LIÈGE université
Sciences Appliquées

On the quest for victims of drowning

Joining forces of flow modelling and forensic medical expertise to speed up body recovery after drowning in urban rivers

Clément Delhez

hece
Hydraulics in environmental and civil engineering

Drowning is a leading killer

Monde

372 000
personnes meurent noyées
CHAQUE ANNÉE

France

1 000
décès/an

la noyade, tous lieux confondus, est la première cause de mortalité accidentelle chez les moins de 25 ans.

Les 12-25 ans

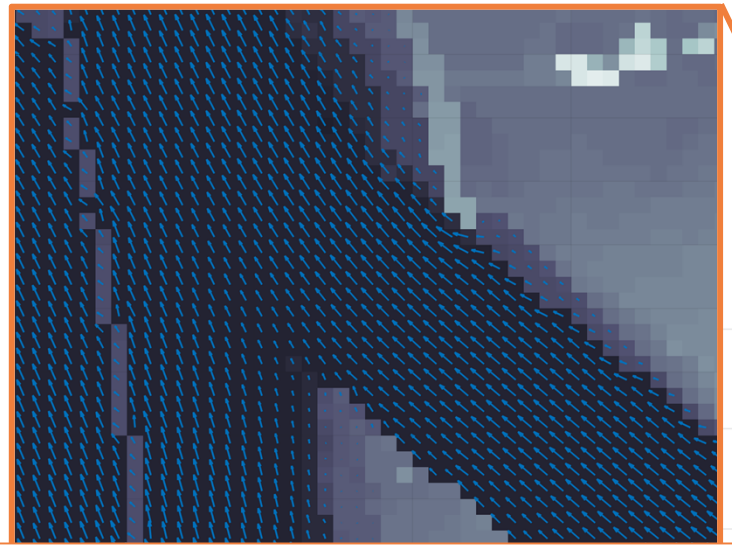
sont les plus touchés par les accidents de baignade sur le réseau fluvial.

40 %
des noyades

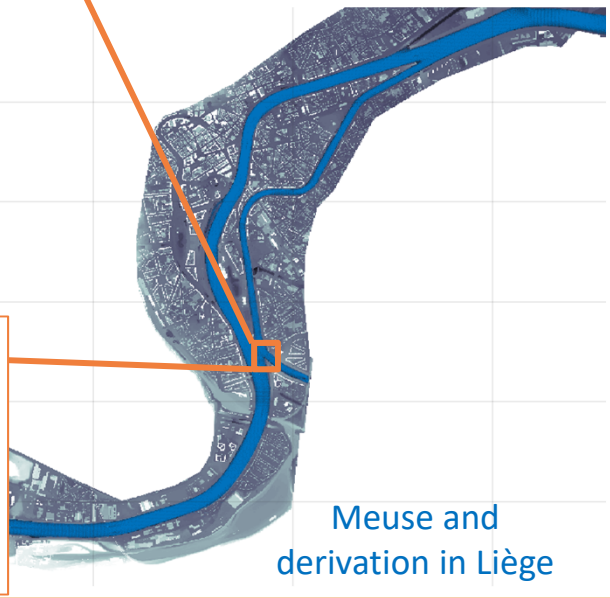
ont lieu dans les cours d'eau ou les plans d'eau.

(source : VNF)

Drowning is a leading killer



Detailed velocity fields, available at high spatial resolution, on over 1200 km of rivers in the Walloon Region



Meuse and derivation in Liège

OBJECTIVES

- ↗ chances of survival (< 1 to 2 h)
- ↘ risks faced by the stakeholders
- ↘ human and material cost
- ↘ waiting time for the relatives
- \+ facilitate judicial investigations

No similar study in urban river

	Marine environment
Horizontal motion	✓
Body geometry	✗
Vertical motion	✗
Decomposition effects	✗

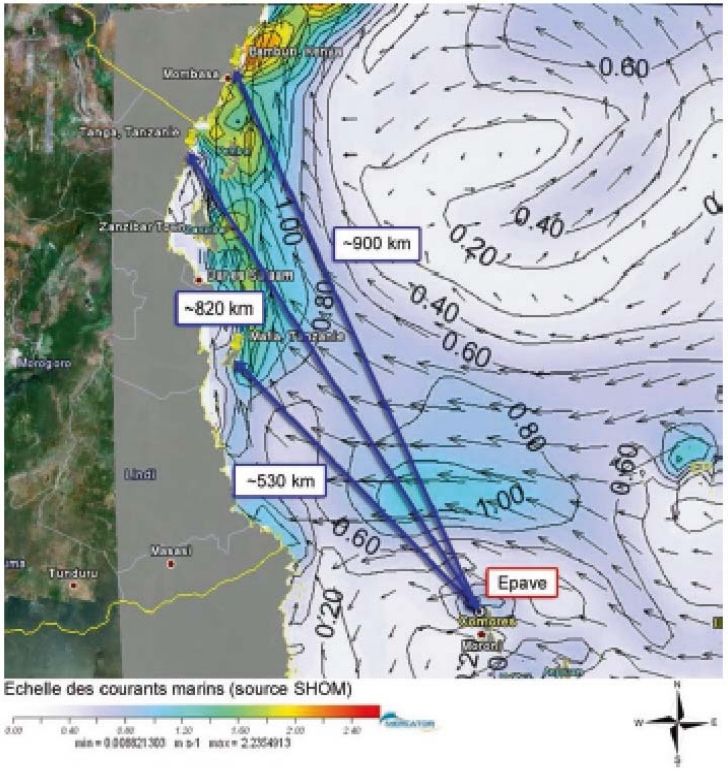


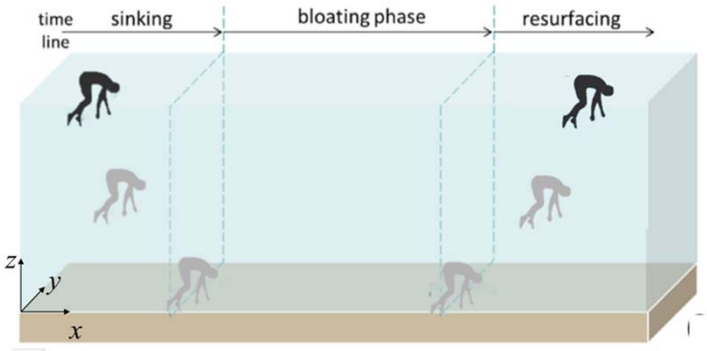
Fig. 9.1 Reconstruction of the drift of the debris and human remains from the Yemenia airplane crash (29th June 2009) with regard to the ocean currents (Commission d'Enquête 2013). Legend "Epave" = wreck, "Comores" = Comoros, "Echelle des courants marins" = scale of marine currents

Carniel et al. (2002)
Megyesi et al. (2005)
Heaton et al. (2010)
Matheus et al. (2013)

No similar study in urban river

	Marine environment	*Forensic medicine*
Horizontal motion	✓	✗
Body geometry	✗	✗
Vertical motion	✗	✓
Decomposition effects	✗	✓

Carniel et al. (2002) *Matheus et al. (2013)*



The degree of decomposition of the body can be predicted based on the concept of *accumulated degree day* (*ADD*) :

$$ADD = \int T\, dt$$

Time

Temperature

No similar study in urban river

	Marine environment	*Forensic medicine*	Debris, driftwood
Horizontal motion	✓	✗	✓
Body geometry	✗	✗	✓
Vertical motion	✗	✓	✗
Decomposition effects	✗	✓	✗
	Carniel et al. (2002)	*Matheus et al. (2013)*	*Persi (2018)*

Mathematical model • numeric • stochastic

	Marine environment	*Forensic medicine*	Debris, driftwood	Thesis
Horizontal motion	✓	✗	✓	✓
Body geometry	✗	✗	✓	✓
Vertical motion	✗	✓	✗	✓
Decomposition effects	✗	✓	✗	✓
	Carniel et al. (2002)	*Matheus et al. (2013)*	*Persi (2018)*	

Existing work on the subject

M. Rozendaal (2018):

Investigation of the assumptions made by particle models for drifting human bodies

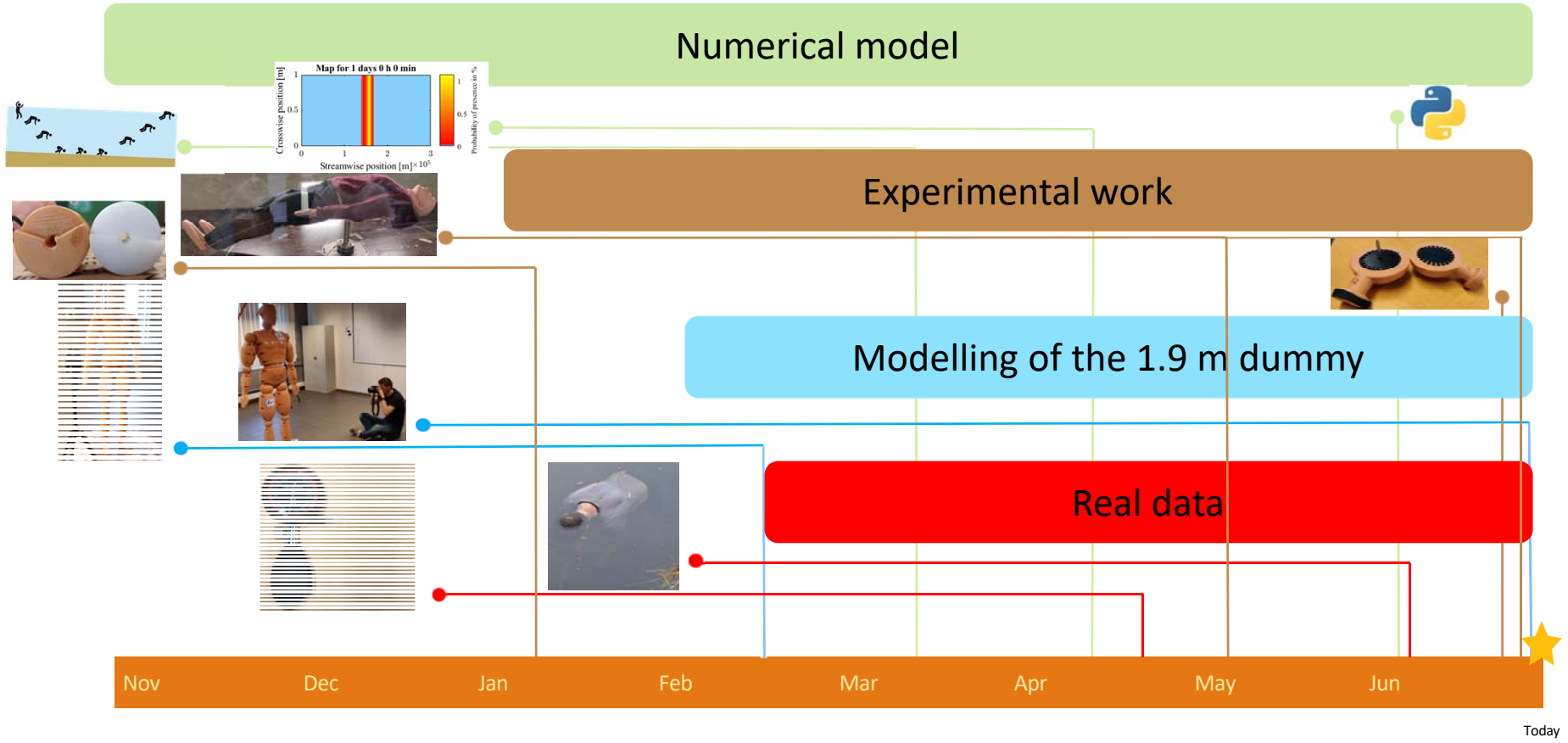
- Internship report
- Designed to guide further research
- Marine environment

L. Pérez & A. Guatame (Ongoing):

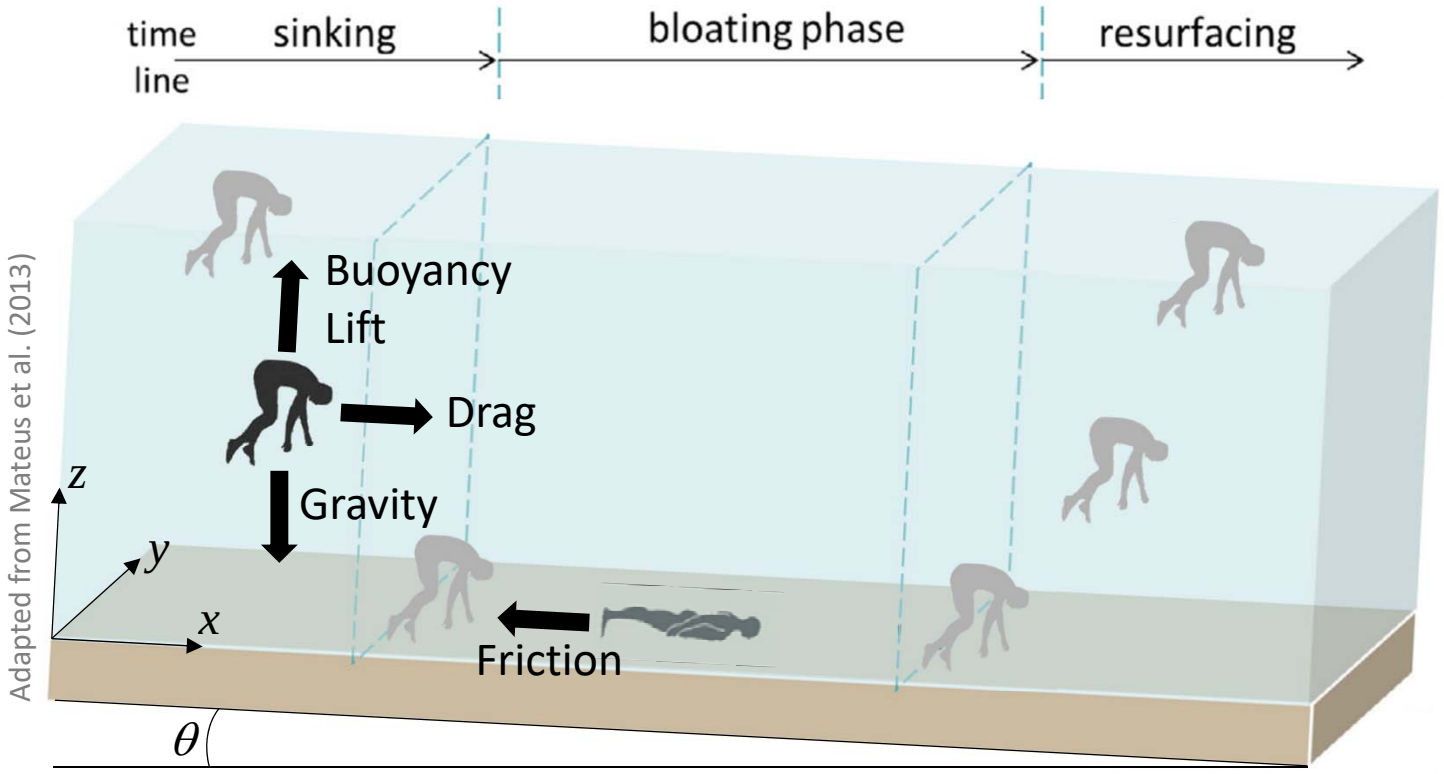
The mathematical model used to find bodies of missing people in Colombia's rivers

- Early stage of the work
- Hyper site specific, works only for the La Miel River

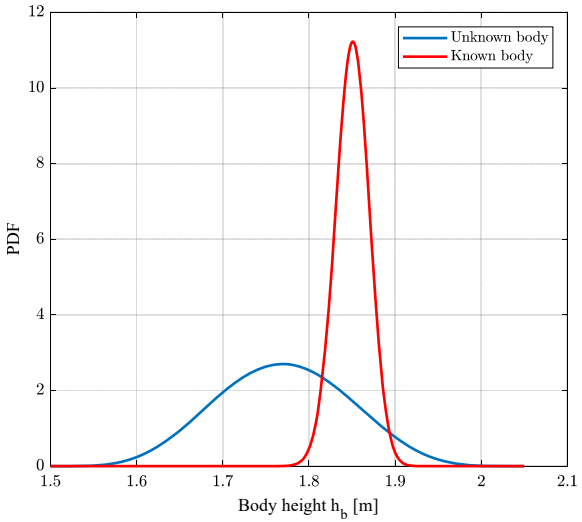
Current year separated into 4 distinct themes

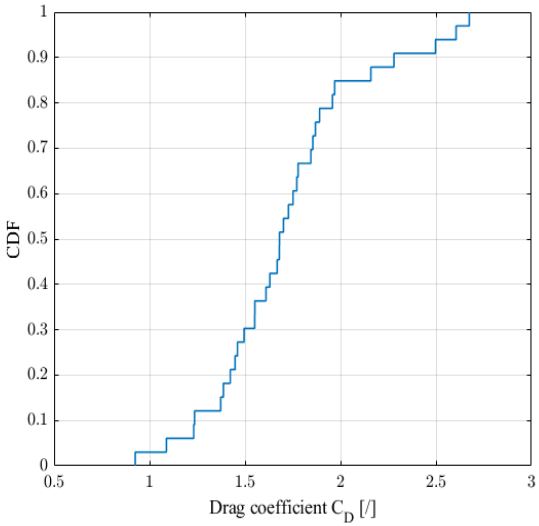


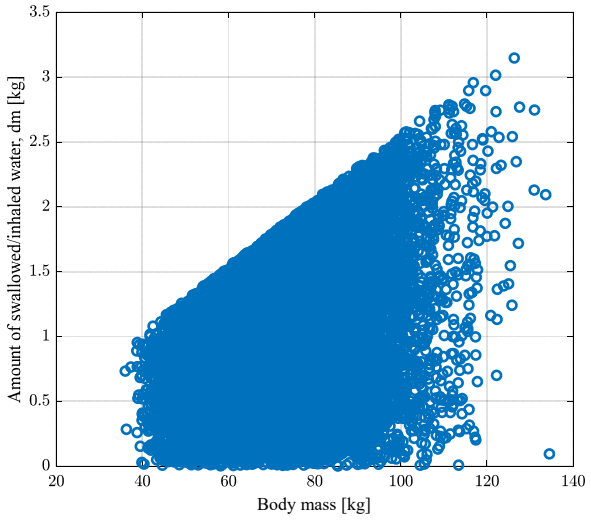
Considered forces in the numerical model



Monte Carlo simulations to represent uncertainties in the 9 input parameters







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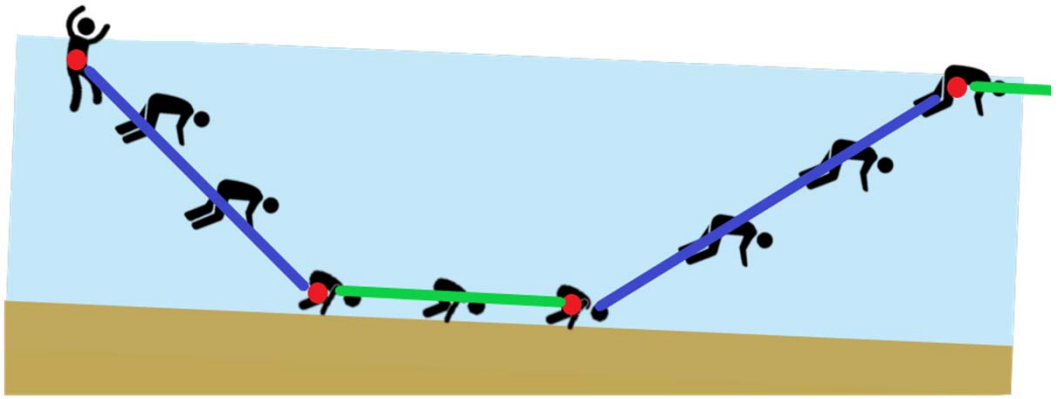
Main modifications to improve the speed of the model and analyse results with huge samples

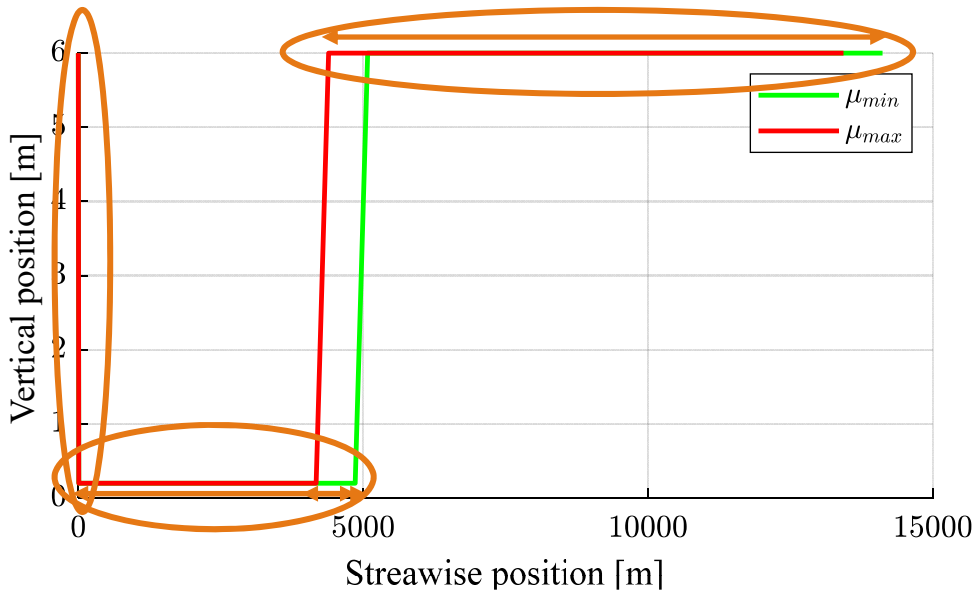
- Parallelisation and on-time sorting of the Monte Carlo samples
- Time step depending on the considered body and its stage in the drowning (dt_{min}, $dt_{variable}$, dt_{max})
- Forced velocity convergence when the body reaches a (almost) stationnary stage



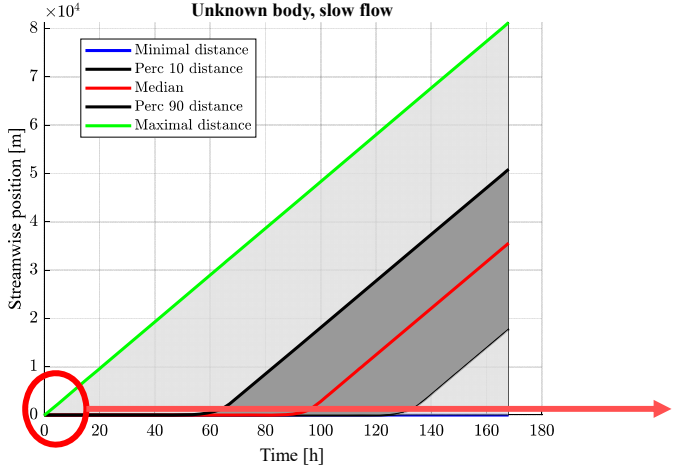
Influence of the uncertain parameters

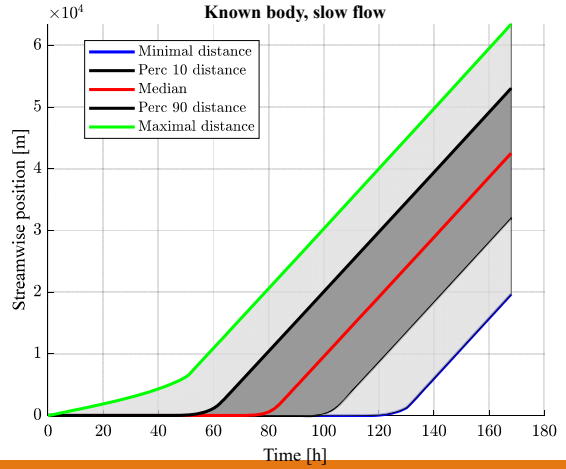
- Two runs in exactly the same configuration except for the friction coefficient with the bottom
- Bodies sink directly
- Bloating phase last for 20h
- Floating phase last for 20h

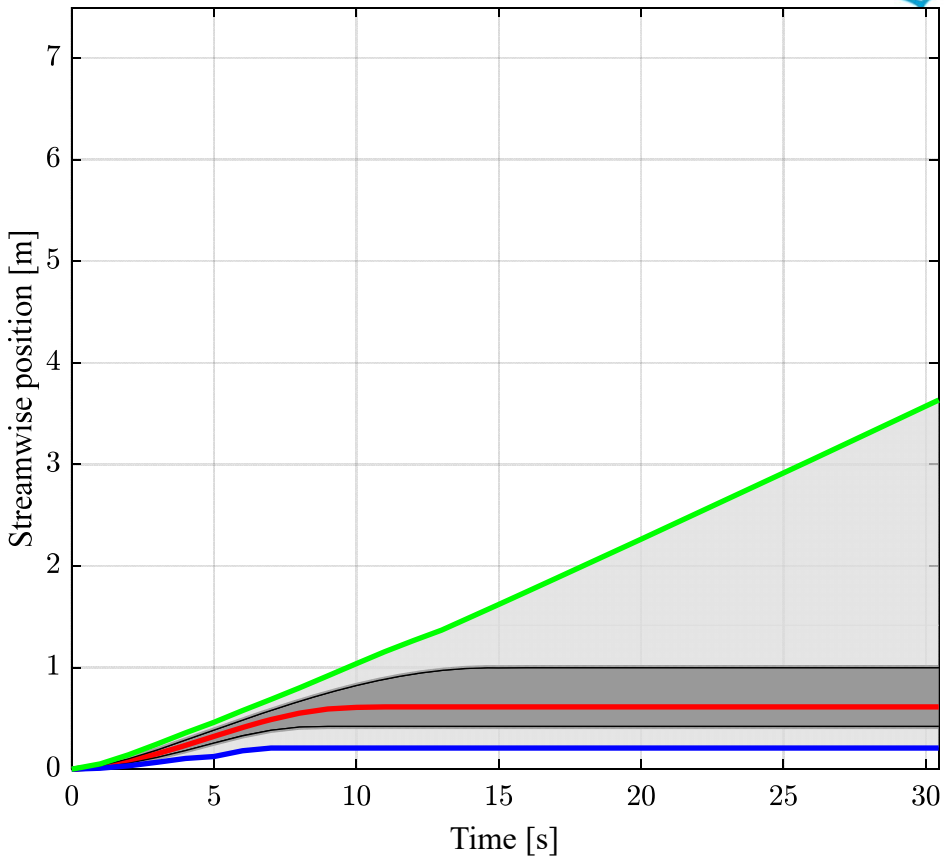
- In this configuration, at the bottom, the body travels for about 15% more with a low friction coefficient
- In this configuration, at the surface, the body travels for about twice the distance in the same time



Numerical results in uniform flow







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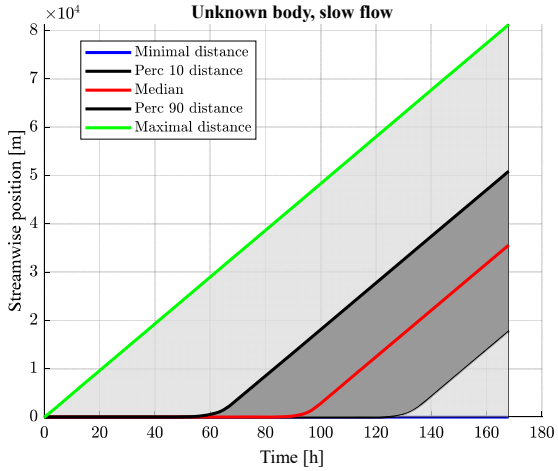

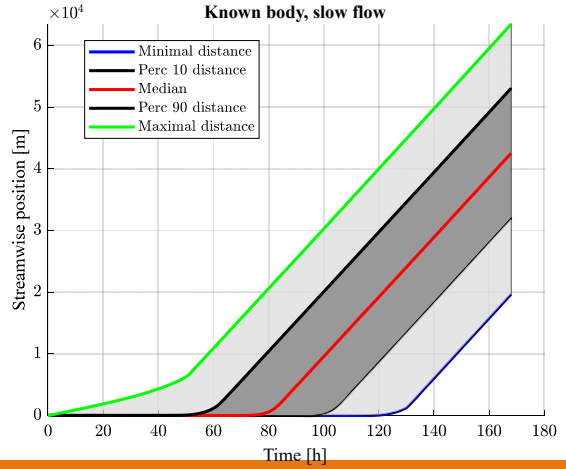

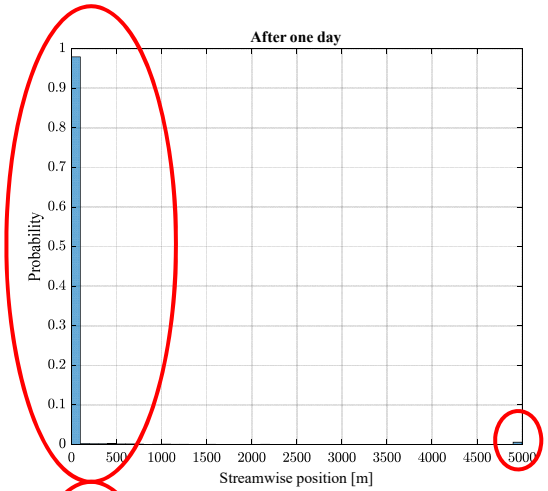

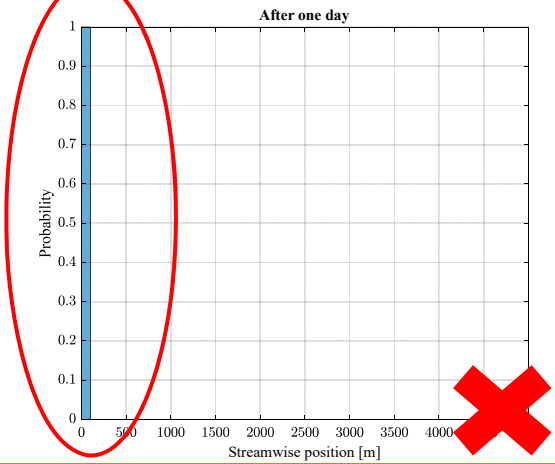

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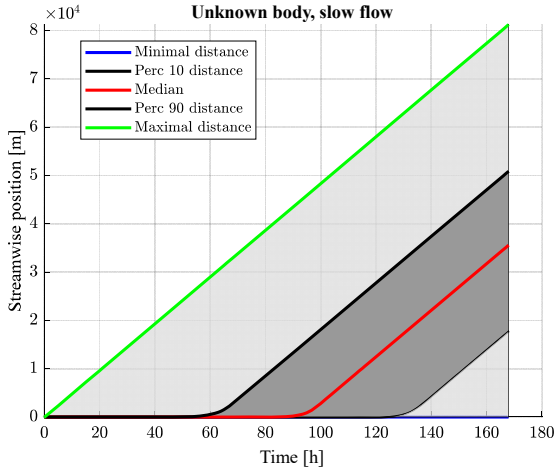
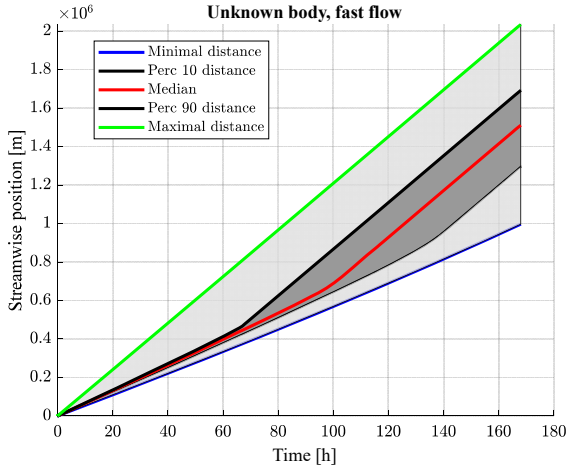
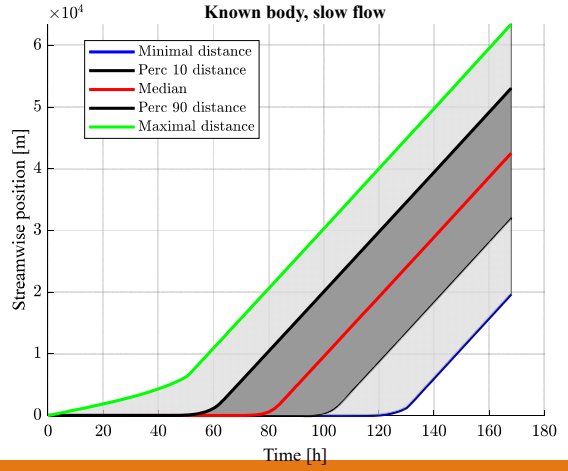
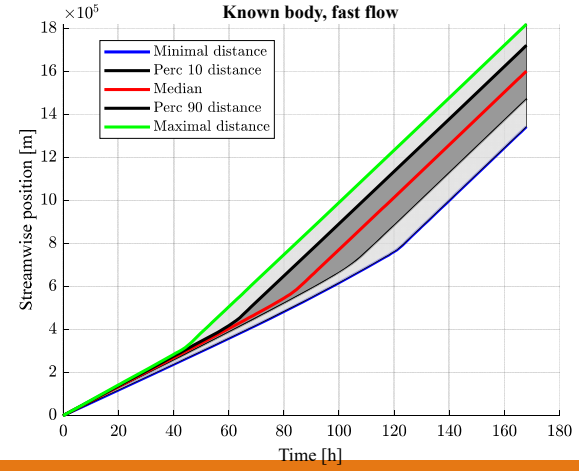




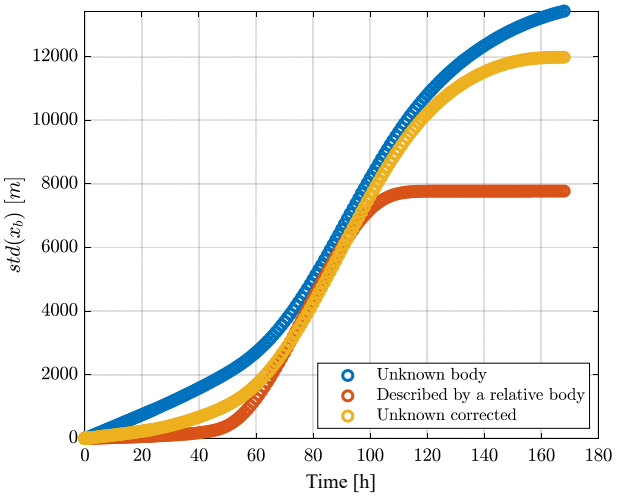


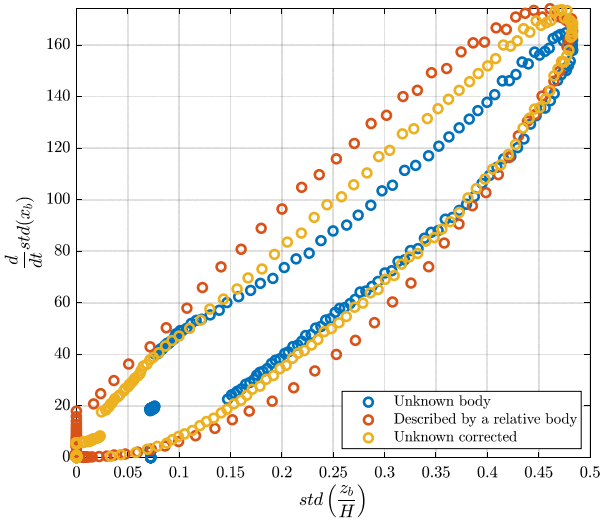


Analysis of numerical results

- Standard deviation of horizontal positions x_b of bodies as a function of time

- Time derivative of the above term as a function of the standard deviation of the vertical position of the bodies z_b normalised by the water height

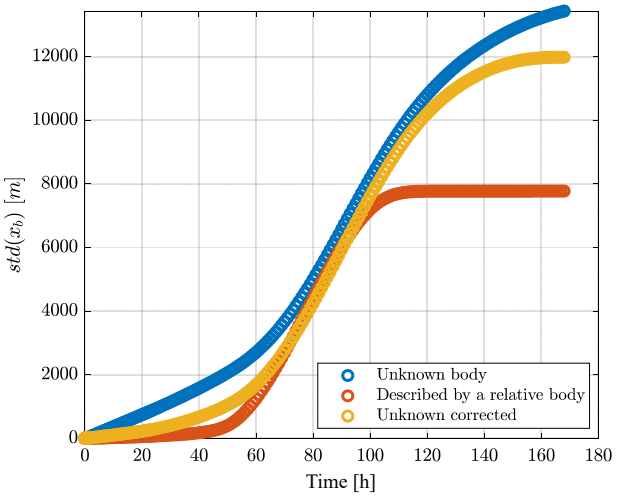


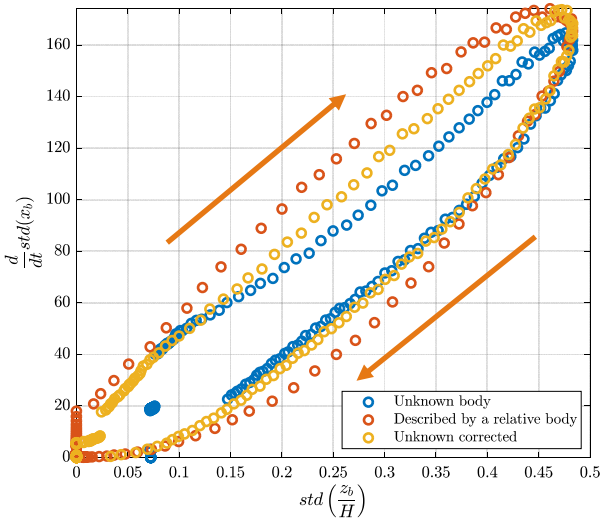


Analysis of numerical results

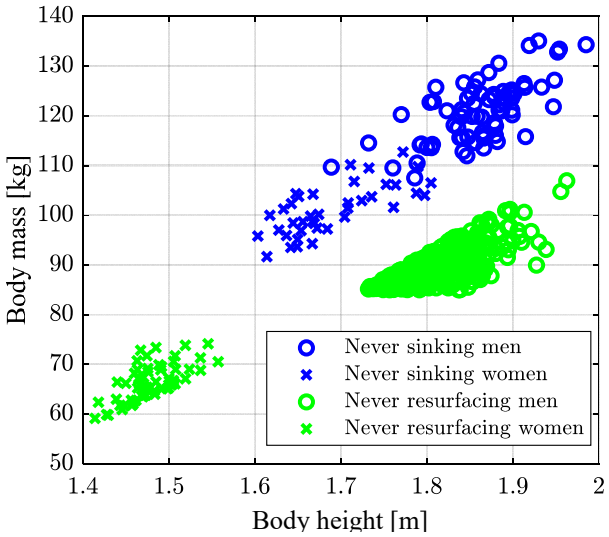
- For a « unknown » body:
  - The dispersion of positions is increasing over time
  - Some bodies stay at the bottom indefinitely and others never sink
  - Taking only bodies which respect a « classical » drowning process (97% of cases), the standard-deviation stabilises

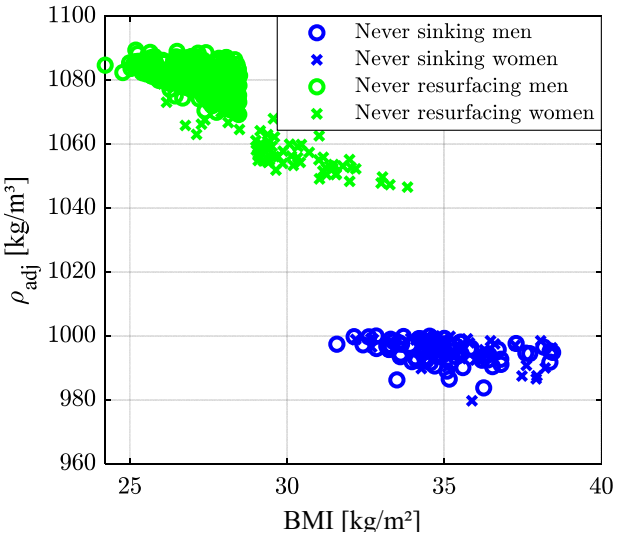
- For a « known » body:
  - The dispersion of positions stabilises after a while
  - The vertical position of the bodies is less dispersed

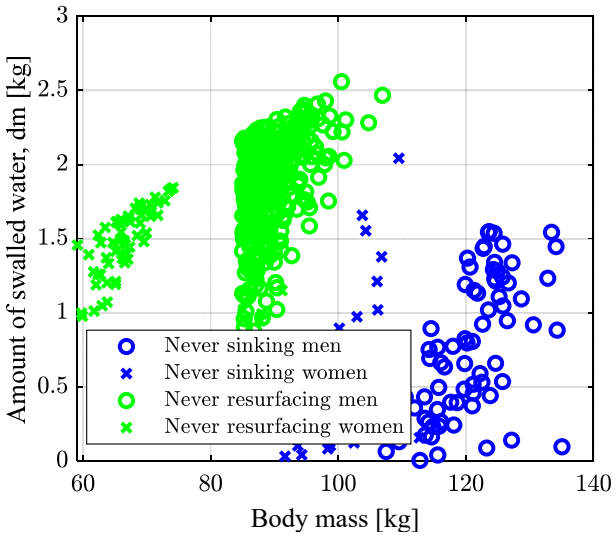




Typical profile of bodies that do not reproduce the classic drowning process







Sobol' index; Sobol', 2001

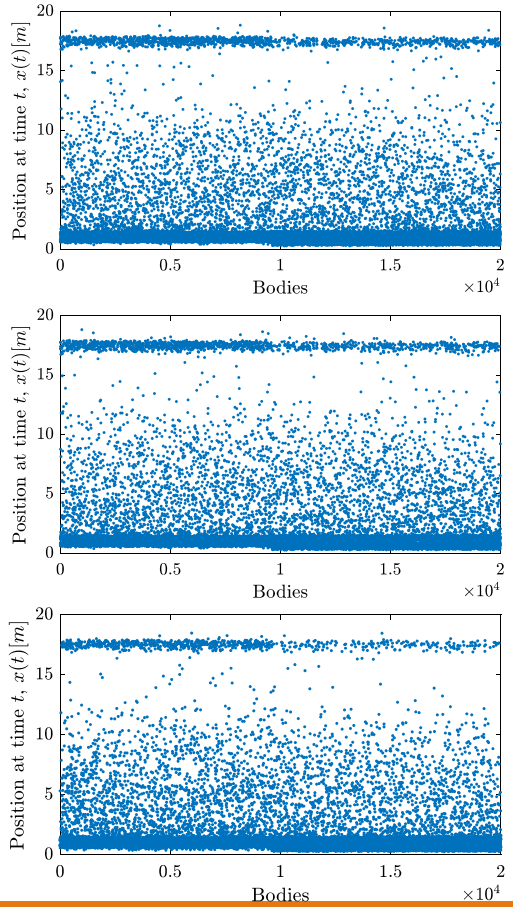
Reference drawing of parameters

Re-drawing of the parameter

h_b	BMI	C_D	...

h_b	BMI	C_D	...

h_b	BMI	C_D	...



$$S_{h_b} = \frac{\frac{1}{2n}\sum_{i=1}^{n}(x_{ref}(t) - x_{h_b}(t))^2}{Var(x)}$$

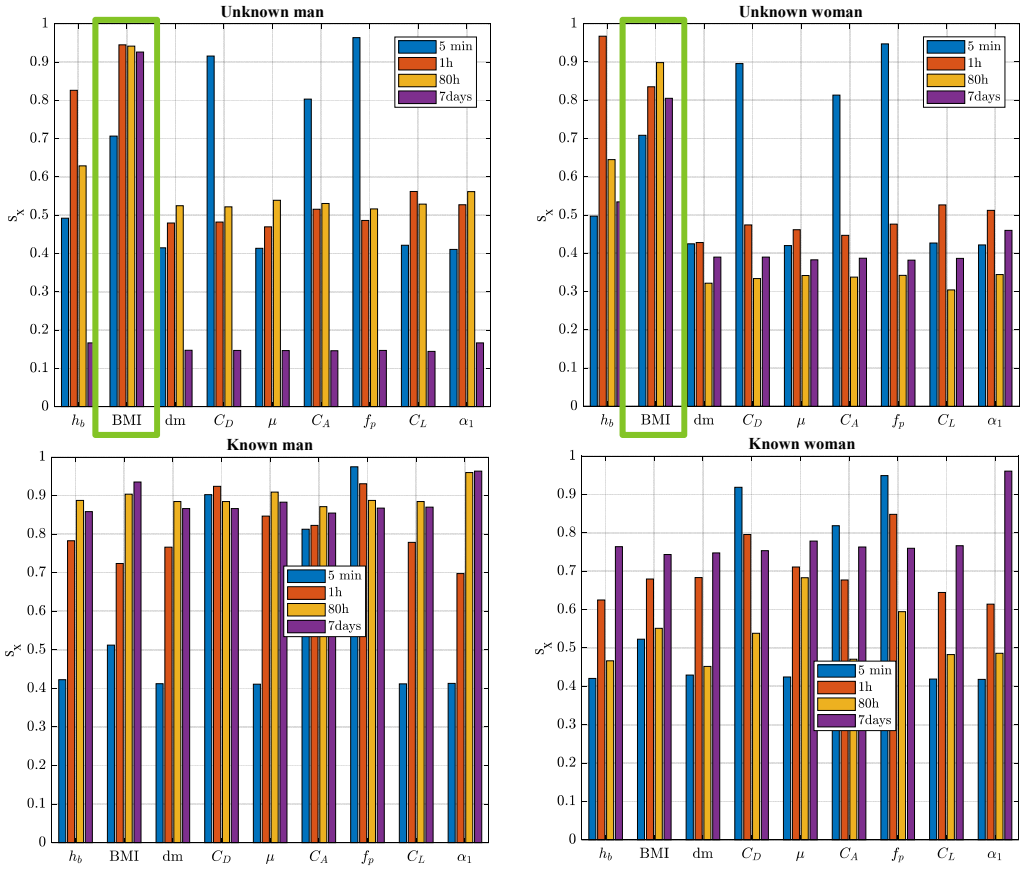
$$S_{BMI} = \frac{\frac{1}{2n}\sum_{i=1}^{n}(x_{ref}(t) - x_{BMI}(t))^2}{Var(x)}$$

Analysis of the Sobol' indices carried out for several different time horizons

- 5min: arrival on site
- 1h: stop search (in summer, 2h in winter)
- 80h: bodies are resurfacing
- 7 days: bodies all supposed to have resurfaced

Analysis of Sobol' indices

- Time horizon considered changes the influence of parameter uncertainties
- It is difficult to identify the most influential parameter(s) in all cases
- For unknown bodies, *BMI* seems to be the parameter with the most influential uncertainties



Analysis of Sobol' indices

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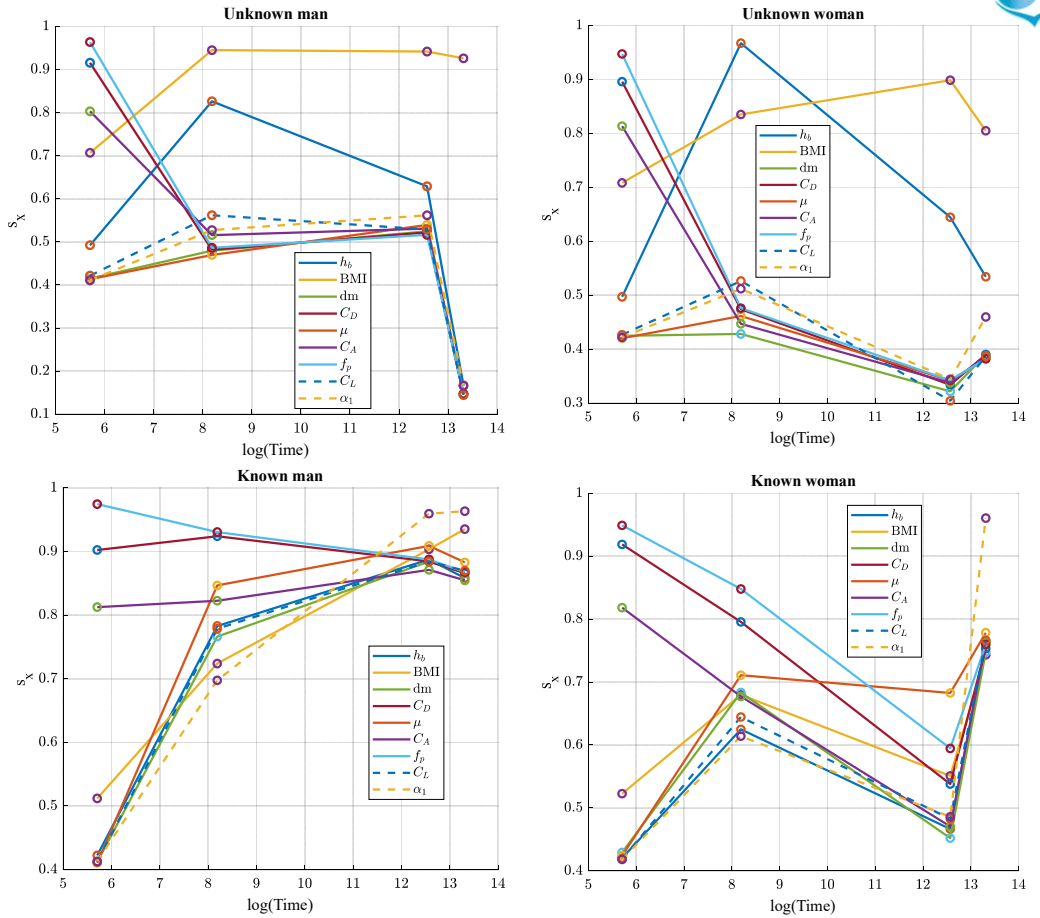
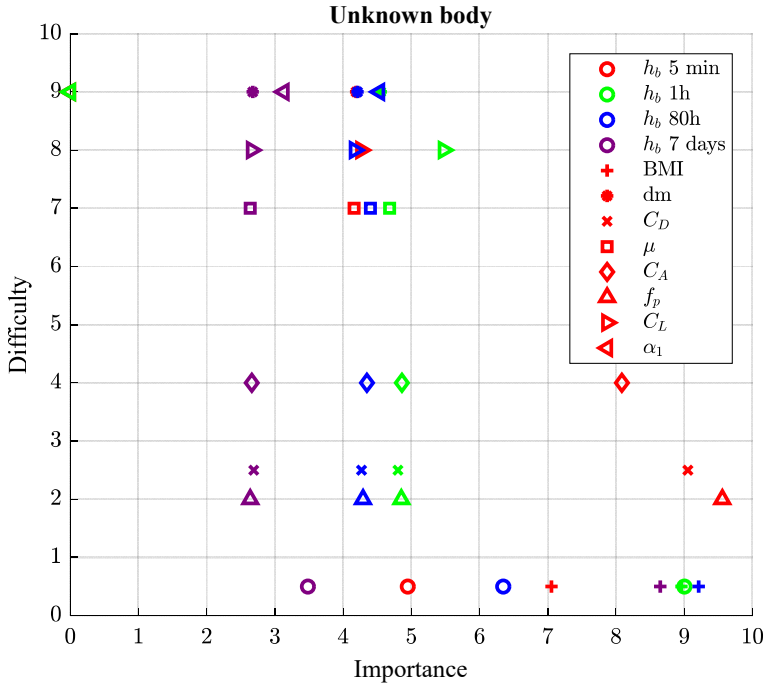
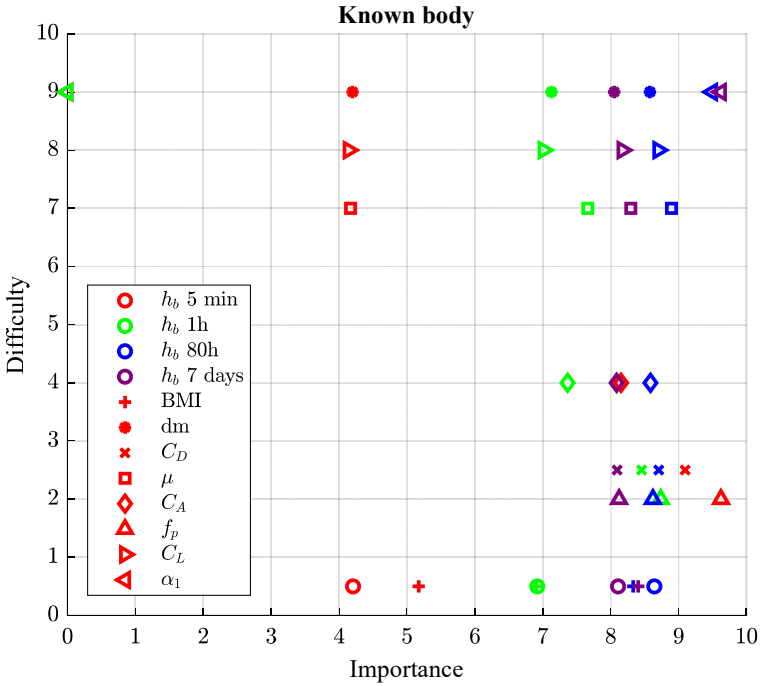


Ranking of uncertain parameters

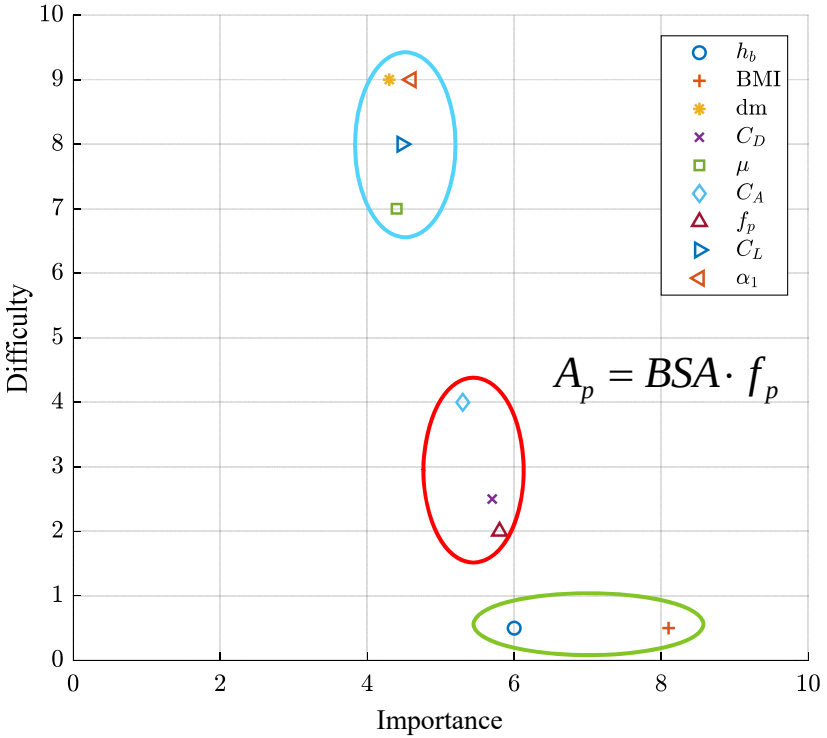




Ranking of uncertain parameters

- Average Sobol index (x10) for the 4 time horizons

- There are 3 groups of parameters:
  1. *h_b* and *BMI* easily precised thanks to a witness
  2. Easy access and important
  3. Difficult to reach and less important

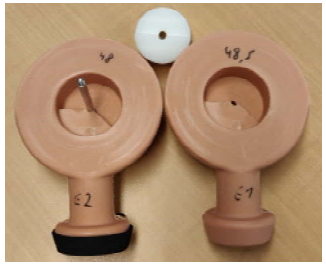


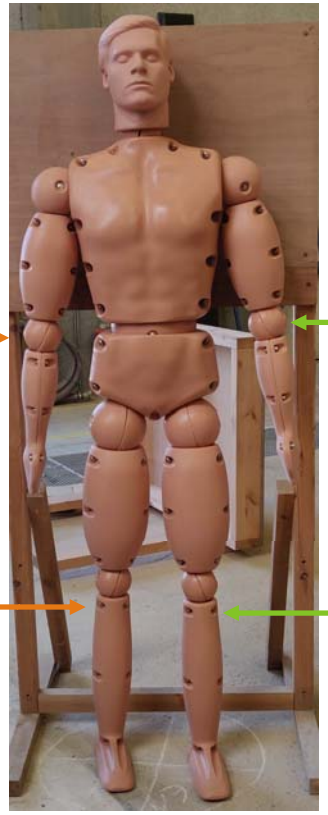
Current year separated into 4 distinct themes

Experimental work

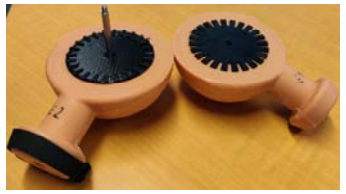
Modifications of the real scale dummy

Balls allowing 90° rotation



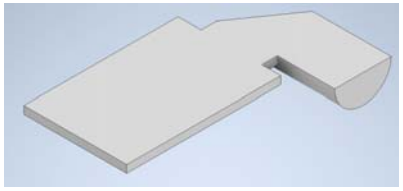


No more rotation allowed



Balls free to rotate in the member

Fixed ball joints in the limb



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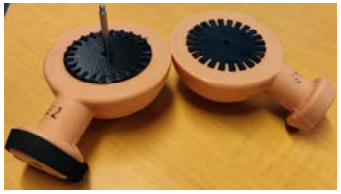
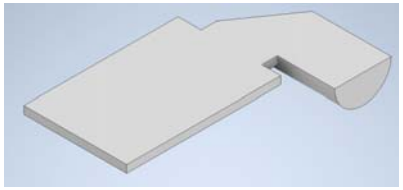
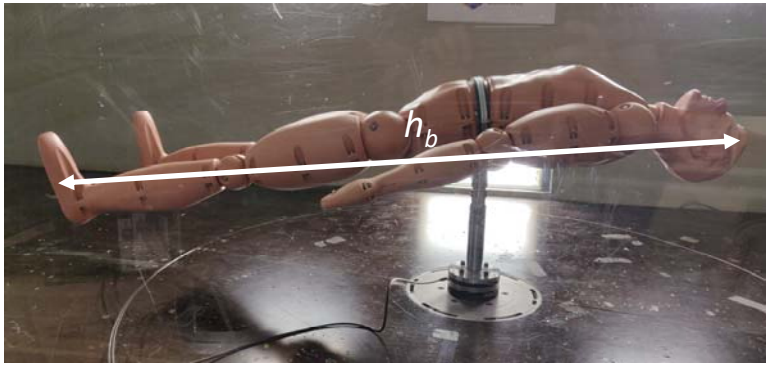
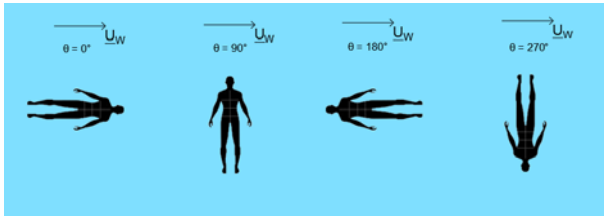


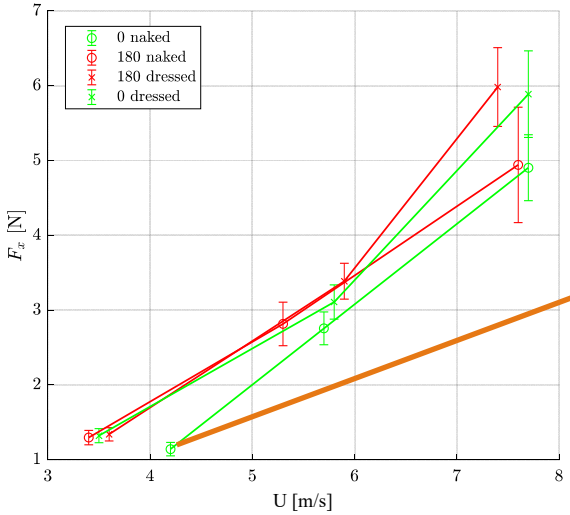
Balls free to rotate in the member

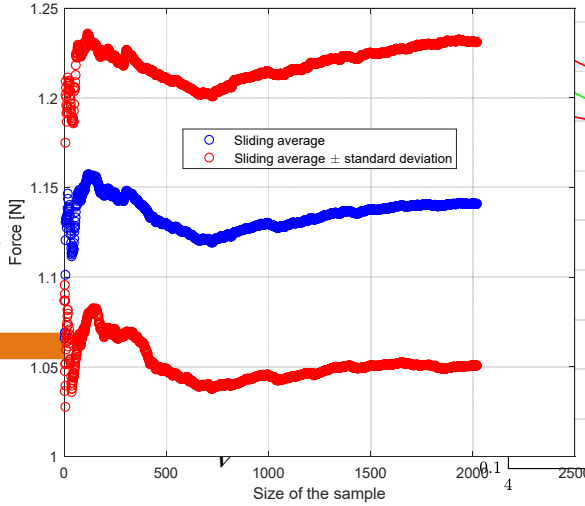


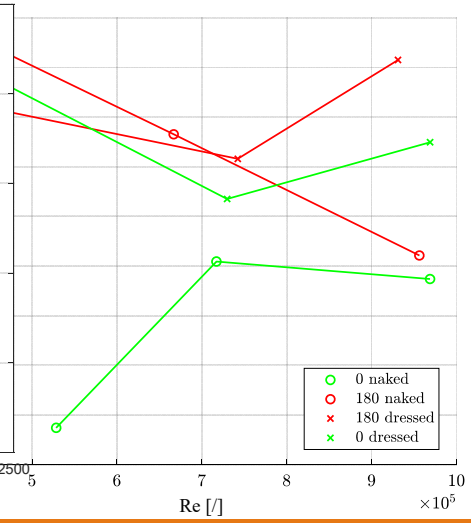
Wind tunnel tests for a naked or clothed body







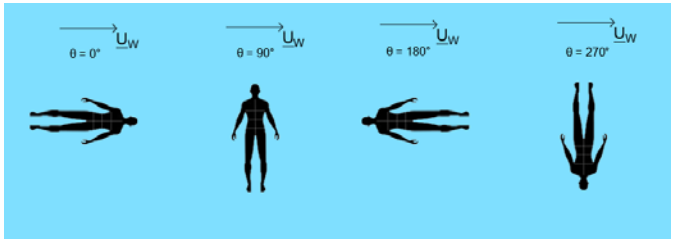


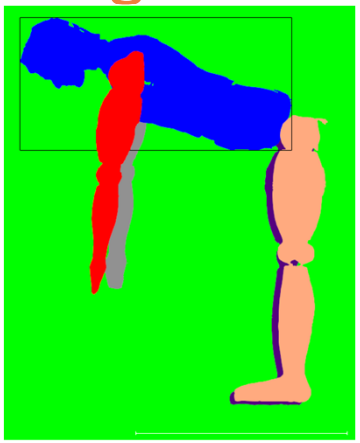


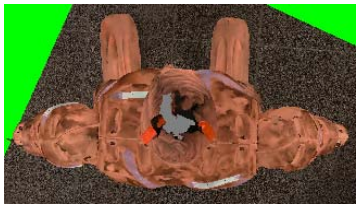
Current year separated into 4 distinct themes

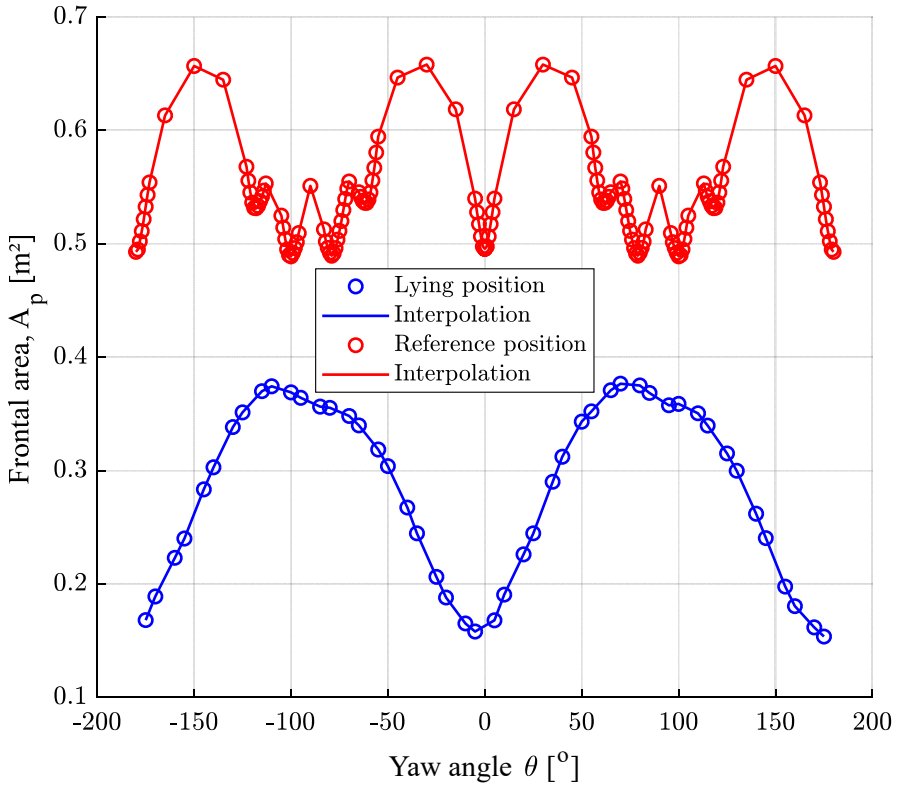
Modelling of the 1.9 m dummy

Determination of the frontal area using the 3D model of the dummy

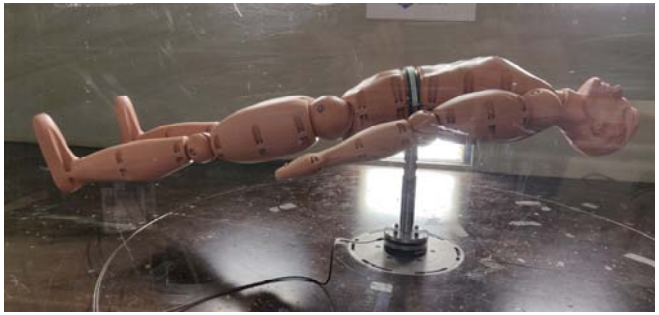


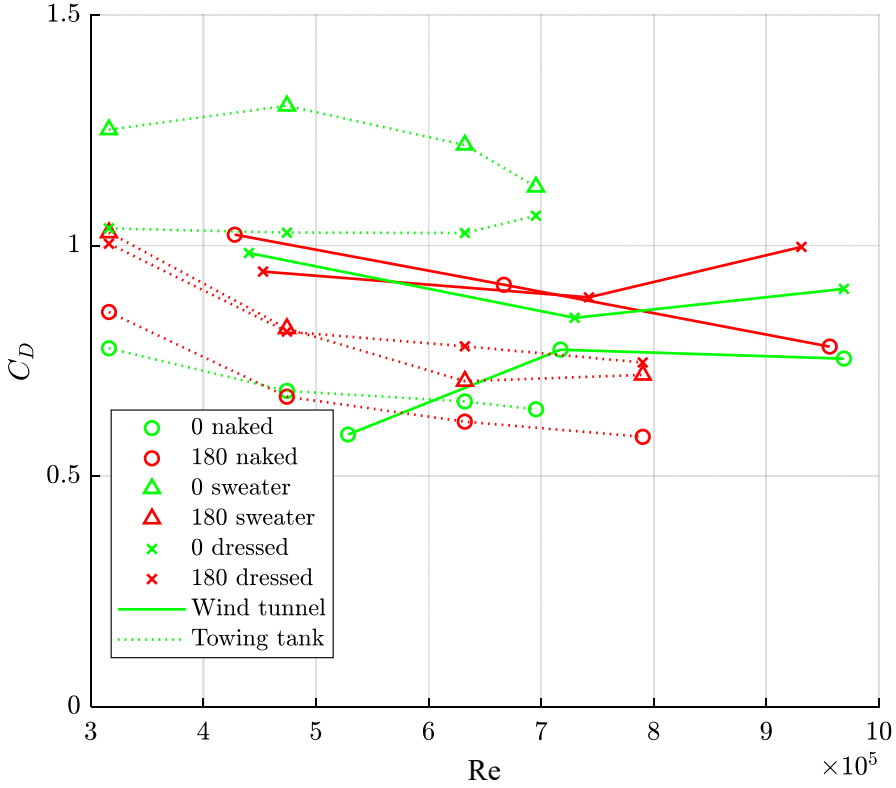






Similar results to previous trials

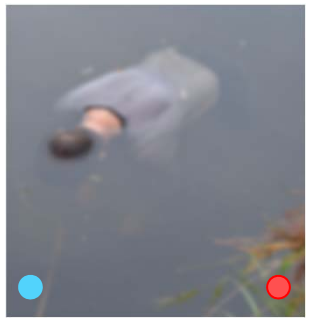




Current year separated into 4 distinct themes

Real data

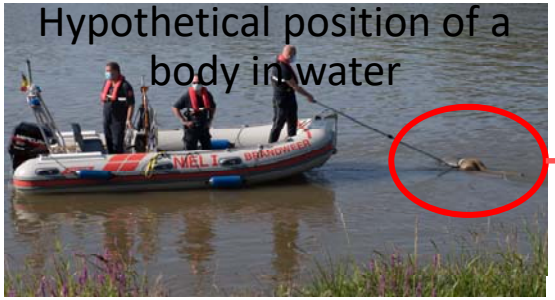
Confirmation of body position assumptions and observation on real cases



- Drowning in river
- Drowning in lake
- Suicide
- Unknown circumstances

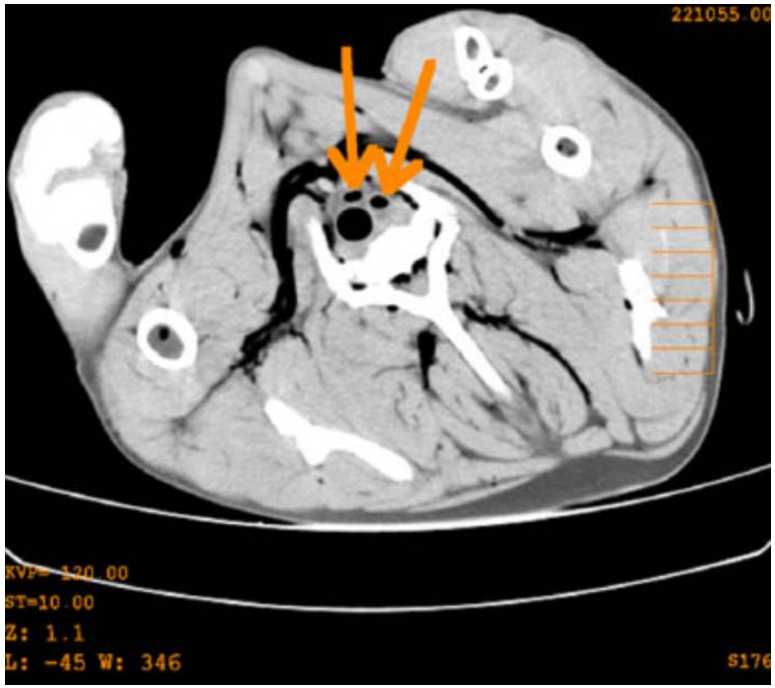
Body on the bank but in a state of rigor mortis, position fixed on the one before leaving the water

Regardless of the hydraulic context or the circumstances of the drowning, the position observed is the same



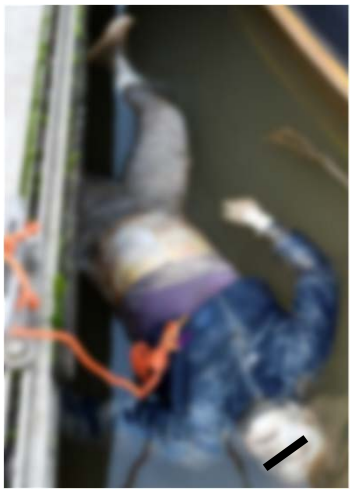
Generation of putrefaction gas

- Gas regularly studied in different situations
- Studies based on composition (Laurent et al., 2011; Armstrong et al., 2016; Brasseur et al., 2012; etc.) and not volume



Laurent et al., 2011

Hypothesis about the absence of intracadaveric pressure measurable with a manometer

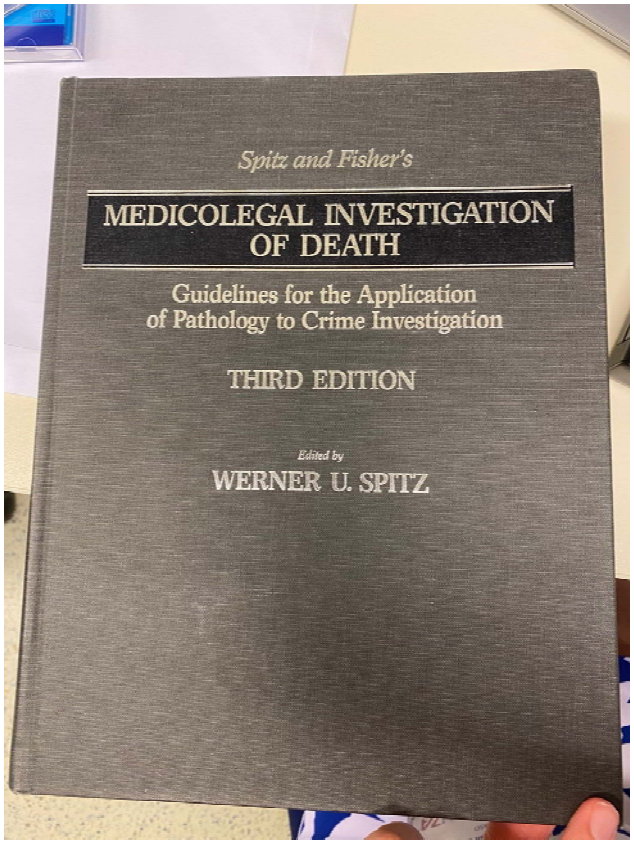


$P_{in} \approx P_{out}$

$P_{in} > P_{out}$

$P_{in} \approx P_{out}$

Possible way to measure pressure in a sealed volume



Jump

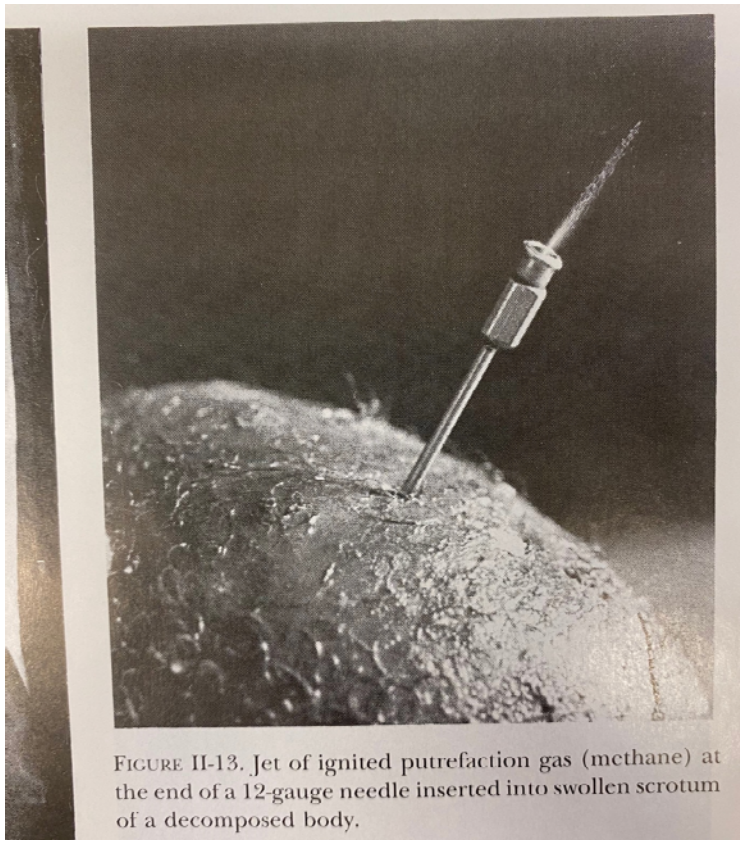


FIGURE II-13. Jet of ignited putrefaction gas (methane) at the end of a 12-gauge needle inserted into swollen scrotum of a decomposed body.

Possible way to measure pressure in a sealed volume

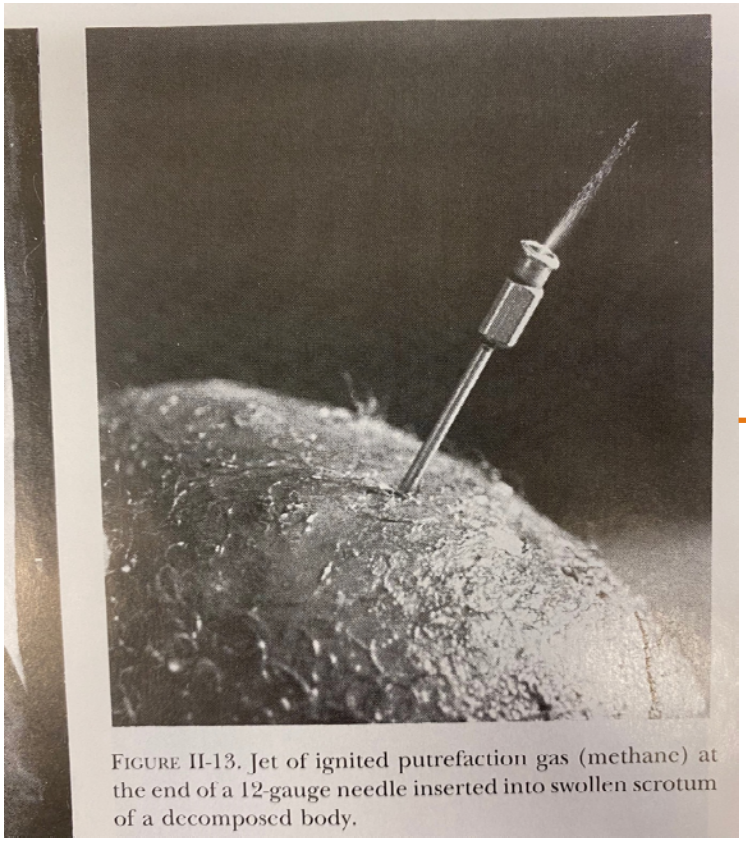
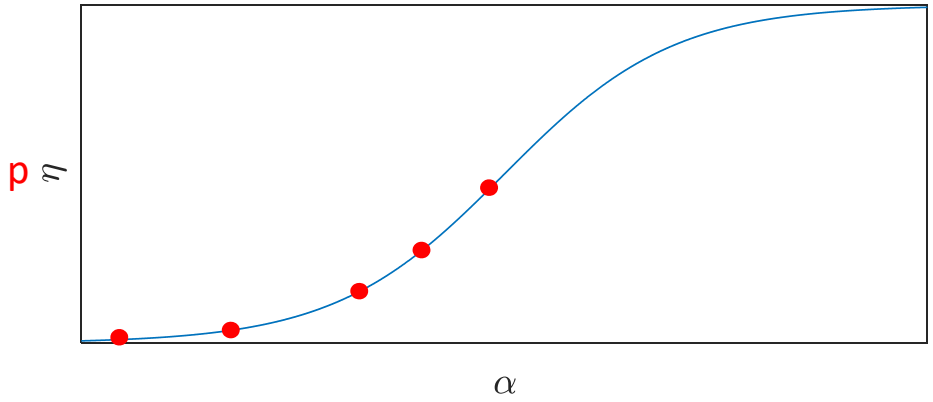


FIGURE II-13. Jet of ignited putrefaction gas (methane) at the end of a 12-gauge needle inserted into swollen scrotum of a decomposed body.

Cases from the UZA database occuring at about the same period (winter) but with various Post Mortem Submersion Interval

Parameter η describing the decomposition

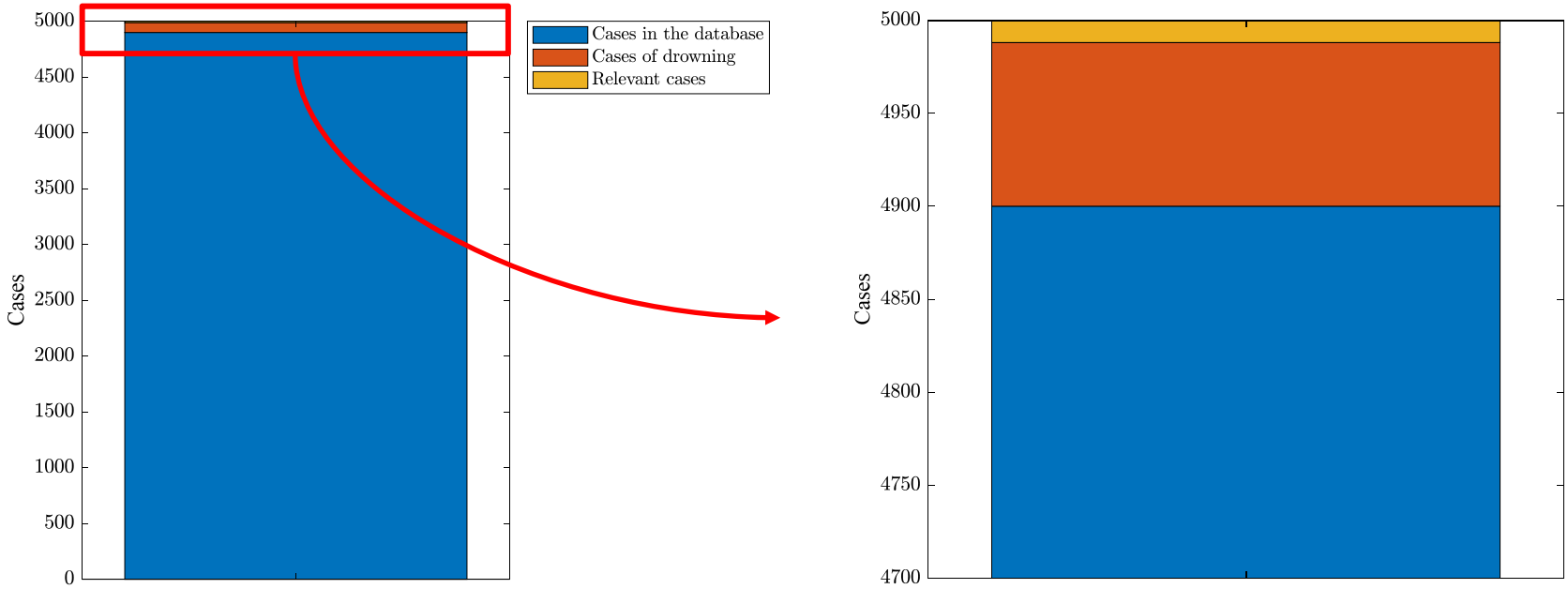
$$V_b(t) = (1-\lambda)\,V_b(0) + \lambda\,V_b(0)[1+\eta(\alpha)]\frac{p_{\text{atm}}}{p_{\text{atm}} + p_{\text{hydro}}}$$



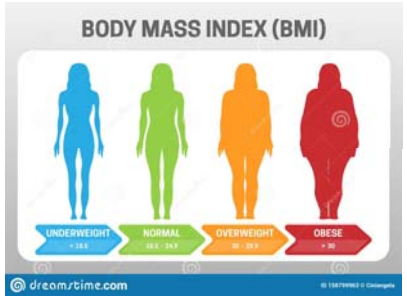
$$\eta(\alpha) = \frac{1}{1+e^{\kappa\alpha}}$$

$$\alpha = \int_{t_0}^{t} T_w dt$$

UZA database between mid-2020 and mid-2022: 12 cases fully relevant for our study



Qualitative data from the database



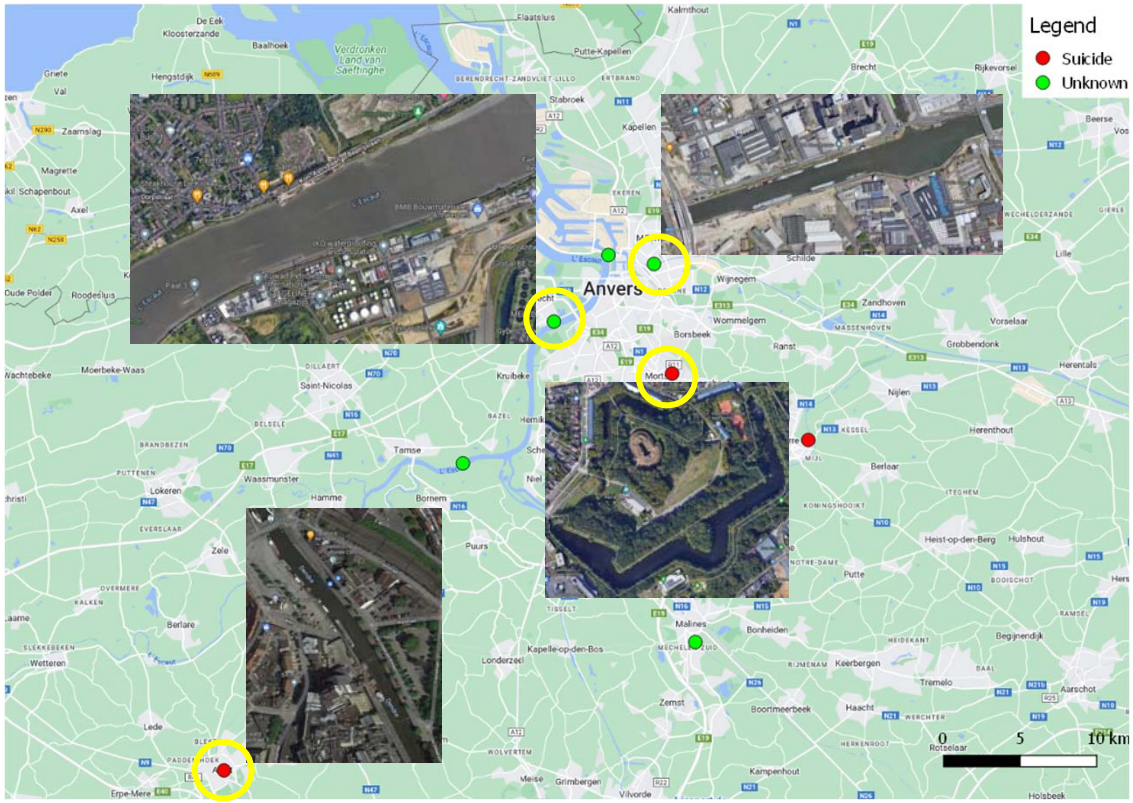
BMI estimation

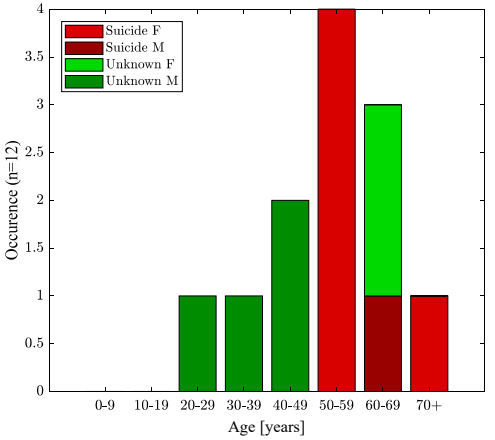
Type of clothing

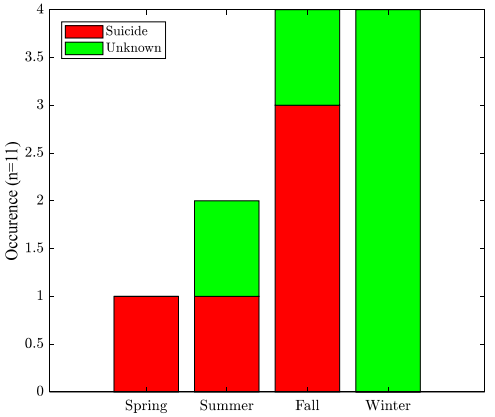
Contact with a boat

Bed load transport

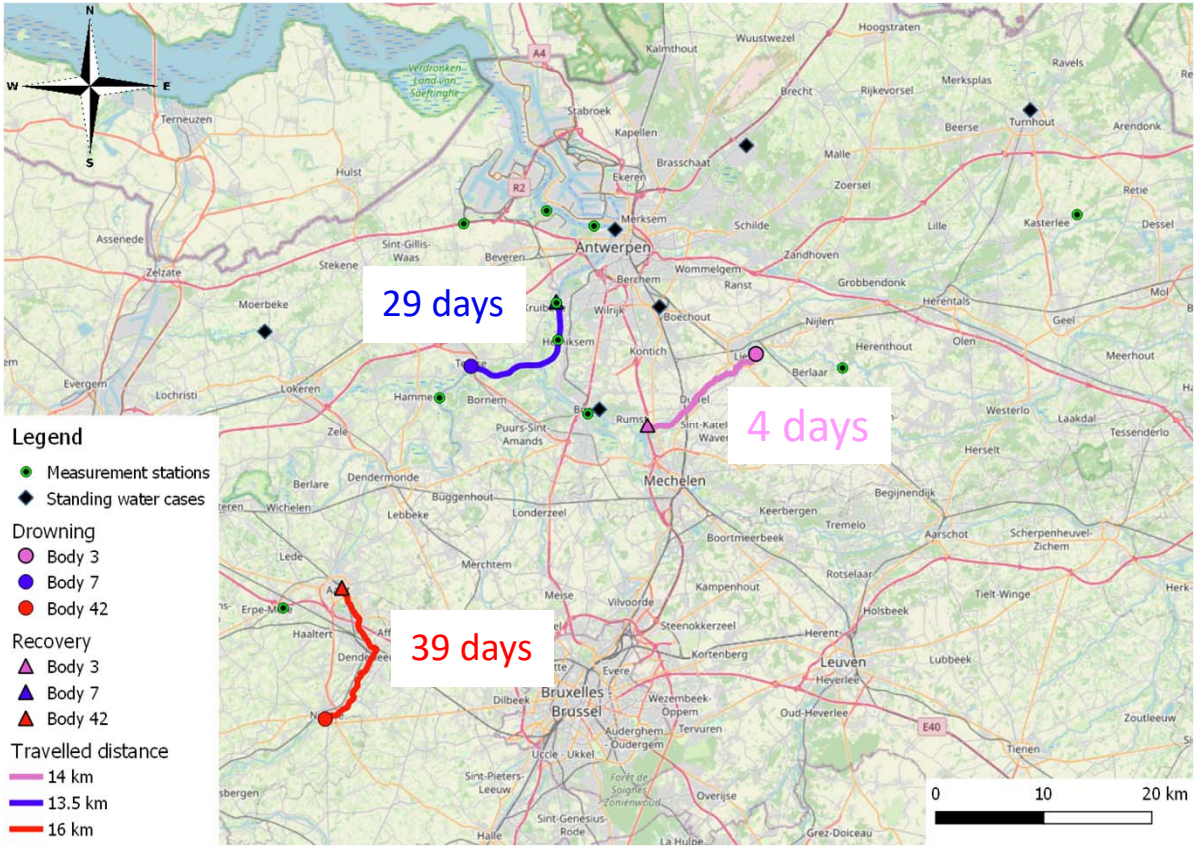
Quantitatives data of the database



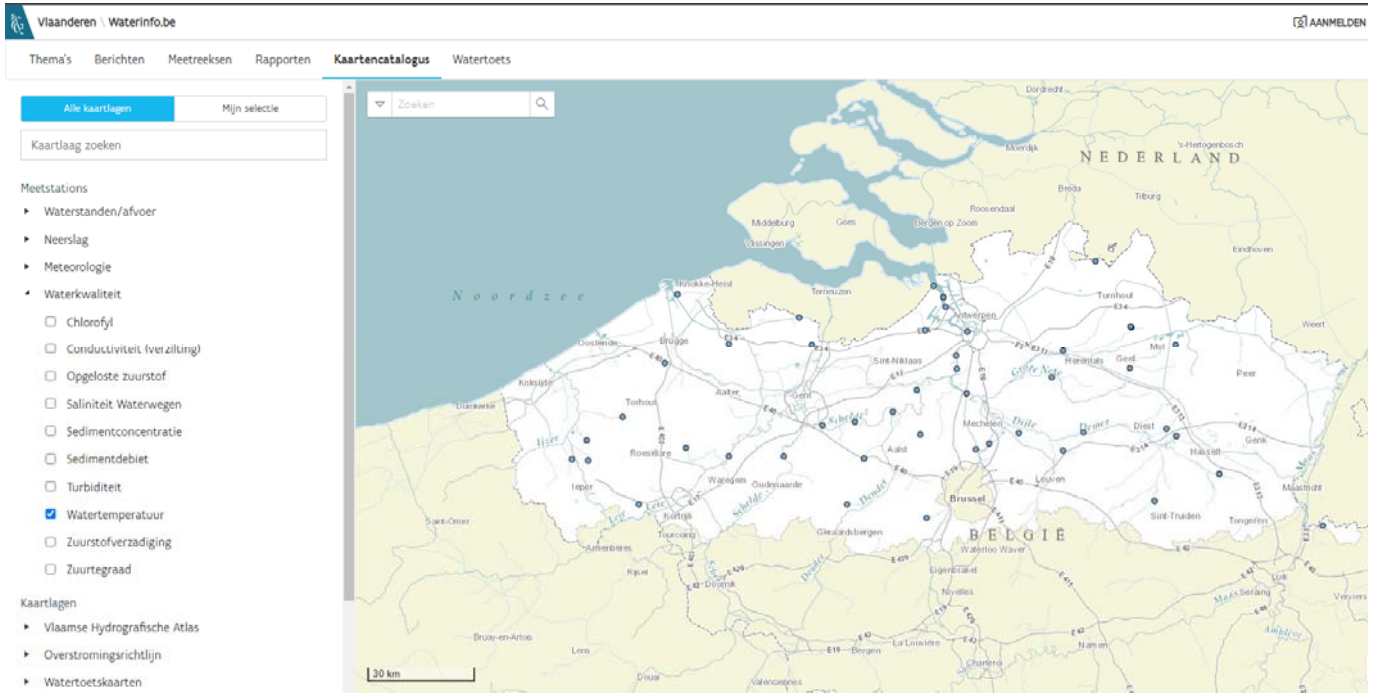




Ability to recreate real-life trajectories

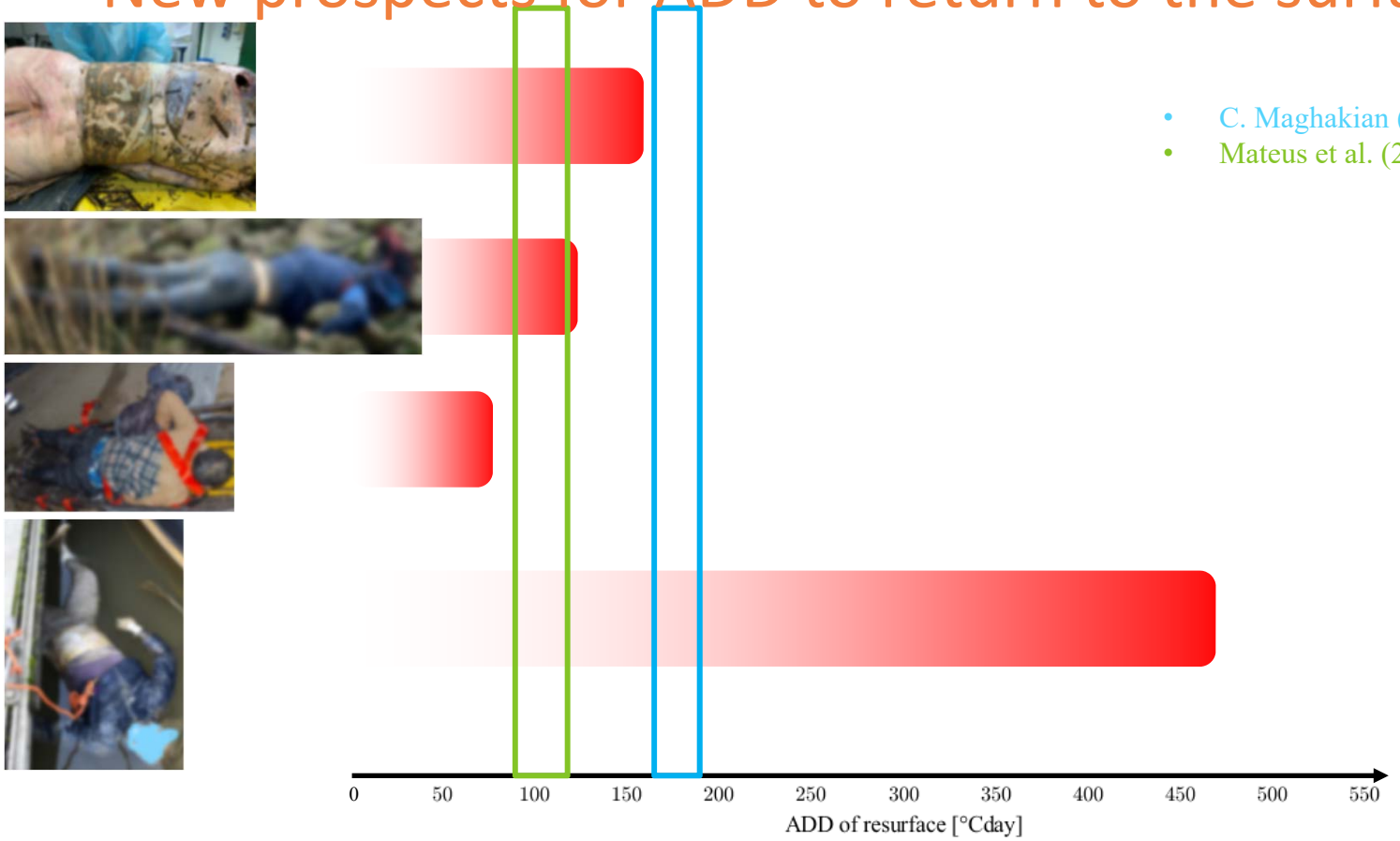


Availability of hydraulic data (waterinfo and c-map)



$$ADD = \int_{t_0}^{t} T_w dt$$

New prospects for ADD to return to the surface



- C. Maghakian (2022): [160; 180] °C day
- Mateus et al. (2013): [95; 117]°C day

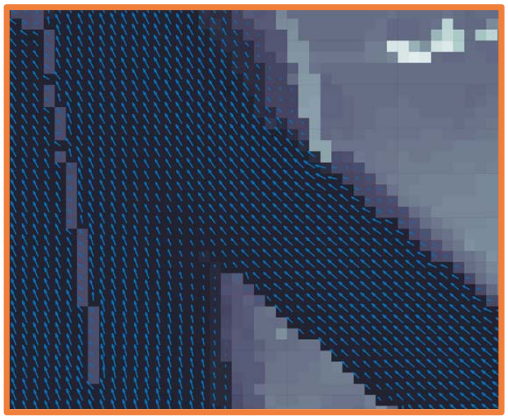
Doctoral training

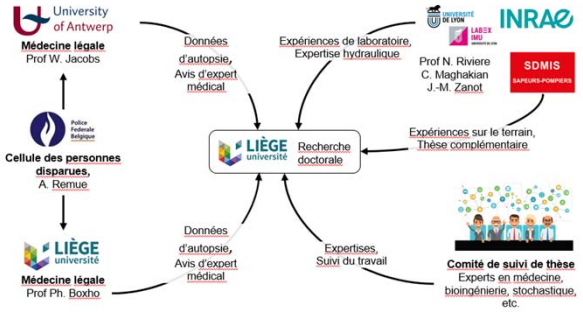
- Thematic training (min. 15 ECTS)
  - Realiability and stochastic modelling of engineering systems (5 ECTS)
  - **Total: 5 ECTS**
- Transferable skills training (min. 10 ECTS)
  - Didactic supervision of courses, total = max = 5 ECTS:
    - GCIV2065-1 (bridges): 12h (2 ECTS)
    - GCIV2035-1 (hydro. flu.): 15h (2 ECTS)
    - APRI0006-1 (personnal project): 12h (2 ECTS)
  - Master thesis supervision: C. Degrève (3 ECTS)
  - **Total: 8 ECTS**
- Scientific production (min. 25 ECTS)
  - Active participation in congres: Oral presentation in IAHR YP (5 ECTS)
  - Public presentation of ongoing research at a local seminar : Fluid Meetings (2 ECTS)
  - **Total: 7 ECTS**
- **Total: 20 ECTS**

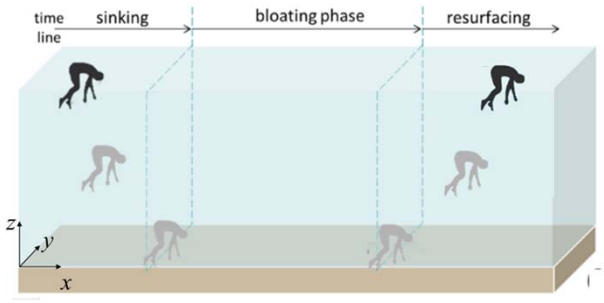
Sum up

- Numerical: sensitivity analysis of the complex process of drowning in a simple flow
- Experimental: setup validated and first results in the wind tunnel
- Modellisation: mesh of the model for any position
- Real data: medical and police data allowing to have very precise data on real drowning cases

Points clés de la candidature







Final grading / Note finale

A+ : Outstanding / A+ : Exceptionnel

THANK YOU FOR
YOUR ATTENTION

APPENDIX