JDD 2015 edspi

Numerical Modeling of Copepod's behavior in Turbulent Flows

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Mechanical Engineering

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25 Juin 2015 – Université d'Artois (FSA)

Université Lille Nord de France
Pôle de Recherche et d'Enseignement Supérieur

Laboratoire Mécanique Lille

Université d'Artois

Thesis title: Dynamics of *Copepods* in Turbulent Flows

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Participants:

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Doctoral Schools SMRE, Laboratoire d'Océanologie et de Géoscience (LOG), UMR 8187

Financial support:

Ministry of higher education and research fellowship, Bourse President Lille 1 for interdisciplinary subjects

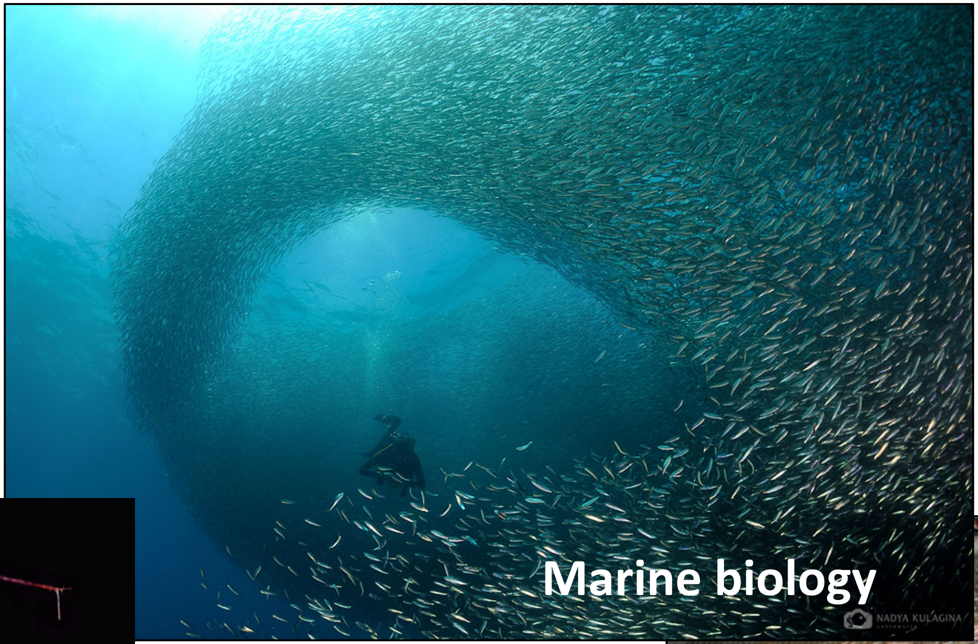
Outline:

- Motivation
- Introduction to Copepods
- Methods
- Analysis
- Perspective

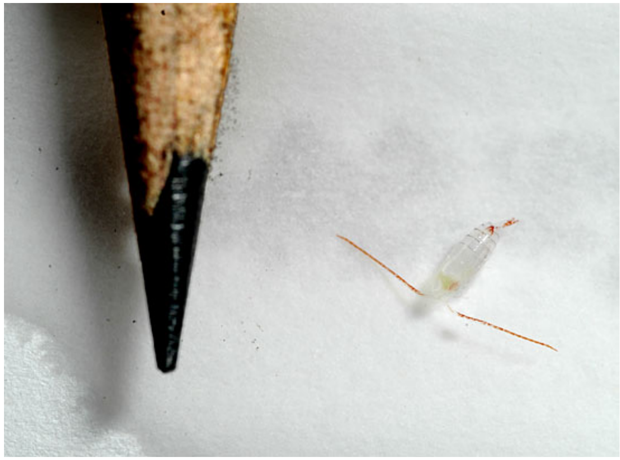
Motivation!

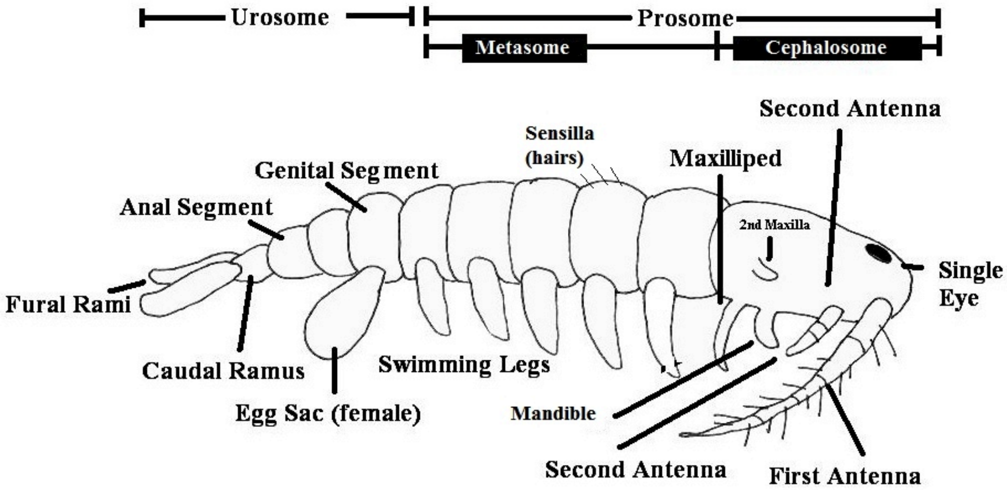
- Important link in the food chain
- Most numerous crustaceans in the ocean

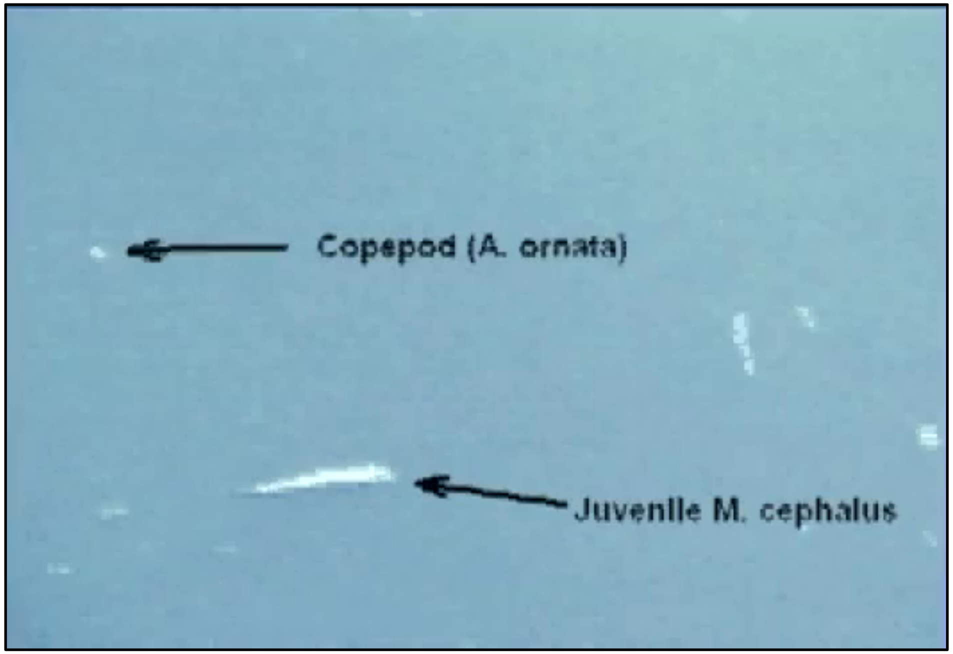
- Fishery Industry
- Better understanding the oceanic life



What are copepods?



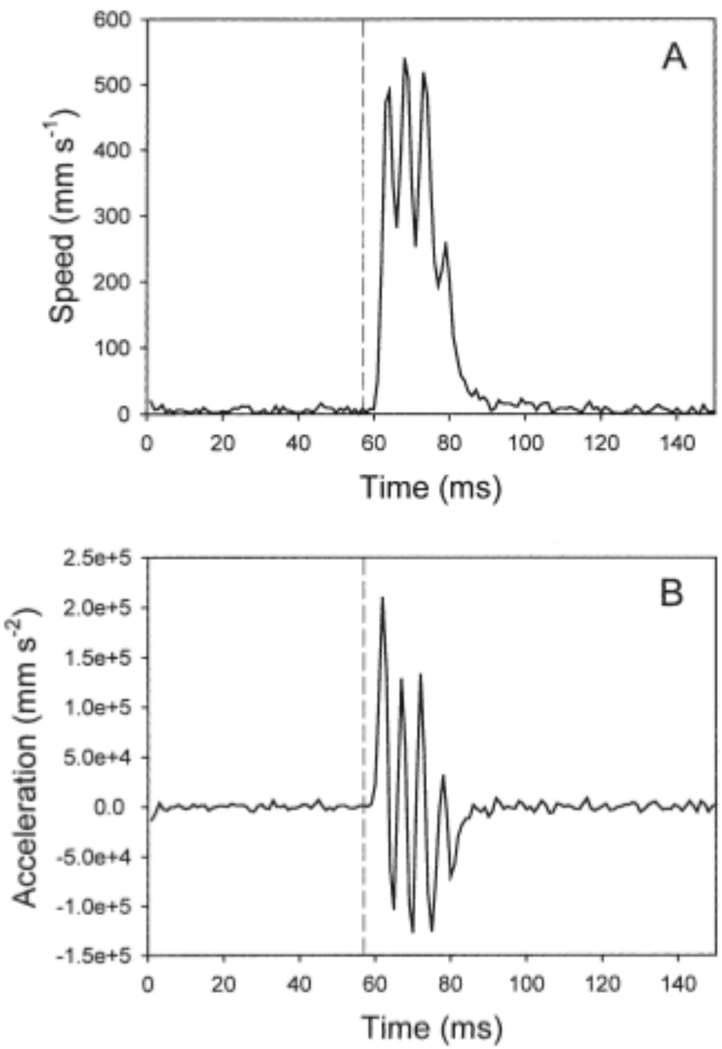




Copepods cultures at LOG Lab in Wimereux

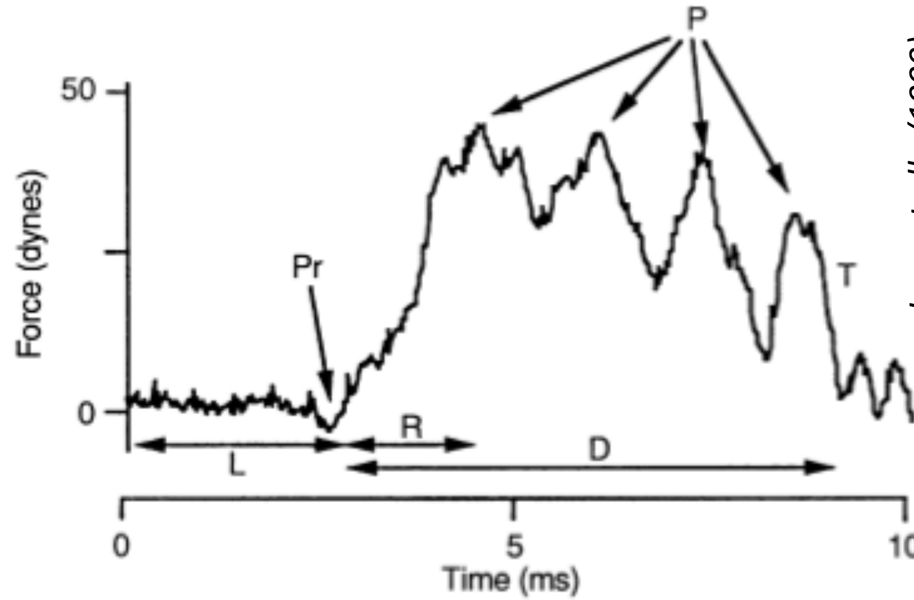
Response to Stimulus

Acartia tonsa: The stimulus occurred 3 (ms) before the initiation of the escape response (dashed line)



Buskey et all., (2002)

Response parameters



Lenz et all., (1999)

Undinula vulgaris giesbrechti response

L: latency to forward propulsion

Pr: preparation

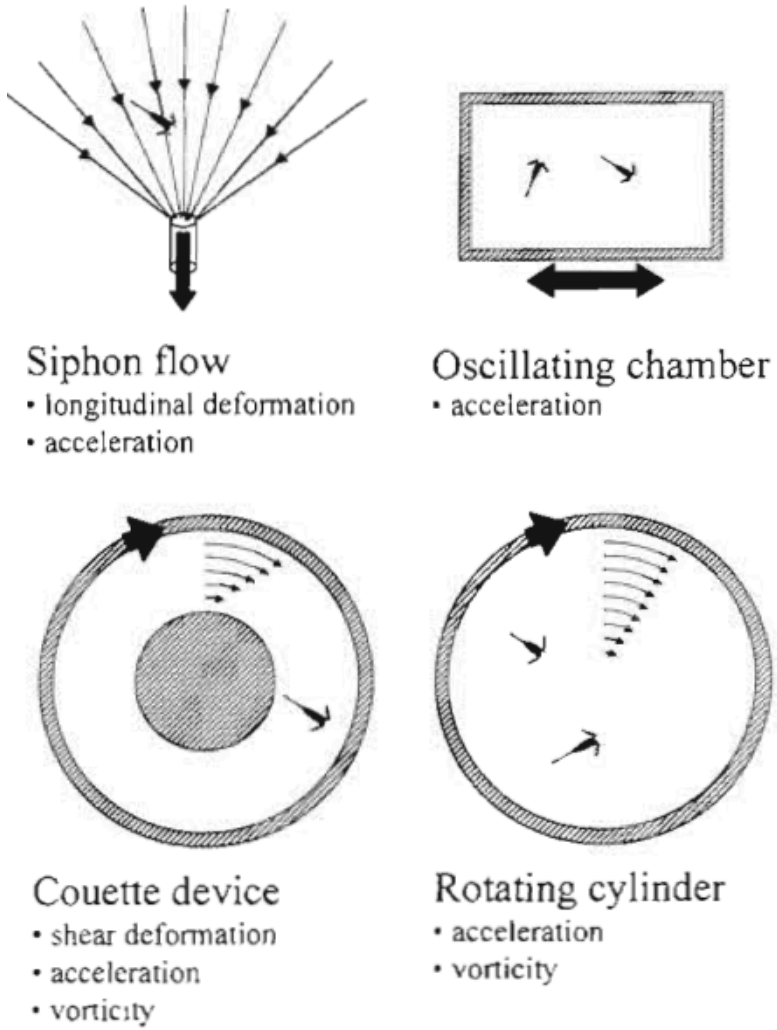
R: rise

P: force peaks

D: kick (power strokes) duration

T: termination

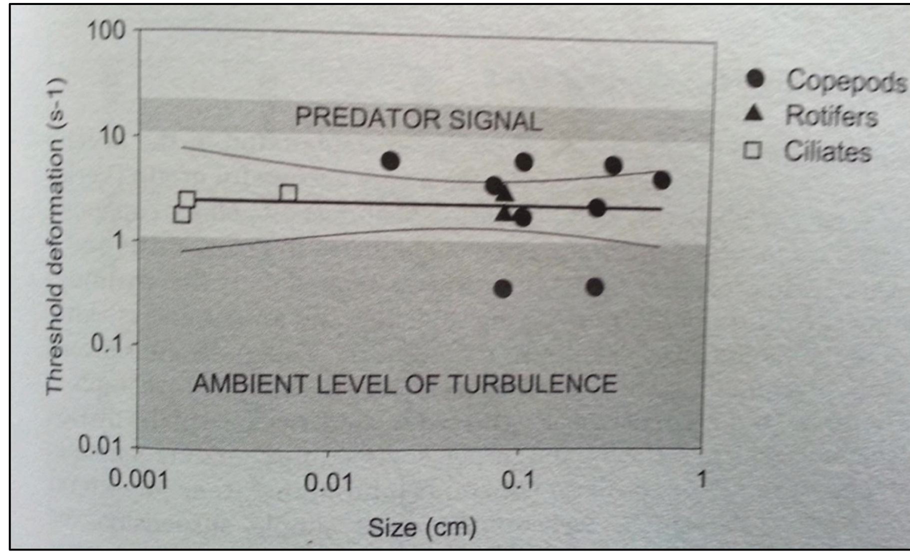
Component of the flow?



Kiorboe et all., (1999)

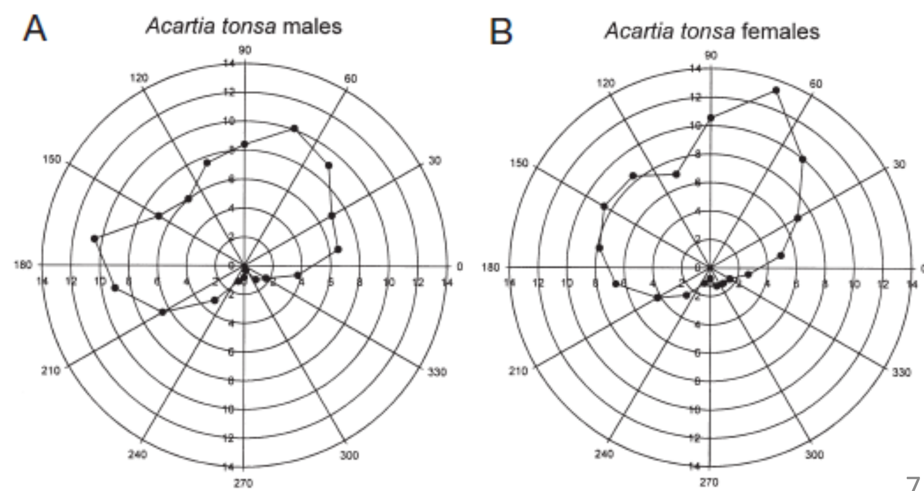
Copepods react to deformation rate

Thresholds



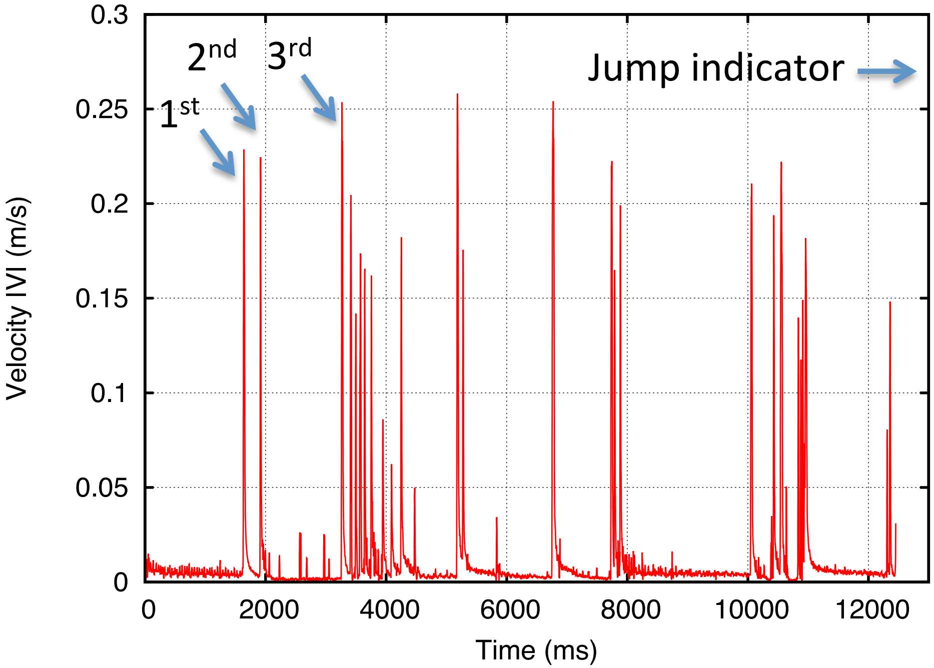
Kiorboe, A Mechanistic Approach to Plankton Ecology, (2008)

Direction of Escape?



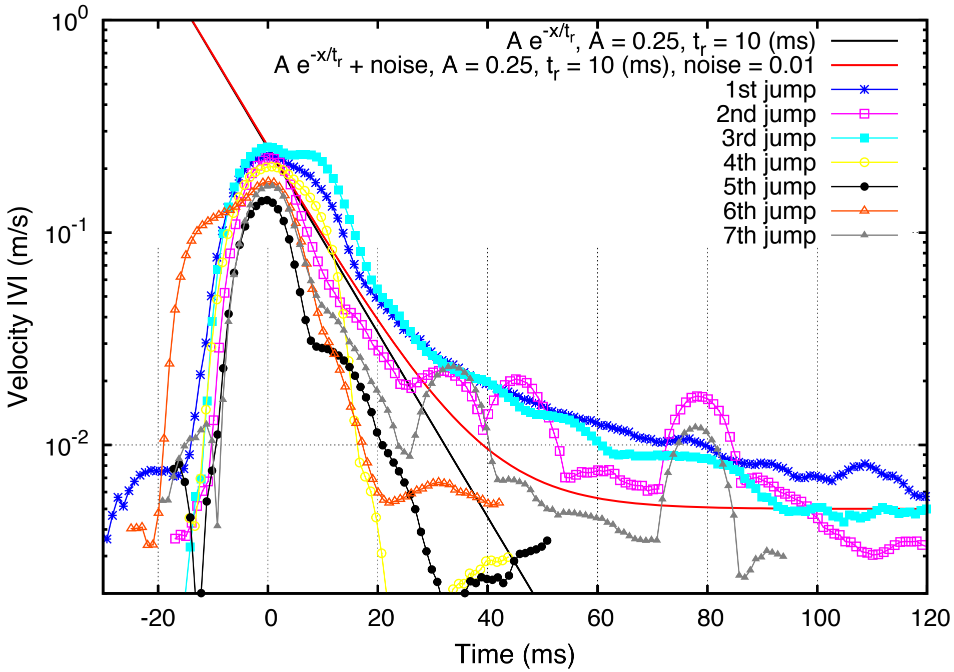
Buskey et all., (2002)

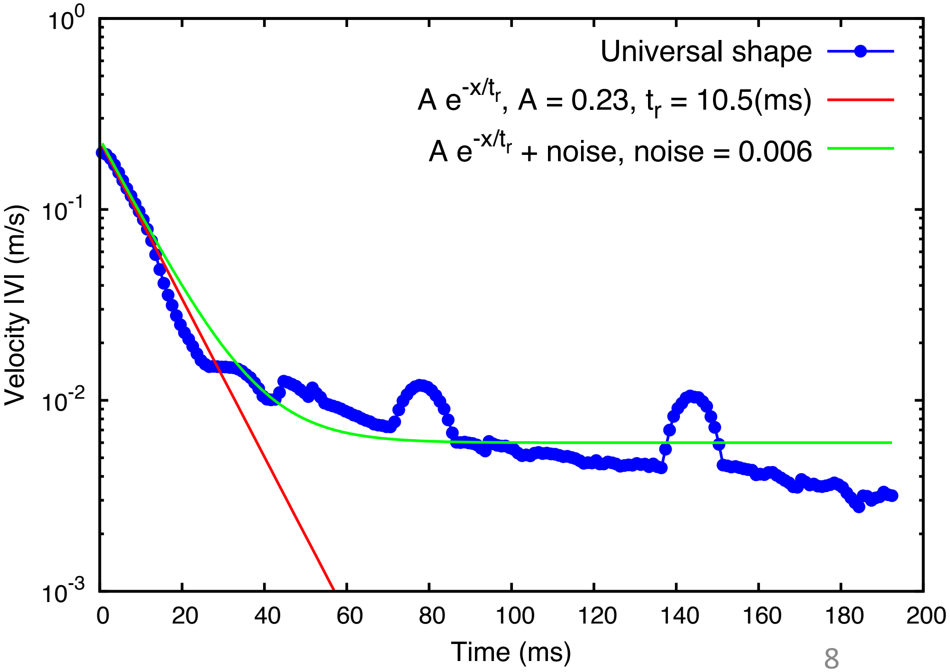
Lagrangian model



Response of copepods in still water,
Data collected by **Ibtissem Benkeddad**
at LOG, Wimereux

Jumps superposed by considering
their peak as a reference.





Lagrangian model

Modified Chlamydomonas model

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{v} + u_s \boldsymbol{p}$$

- $\boldsymbol{v}$ Fluid velocity
- u_s Slipping velocity
- $\boldsymbol{p}$ Direction of motion

$$u_s(t) = u_F + u_J \; e^{-(t-t_0)/\tau_J}$$

Foraging velocity (u_F) Jumping velocity (u_J)

PARAMETER	UNIT	RANGE OF VALUES		VALUE
ν	$m^2 s^{-1}$	$O(10^{-6})$		10^{-6}
ϵ	$m^2 s^{-3}$	10^{-8}	10^{-4}	10^{-6}
η	m	3×10^{-3}	3×10^{-4}	10^{-3}
τ_η	s	10	0.1	1
u_η	ms^{-1}	3×10^{-4}	3×10^{-3}	10^{-3}
Re_λ	–	$O(10^2)$		

Properties of the ocean water

Dimensionless control parameters

$$\frac{u_J}{u_\eta} \qquad \frac{\tau_J}{\tau_\eta}$$

$$S_{threshold} \times \tau_\eta$$

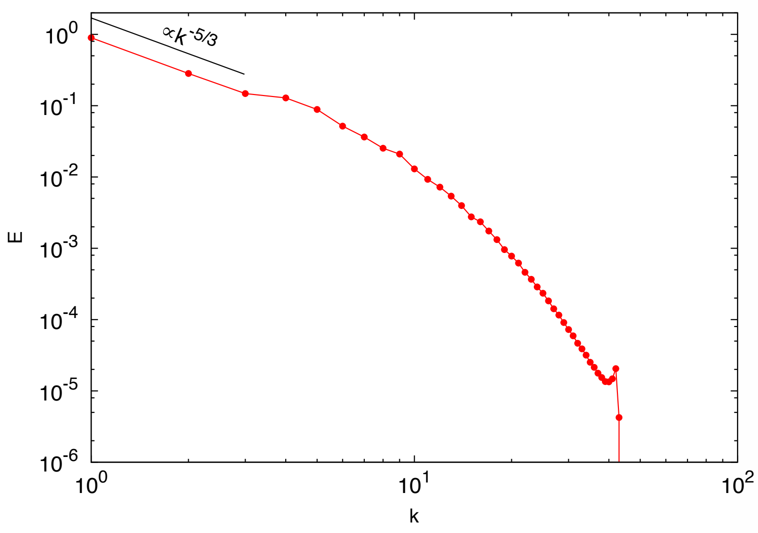
Methods

Eulerian - Lagrangian

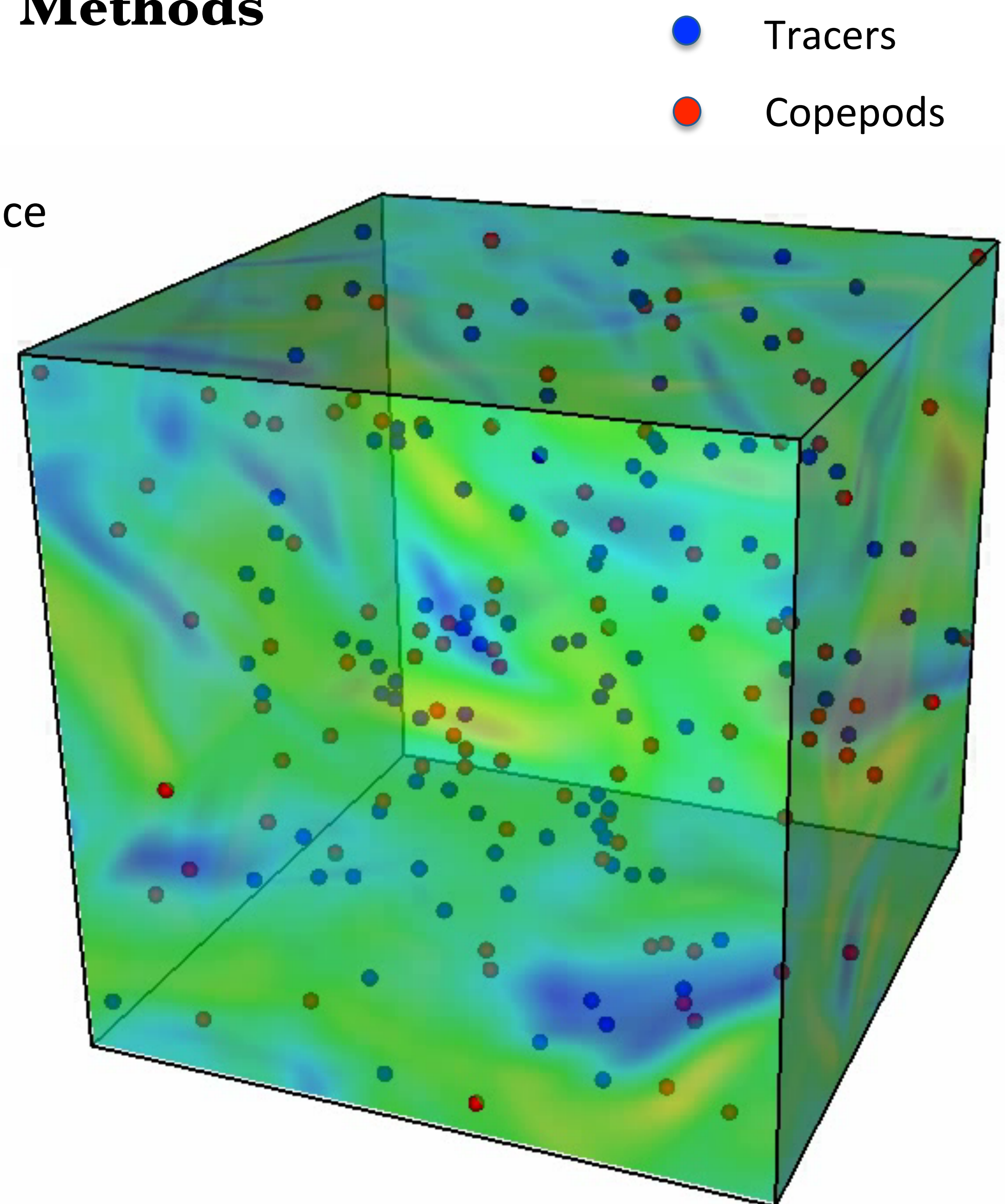
Homogeneous Isotropic Turbulence

$$\partial_t \mathbf{u} + (\mathbf{u} \cdot \nabla)\mathbf{u} = -\nabla P + \nu \nabla^2 \mathbf{u}$$

$$\nabla \cdot u = 0$$

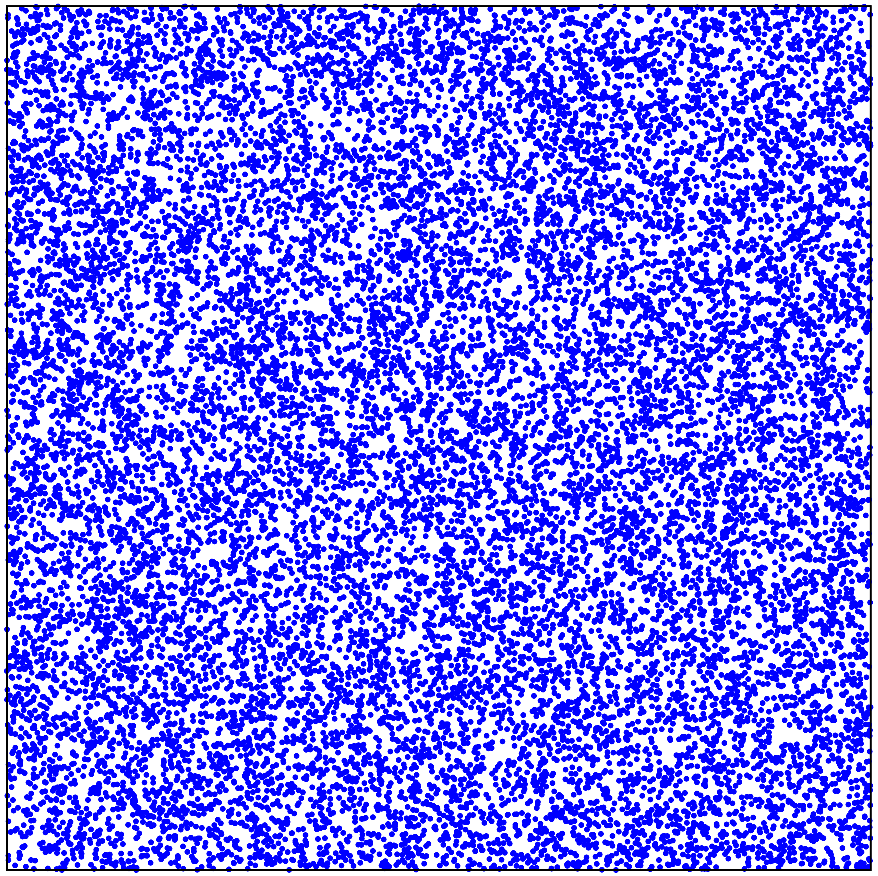


Spectral Method

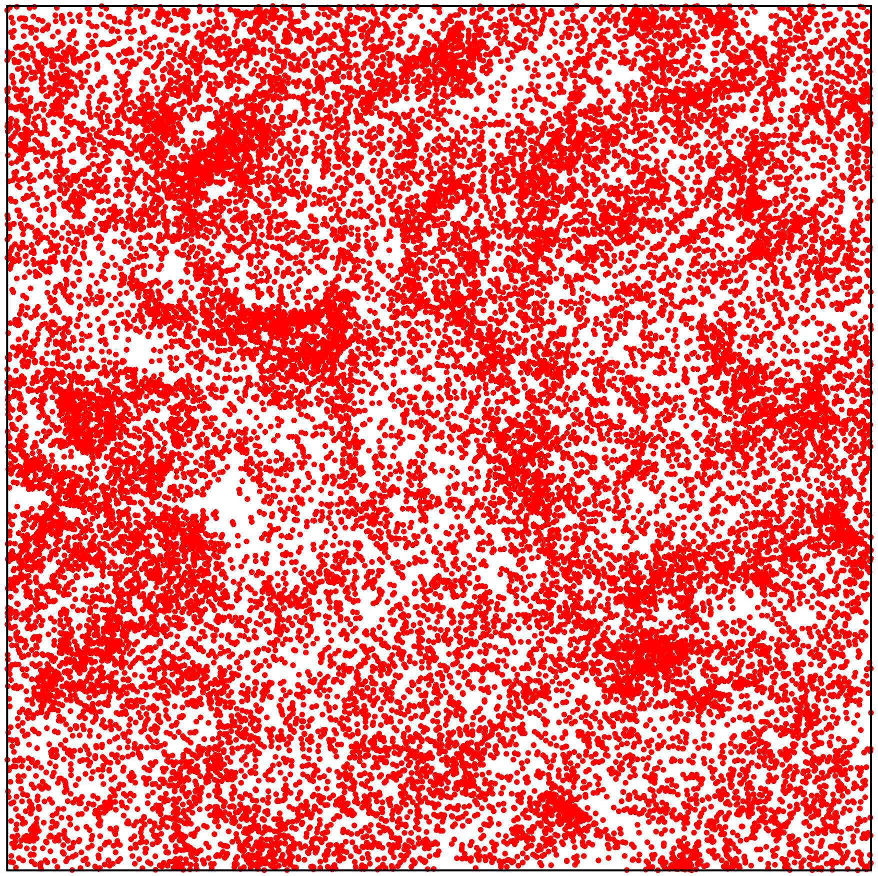


Analysis

Tracers



Copepods



Patchiness

Analysis

Quantifying spatial distribution of the copepods : Fractal dimension D_2

The **Grassberger-Procaccia** Algorithm:

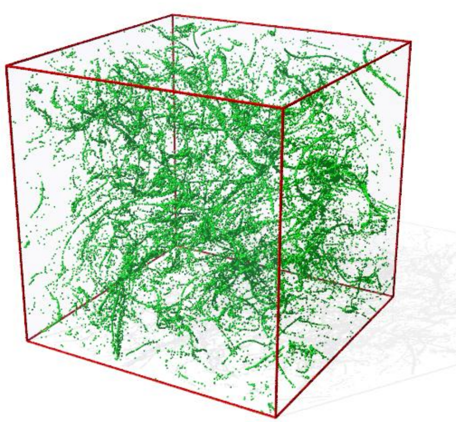
$$\hat{C}(r) = \frac{2}{N(N-1)} \sum_{i<j} \theta(r - |\mathbf{x}_i - \mathbf{x}_j|)$$

$\theta(x)$ is Heaviside step function

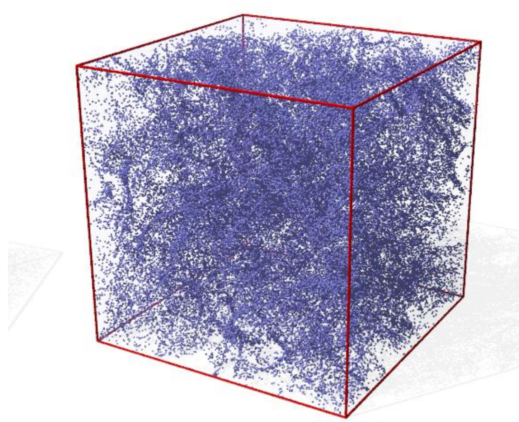
Monotonically decreasing like power law $C(r) \sim r^D$ as $r \to 0$

Probability to find a couple of particle whose distance is below r

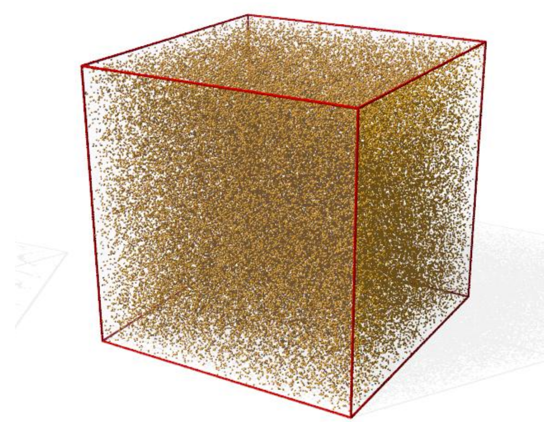
$$D = \lim_{r\to 0} \frac{\log C(r)}{\log r}$$



$D_2 \approx 1$



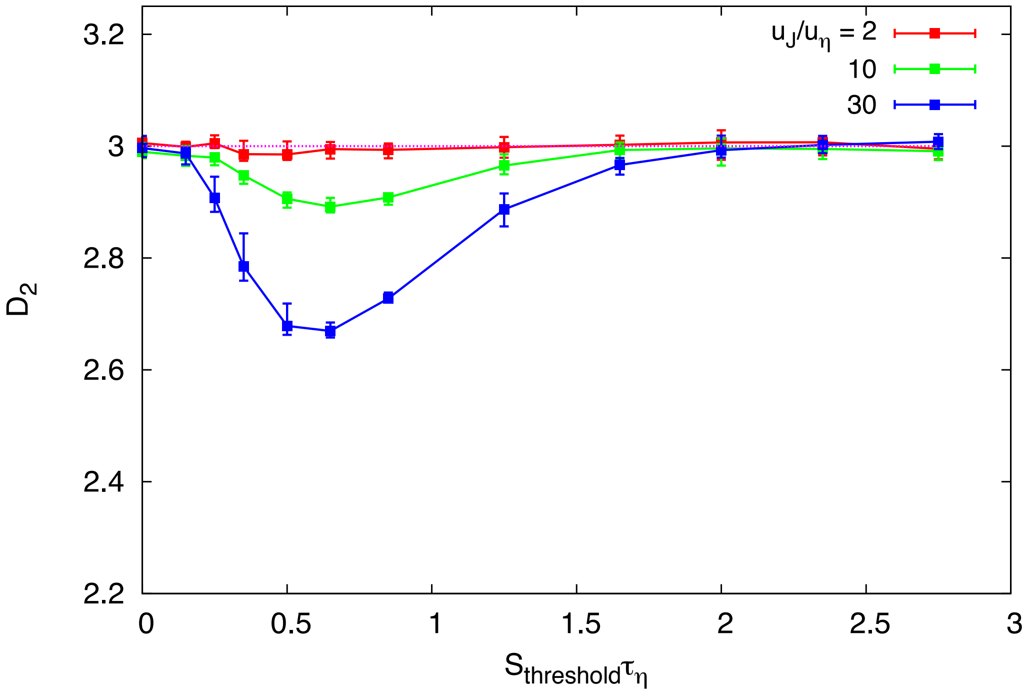
$D_2 \approx 2$



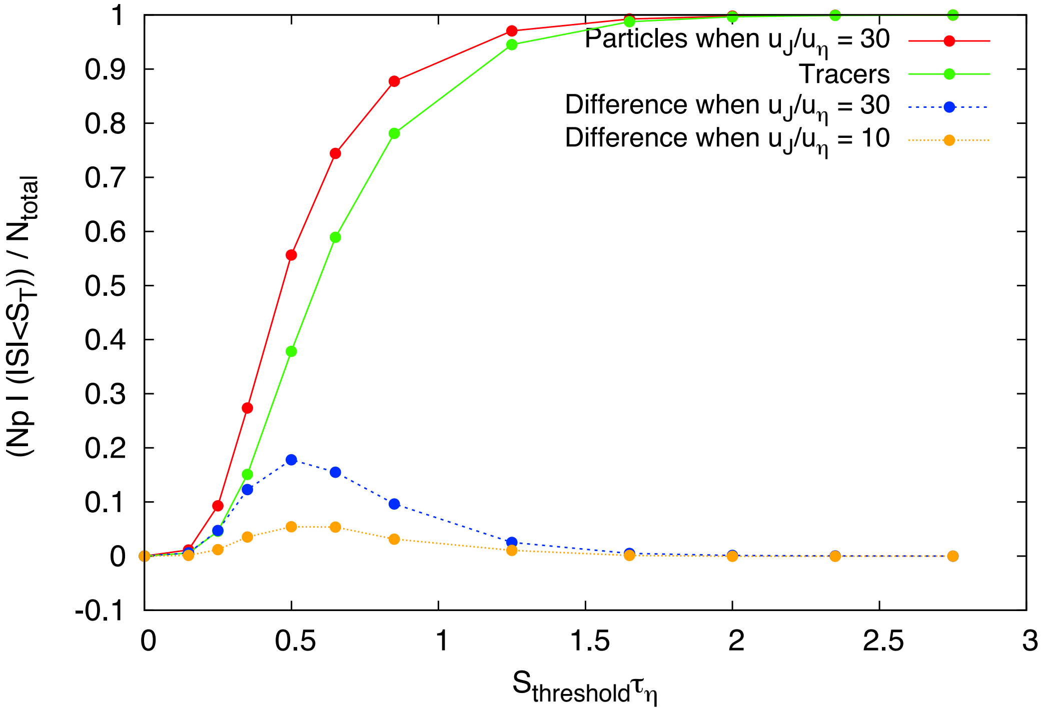
$D_2 = 3$

Maxey JFM87, Squires & Eaton PF91, Fessler Eaton IJMF94

Analysis

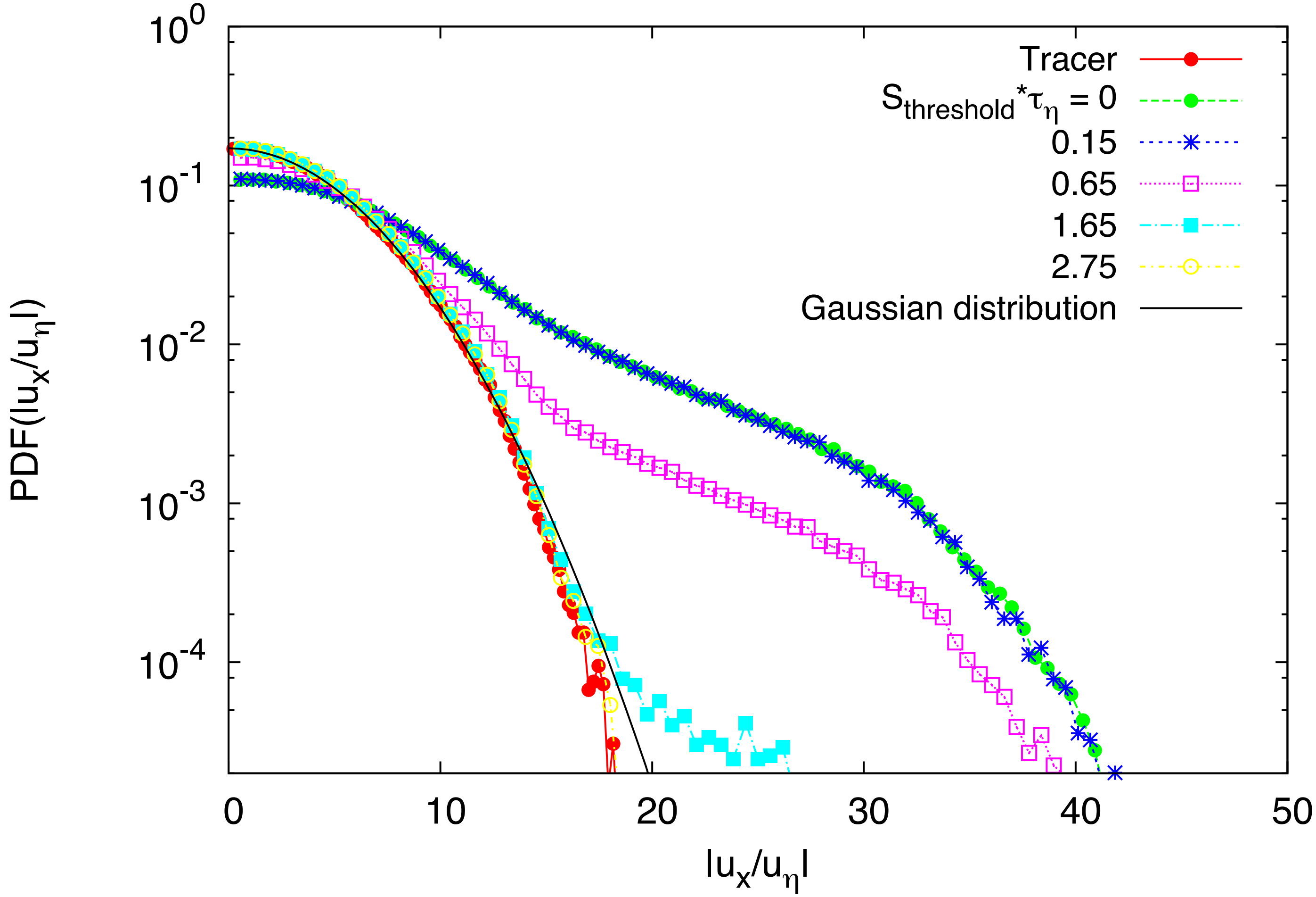


Fractal dimension estimation as a function of the threshold value of the strain rate



Efficiency of the jump by considering the number of particles

Analysis

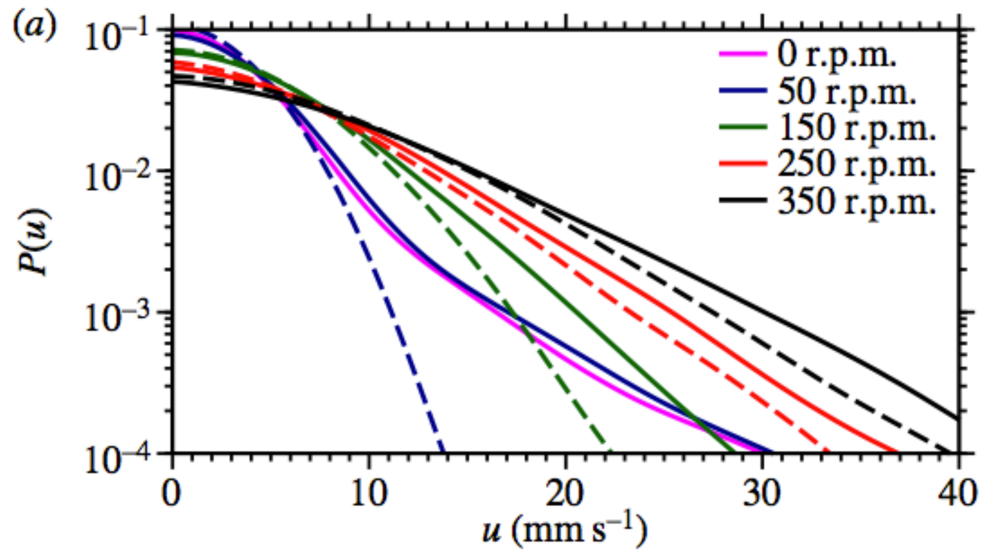


PDF of absolute value of single component velocity

Perspective

Collaboration with **Institute of Environmental Engineering ETH Zurich,** Switzerland

François-Gaël Michalec, **Markus Holzner**



- Tune the model's parameters
- Predict the behavior

Thank you!