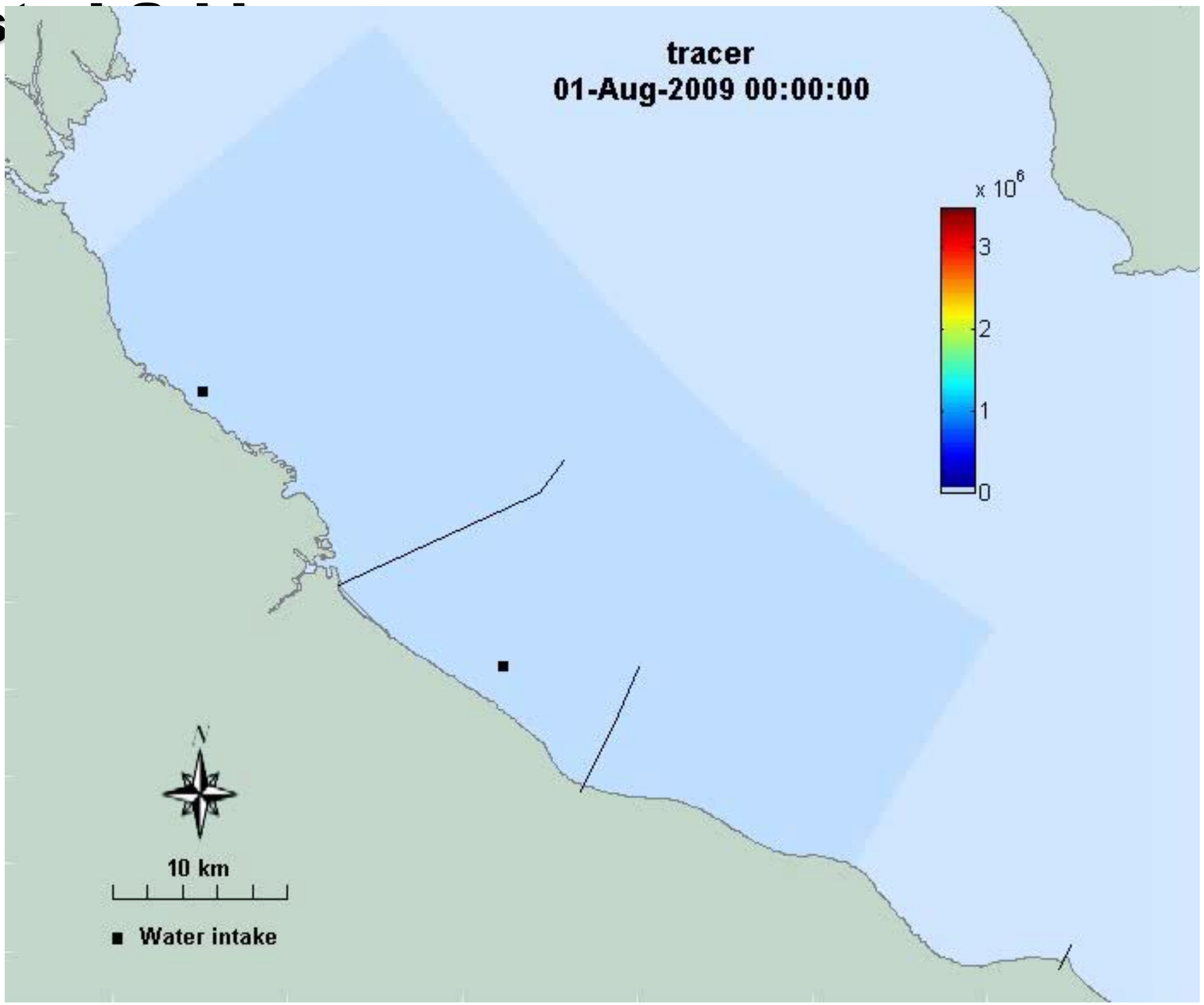
Simulation Results – Particle Tracking Model
Nes



Courtesy: Phil Roberts, Georgia Tech