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► **To cite this version:**

Matteo Zaegel, Mathis Vehils-Vinals, Hugo Guastalla, Benjamin Benabou, Auguste Gires. Should you walk, run or sprint in the rain to get less wet?. *European Journal of Physics*, 2023, 45 (2), pp.025802. 10.1088/1361-6404/ad06bf. hal-04578724

HAL Id: hal-04578724

<https://enpc.hal.science/hal-04578724v1>

Submitted on 17 May 2024

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Should you walk, run or sprint in the rain to get less wet?

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July 2021

Abstract. We have all wondered once whether we should walk, run or sprint under the rain in order to stay as dry as possible. Previous publications already addressed this subject using simple models, as for the shape of the body and the description of the rain and wind. This paper presents a detailed approach which relies on a more realistic 'human body' shape and accounts for the variability in time of both the wind and the rain drop size and velocity distributions. It appears that in some seldom cases with tailwind and light rain, there is an optimum velocity, but in general it is better to run as fast as possible. While 'running' instead of 'walking' yields significant gain, the extra effort required to 'sprint' is not always worth it.

1. Introduction

Picture yourself in your office or into your friend's apartment. It is about time you go home and you've just noticed that it's raining cats and dogs outside and that you do not have an umbrella. While lacing your shoes you wonder whether you should run or walk under this heavy rain. Running surely decreases the time you spend outside but it also increases the number of raindrops you collide with, while walking slowly does the opposite. Is there even an optimal speed between those two solutions ?

Authors have been addressing this daily life issue for decades (see [11, 2] for early examples). [7] studied simple cases by considering neither wind nor any disparity in the size of the raindrops. They used an approximate shape for the body with a spherical head and a rectangular part for rest the body. They found a decrease in wetness for the runner. They calculated that running twice as fast as walking would only reduce the wetness by 10%. They concluded that running is best if you feel like the rain is going to intensifies and walking is best if it is about to stop since this way you may give rain enough time to stop.

[1] came to same conclusions relying on even stronger hypothesis to solve this issue, i.e. not accounting for wind and considering rain as one unique flow. Thus the conclusion

is clear, it is better to run as fast as possible but it is not really worth the effort. In practice running at Usain Bolt speed would get you only 10% less wet. Furthermore the size of the person moving in the rain can also be taken into account, like highlighted in [9]. Indeed, the author notes that a taller person walking at the same pace as a smaller one will be less wet despite having a larger surface area exposed to rain, thanks to the fact that a taller person will in practice walk faster and therefore spend less time outside.

On the contrary [3] accounts for wind and presents the more in-depth results on the topic. It relies on different hypothesis, the ground is flat, the road is straight and it keeps raining with a constant rate at least along the way. Body movements is rigid i.e. it is a simple translation. However they do not take in account the disparity in the size and velocity of raindrops. The conclusion he comes to in the case of vertical rain is that the best strategy is to run as fast as possible. The same applies to traveling against the wind. He reports that the presence of a tailwind seems to be a favorable condition for the existence of optimal speed, but it is not always a necessary condition. In some cases, he found that the value of an optimal speed depends on the drop size (and more precisely its fall velocity), but in others it does not. This will only happen if the ratio between the body cross-section perpendicular to the movement and the horizontal cross-section is large enough; otherwise, again running at the maximum achievable speed is your best bet.

Alongside those theoretical investigations, practical experiments have been made. [10] addresses the problem first theoretically and then experimentally. First of all, they account for accurate values for the velocity corresponding to running and walking, then they consider the fact that with heavier rains, the size of raindrops can vary which changes their vertical velocity and their mass. In addition, they account for the fact that when running, we lean forward which changes the shape of the body. Finally they account for the wind in the equations. Relying on these equations, they obtain that for a light rain with no wind and no forward lean, running provides only a 16% benefit. But for heavy, wind-driven rain with the runner leaning forward, the benefit of running is a 44% decrease in wetting, i.e. mass of received water. After this, they also did the experiment in their lab and the wetness of the runner was similar to what they had expected.

Since this problem belongs to the "real life" and is not just pure academic investigations, it has raised a widespread interest. However, very few articles examine the influence of the raindrops disparity and to our knowledge, none accounts for the variability of wind and drop size and velocity distributions in time.

The aim of this paper is to use a similar approach as in the previous studies while reducing the number of assumptions made to mimic more realistically real life situations. The shape of the body will be taken into consideration as well as the full rainfall drop size distribution (DSD) and its temporal evolution as well as the wind's. The paper is structured as follows. Data and methods used are presented in section 2. Section 3 shows the results and gives an overview of the influence of the different parameters. At

the end, a conclusion is made in order to answer as precisely as possible to how fast we should move under rain to get as less wet as possible.

Before going on, it should be stressed that this paper is the outcome of a teaching project carried out by the first four authors of this paper as part of their undergraduate studies, under the supervision of the last author. This very basic real life problem actually enables to introduce various physical and geophysical notions to graduate and undergraduate students which makes it relevant for this journal.

2. Method and data

2.1. Overview

In this paper, we aim at computing the total mass of water collected by a 'human shape' while it is moving (simply translating) under rainfall and wind over a 1 km path. We assume that the shape is moving at velocities ranging from 1 to 10 m.s⁻¹. Hence, we have selected 20-minute rainfall events for this study, which corresponds to slightly more than the duration needed to cover the 1 km path at the lowest considered velocity. In order to better study the potential effect of the wind, we considered three types of path: (i) 1 km along the x-axis (towards East), (ii) 1 km along the y-axis (towards North) and (iii) 500 m along the x-axis followed by 500 m along the y-axis. The latter enables to account for the fact that real life paths are rarely in a single direction.

The model developed in this study relies on previous findings and notably the formalism introduced by [3] which is updated to account for DSD and wind temporal variability (section 2.3). In addition to the rainfall and wind conditions (section 2.2) a key parameter is the projected wet area of the considered shape in the direction of the relative drop velocity. Its computation as well as the more realistic body shape we used to model a human body are introduced in section 2.4.

2.2. Rainfall and wind data

Rainfall and wind are known to exhibit extreme variability in both space and time. In order to account for the temporal variability in this study, we used data collected on a meteorological mast located on Pays d'Othe wind farm which about 110 km southeast of Paris (France). An in-depth presentation of the whole data set as well as a link to download it are available in [5]. Only the required elements are summarized here.

The rainfall data is collected by a disdrometer which gives access to the size and velocity of falling raindrops. More precisely, the device gives access for each time step Δt of 30 s to the matrix $n_{i,j}$ which is the number of drops within the diameter class D_i and velocity class v_j . The width of the classes are denoted ΔD_i and Δv_j respectively. The effective sampling area is slightly dependant on the drop size to account for side effects and is denoted $S_{eff}(D_i)$. All the values can be found in [5]. Rainfall related quantities can be derived from the matrix $n_{i,j}$. Horizontal wind measurements are obtained from a 2D sonic anemometer inserted within a mini meteorological station. It provides data

each second along the \underline{e}_x (towards East) and \underline{e}_y (towards North) axes. To match rainfall data time steps, wind velocities are averaged over 30 seconds time steps.

Out of the three months of available data, 11 rainy days were selected and the 20 min time window that gathered the greatest cumulative rainfall depth within each day was manually extracted. An illustration of the used data is shown in Fig 1. It corresponds to data collected on 05/04/2021 starting at 11:39:00. The temporal evolution of the wind in m.s^{-1} along the two horizontal axes is in Fig. 1.a. The standard size/velocity map for the whole 20 min period is in Fig. 1.b. It can be seen that data is spread around the solid black line which is a standard relationship of the terminal fall velocity of drops vs. their equivolumic diameter [8]. The disparities in terms of both size and fall velocity of drops is visible and corresponds to what we want to account for. Indeed the differences in fall velocity result in differences in the relative velocity of the drop to the moving shape which affects how it gets wet. It is also possible to notice that the most numerous drops have an equivolumic diameter smaller than 2 mm. The temporal evolution of the rain rate in mm.h^{-1} is displayed in Fig. 1.c with 30 s time steps. For this specific 20 min period, it is stronger at the beginning.

2.3. Model to compute collected mass of water

The aim is to study the motion of a shape (later corresponding a human's body) going from point A to point B , separated by a length L . A Cartesian coordinate system is used ($\underline{e}_x, \underline{e}_y, \underline{e}_z$), in which \underline{e}_x is toward East and \underline{e}_y towards North and \underline{e}_z is the ascending vertical.

Let us denote \underline{u} (in m.s^{-1}) the velocity of the shape, \underline{v} , the velocity of the falling rain drops in 3D (see later for refinements) and ρ the liquid water content, i.e. the amount of water contained in a given volume (in kg.m^{-3}). The velocity of the drops are defined as follow: (i) the vertical component along \underline{e}_z is derived from direct disdrometer measurements (ii) the horizontal components are assumed to be equal to the wind's ones during each 30 s time step. This is a strong hypothesis that should be refined in future developments. More precisely, drops respond to wind fluctuations over few tens of seconds [6], but computations over 30 s should be carried out to confirm this assumption, notably because of the significant small scale wind fluctuations. For our study, we need to define various quantities. Firstly, the relative speed of the rain with regards to the shape $\underline{v}_{rel} = \underline{v} - \underline{u}$. Then the quantity $S_{pr}(\underline{v}_{rel})$, which is the projected area of the studied shape exposed to rain. It corresponds to the area really wet from rain. We define the rain density vector \underline{j} as follows:

$$\underline{j}(\underline{u}) = \rho \underline{v}_{rel} \quad (1)$$

1st Hypothesis: let us first assume a simple configuration with unique drop size and uniform wind, hence \underline{v}_{rel} is constant.

The flux of rain passing through a surface element dA is expressed as:

$$\delta\phi = \underline{j}(\underline{u}) \cdot d\mathbf{A} = \rho \underline{v}_{rel} \cdot d\mathbf{A} \quad (2)$$

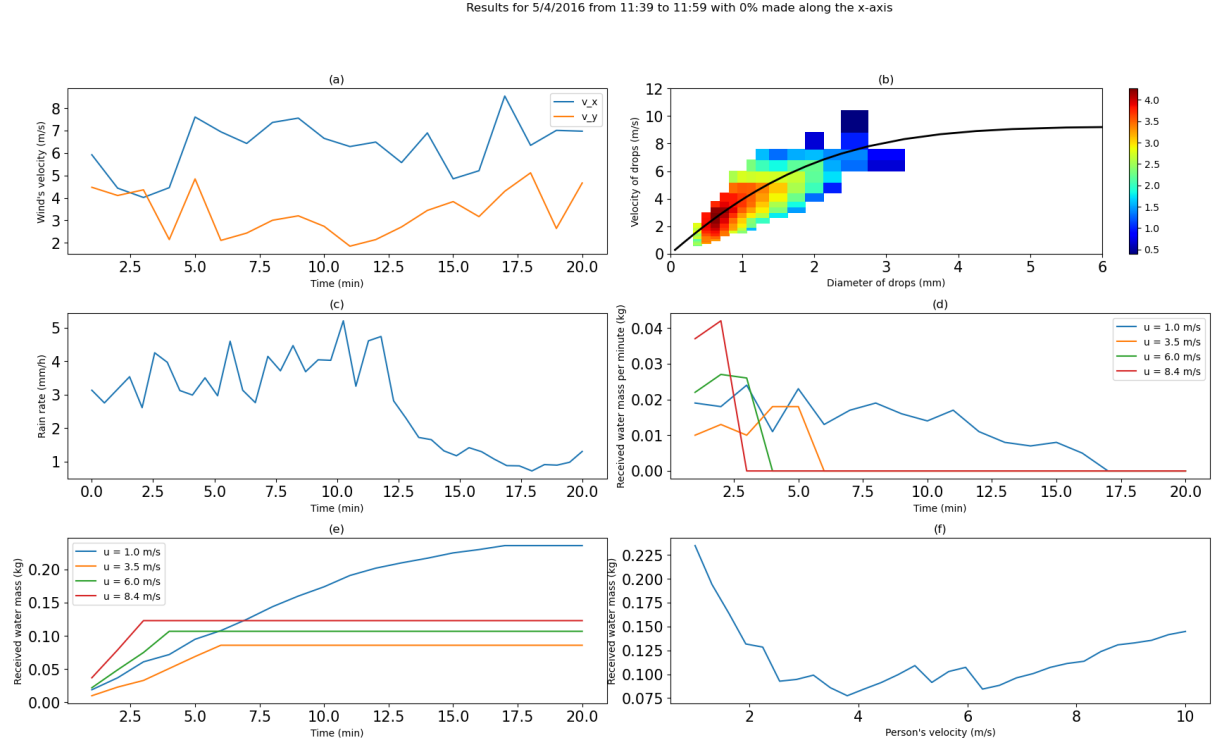


Figure 1. Study of 'human' shape moving 1 km along the x-axis for a rainfall event that started on 05/04/2021 at 11:39:00. (a) Temporal evolution of the horizontal wind in m.s⁻¹ with 30 s time steps. (b) Map of the number of drops according to the velocity and size classes of the collecting disdrometer. The solid black line is a standard relationship of the terminal fall velocity of drops vs. their equivolumic diameter [8]. (c) Temporal evolution of the rain rate in mm.h⁻¹ with 30 second time steps. (d) Temporal evolution of received water mass in kg with 60 s time steps for different velocity of the moving shape during its path. (e) The corresponding temporal evolution of total cumulative rainfall mass received by the moving shape. (f) Total collected rainfall mass as a function of velocity for this event

We integrate over the entire surface to obtain the total flux:

$$\Phi_{tot} = \int \int \rho \underline{v}_{rel} \cdot \underline{dA} = \rho |\underline{v}_{rel}| S_{pr}(\underline{v}_{rel}) \quad (3)$$

Finally, by multiplying by the time interval during which the shape is under the rain, $\Delta t = \frac{L}{u}$, we obtain a formula giving the mass of water received by the shape under uniform rainfall as a function of the shape's velocity:

$$m(\underline{u}) = \Phi_{tot} \Delta t = \frac{L}{u} \rho |\underline{v}_{rel}| S_{pr}(\underline{v}_{rel}) \quad (4)$$

2nd Hypothesis: now we account of the variability in size and velocity of falling drops as well as wind.

In that case, the contribution of all the drops should be decomposed according to their class of size and velocity. This is relevant to do this because the fall velocity of a drop changes with its size, which results in changes in \underline{v}_{rel} that affect the computation

of amount of received water (Eq. 1). We start by introducing the contribution of each raindrop diameter in the computation of the liquid water content for each time step (denoted $\rho_{\Delta t}$). This is achieved with the help of the DSD $N(D)$ ($N(D)dD$ corresponds to the number of drops per unit volume with a diameter between D and $D + dD$ in m^{-3}). Then the formula is discretized to account for the available data which is binned. More precisely $N(D_i)\Delta D_i$ corresponds to the number of drops per unit volume with a diameter D_i , where ΔD_i is the width of the raindrop diameter class D_i . This yields:

$$\rho_{\Delta t} = \rho_w \frac{4}{3} \pi \int_{D_{min}}^{D_{max}} N(D) \left(\frac{D}{2}\right)^3 dD = \rho_w \frac{\pi}{6} \sum_i N(D_i) D_i^3 \Delta D_i \quad (5)$$

where ρ_w is the water density. The discrete DSD for a time step Δt is computed as [5]:

$$N(D_i) = \frac{1}{S_{eff}(D_i) \Delta D_i \Delta t} \sum_j \frac{n_{i,j}}{v_j}. \quad (6)$$

which yields:

$$\rho_{\Delta t} = \rho_w \frac{\pi}{6 \Delta t} \sum_{i,j} \frac{n_{i,j} D_i^3}{v_j S_{eff}(D_i)} \quad (7)$$

Combining this equation with similar computation as with the simple 1st hypothesis, one can obtain:

$$\Phi_{tot,\Delta t} = \rho_w \frac{\pi}{6 \Delta t} \sum_{i,j} \frac{n_{i,j} D_i^3}{v_j S_{eff}(D_i)} |v_{rel}| S_{pr}(v_{rel}) \quad (8)$$

where $\Phi_{tot,\Delta t}$ is the total flux in $kg.s^{-1}$ of water received by the moving shape, and it is valid only for the duration of the 30-second time step Δt . Finally the total mass received by the moving shape is computed by simply adding the masses received during each time step $\Phi_{tot,\Delta t} \Delta t$. One should note that v_{rel} accounts for the velocity of the moving shape and the drops' ones, which are updated for each time step.

2.4. Calculation of the projected wet area

In order to compute the amount of rain collected by the moving body using Eq. 8, we need to evaluate the quantity $S_{pr}(v_{rel})$, i.e. the projected area of the studied shape exposed to rain. The method we developed to achieve this is explained in this sub-section and illustrated in Fig.2.

Let us first consider a given direction which would represent a rain drop falling direction. We first consider a vector in this direction and we check whether it intersects the studied shape. If the vector intersects the shape we add 1 cm^2 to the current wet area. Then we translate the vector by one centimeter on the plan orthogonal to this vector and we repeat the test to see if this new vector intersects our shape. By translating by 1 cm^2 in every direction on the orthogonal plan, we are able to estimate the wanted projected area in this direction, which is after converted in m^2 . Then, the

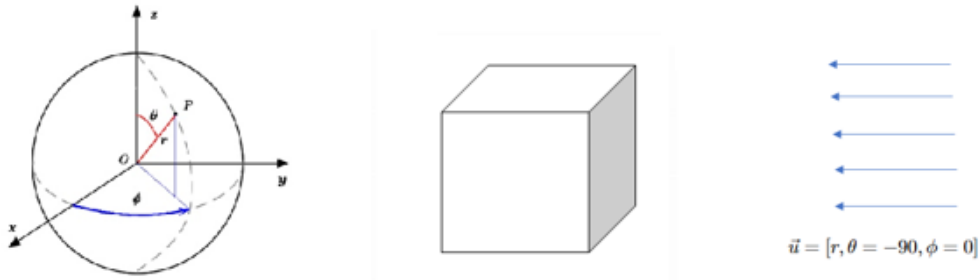


Figure 2. Illustration of the developed method to compute the projected area of the studied shape exposed to rain. (left) Reminder of the spherical coordinates used. (middle) Studied cube for this example (right) Used vectors for an horizontal direction (see text for more explanations).

process is repeated for all directions which are described by their angles θ ($[0, 360]$) and ϕ ($[0, 180]$) in spherical coordinates (in $^\circ$). Fig.2 illustrates the process for a cubic shape and horizontal direction. These vectors in blue would represent a direction corresponding to horizontally falling drops. It might not be realistic but it enables to better understand how it works. The wet area of this cube, i.e. the portion hit by the vectors, is colored in grey.

We first implemented this method with a sphere and rectangular cuboids in order to check the validity of the developed scripts on simple cases. Once we had these elementary shapes, we could build a simple 'body' made of a sphere for the head, and five rectangular cuboids for the trunk, the arms and the legs. With this body we used the same method and we eventually calculated the projected wet area for all directions without distinguishing the head and the body, unlike in [4]. Indeed, in this paper in addition to proposing a mathematical model of the issue which relies on a cylinder to model the human body, author suggest to introduce a difference depending on where on the body the water is received, i.e. either on the head or on the rest. Such discrimination is not accounted for here.

Figure 3 displays the evolution of the projected wet area for various directions for this 'human body'. On the left we have the area as a function of ϕ with $\theta = 90^\circ$ fixed, and on the right we have the area as a function of θ with $\phi = 90^\circ$ fixed. We also added images of wet area of the 'human body' for specific directions to help the reader grasp better the process and the shape. The wet projected areas is in white. Thus we can see that when $\phi = 0, \theta = 90^\circ$, the body is viewed from a side. When $\phi, \theta = 90^\circ$, the body is viewed from the front. When $\theta = 0, \phi = 90^\circ$, we see the body from above.

The results for all directions are shown in Fig. 4 which displays in a color map the projected area as a function of both ϕ on the x-axis and θ on the y-axis. These angles are displayed in tens of degrees on their respective axis. We can see that we obtain a maximum when the body is slightly oriented but not forward. This is mainly due to the fact that when we are slightly oriented, on top of being touched by the rain on our

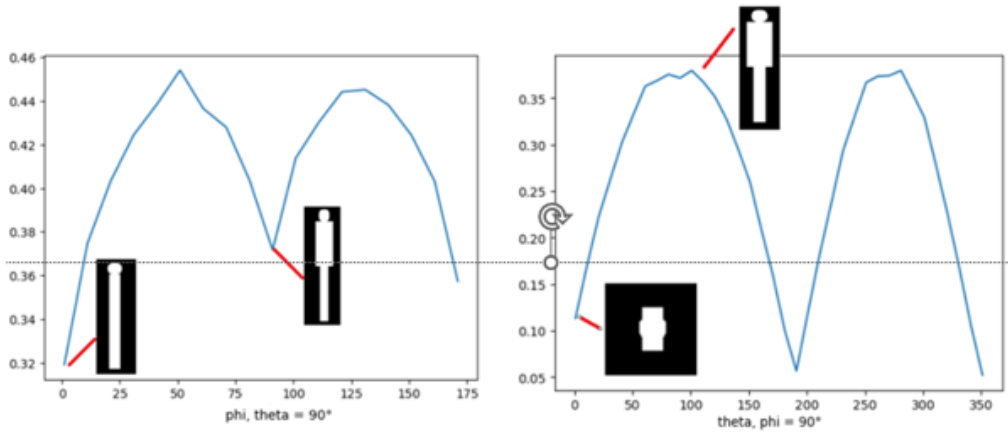


Figure 3. Area in m^2 in function of the angles in $^\circ$ for the studied 'human' shape. Shade for specific directions have been added for pedagogical purposes.

front, we also get wet on our side. So we eventually get wetter when the rain touches our side in addition of our front.

When implementing Eq.8, the direction of each \underline{v}_{rel} is first computed, and then the corresponding projected wet area is extracted from the matrix used to plot Fig. 4.

3. Results

3.1. Simplistic case case

In this first step, we tested the methodology developed with simplistic assumptions, i.e. a spherical shape, constant wind and rain rate with a unique drop size meaning that there is a single rain direction. Figure 5 displays the total mass of water received along the path as a function of shape velocity for four angles of rain direction. One can notice that for angles 60° , 90° , 120° the curves do not have a local minimum which would mean an optimal velocity. On the contrary, if we look at the angle of 30° (the blue curve), there is a local minimum for a velocity $4 \text{ m}\cdot\text{s}^{-1}$. It means that for this particular angle with tailwind (i.e. the rain coming from behind) there is an optimal velocity.

The existence of an optimal velocity that minimises the amount of water received depends on the direction of the raindrops. If we face the rain (headwind situations), running as fast as possible is the best solution. If the rain comes from behind, there is an optimal velocity which basically equals the component along the direction of motion of the raindrops velocity (which in this study is always equal to the speed of the wind along this same direction). These results are the same as those found in [3] which confirms that the developed scripts are working in the simple cases.

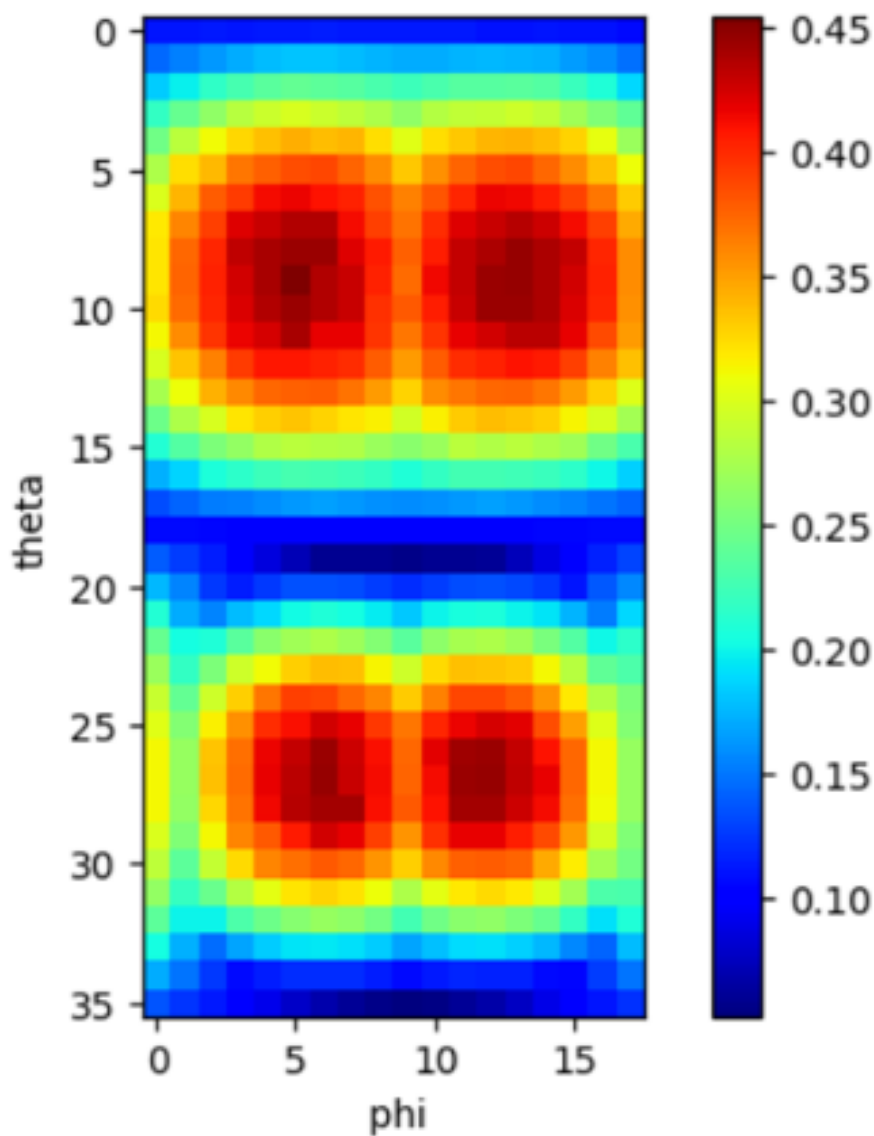


Figure 4. Color map of the Areas in m^2 as a function of the angles in spherical coordinates (values on the axis should be multiplied by tens to obtain their values in $^\circ$) for the studied 'human' shape.

3.2. Illustration of real life situation for three events

Now we get rid of the simplistic assumptions and consider the body shape presented in section 2.4, the whole disparities in size and velocity of raindrops and their temporal evolution as well as the wind's. Let us consider the event that started on 05/04/2021 at 11:39, and the body moving 1 km along the x-axis at various velocities. Results are summarized in Fig. 1 for which the meteorological data was already presented in section 2.2.

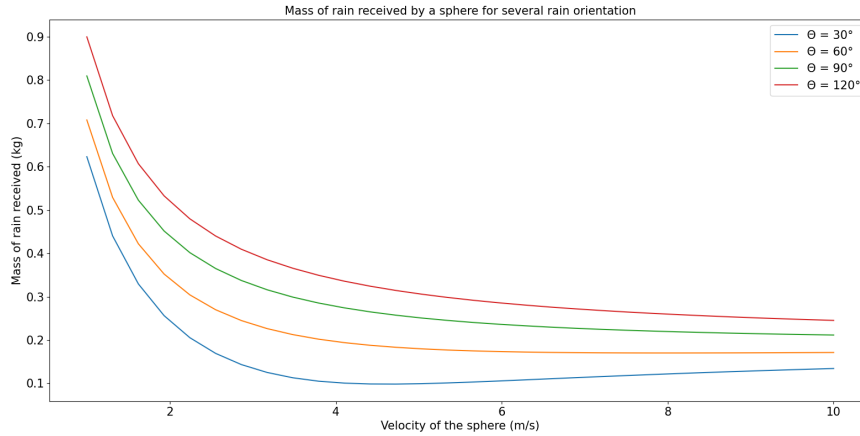


Figure 5. Mass of collected water by a sphere moving over a 1 km path under constant rainfall for various constant wind angles as a function of the velocity of the sphere.

Fig. 1.d displays the temporal evolution of received water mass per minute for different velocity of the moving shape during its path. The fluctuations we see come from variations in wind velocity and direction as well as variations in the rain rate and DSD features that we took into account. It can be seen that from a given time, the curves are becoming equal to zero. It simply means that the moving shape has reached its destination and is therefore no longer subject to rain. This obviously occurs more rapidly for greater velocities. Fig. 1.e shows the corresponding temporal evolution of total cumulative rainfall mass received by the moving shape. It can be seen that moving at a greater velocity generally results in getting more wet, but since you will remain under rain less time, it could be the best option. During this event, we clearly see that neither walking (blue curve) nor running fast (red curve) are the best solutions for staying as dry as possible. Fig. 1.f displays the total mass of water collected by the moving shape as a function of its velocity. In this case, we can find an optimal velocity of 4 m.s^{-1} which minimizes this quantity. During this event, the wind was coming from behind ($v_x > 0$) and the optimal velocity is slightly smaller than the wind's. It is also possible to notice that running really fast is still a better option than walking for this event.

Figure 6 displays similar plots as in Fig. 1 but for an event that started on 13/03/2021 08:20:00, again for a shape moving 1 km along the x-axis. It is basically a tailwind event ($v_x > 0$, Fig. 6.a) with a stronger side wind that the previously studied one. Even with the shape moving with wind coming from the back it is better to run as fast as possible as shown on the last in Fig. 6.f. It is agreement with some existing results [3] saying that the existence of an optimum velocity depends not only on the wind direction but also on the raindrop sizes.

Figure 7 displays similar plots as in Fig. 1 but for an event that started on 19/03/2021 04:39:00, again for a shape moving 1 km along the x-axis. It is basically

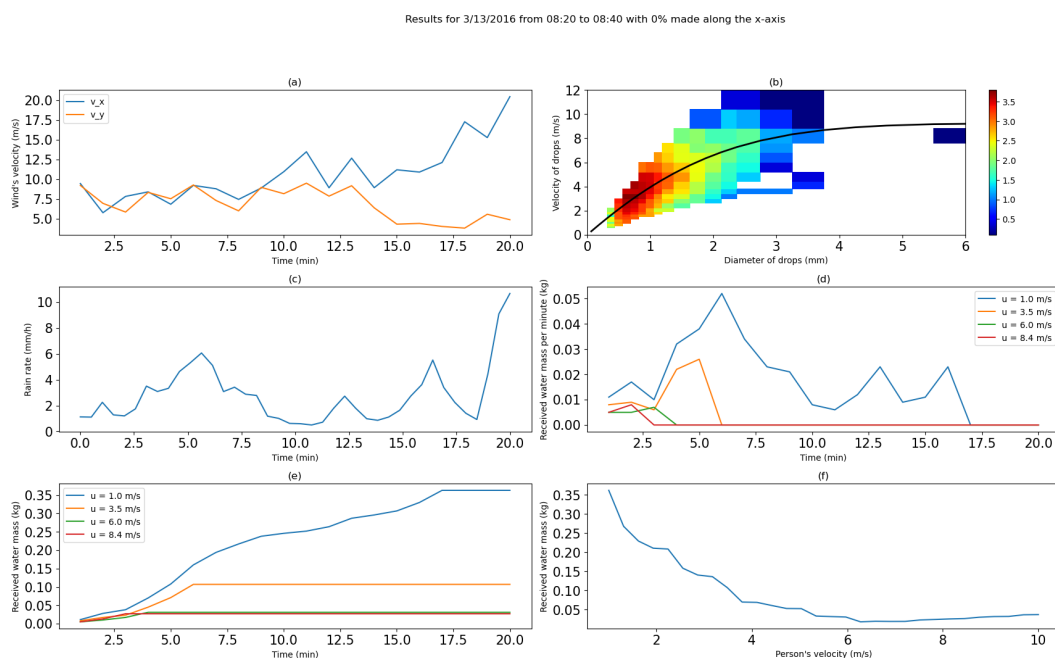


Figure 6. Same as in Fig. 1 but for an event that started on 13/03/2021 at 08:20:00

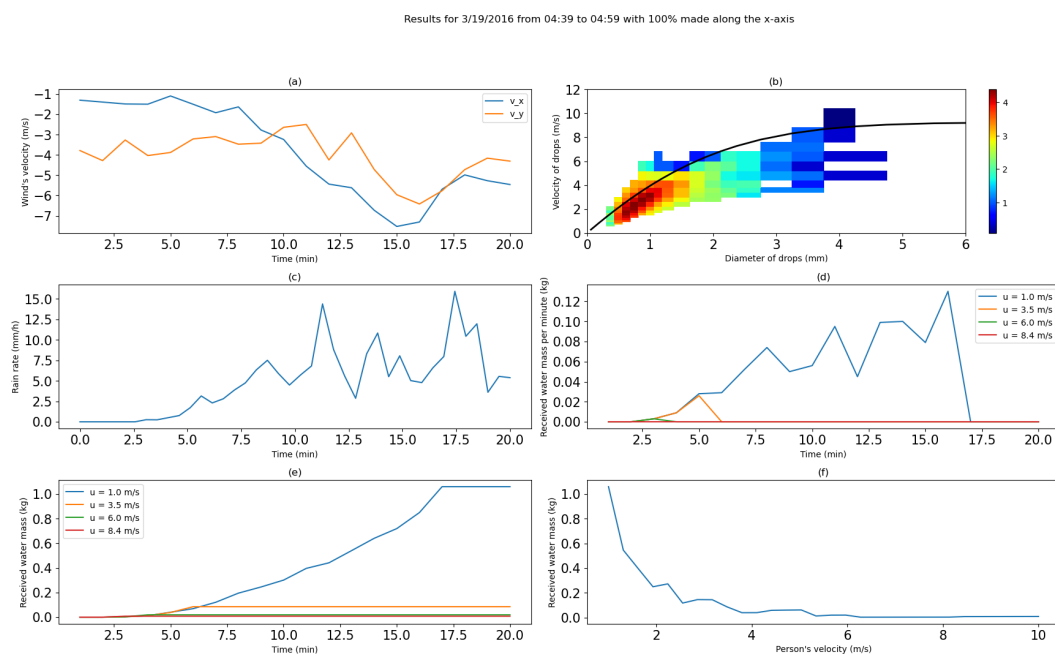


Figure 7. Same as in Fig. 1 but for an event that started on 19/03/2021 at 04:39:00

a headwind event ($v_x < 0$, Fig. 7.a). Even with droplets smaller than the previously discussed event (Fig. 7.b), there is no optimum (Fig. 7.f). The result we obtain agrees with the well known one that with in a headwind situation the best option is to run as fast as possible.

	Along y			Along x and then y			Along x		
	Average wind speed in m/s (vy)	4->12 km/h	12->18 km/h	Average wind speed in m/s (vx;vy)	4->12 km/h	12->18 km/h	Average wind speed in m/s (vx)	4->12 km/h	12->18 km/h
11-mars	10.7	-78,3%	-32,8%	11,6;5,5	-73,9%	-25,2%	5,3	-73,4%	-19,8%
12-mars	4,1	-66,7%	-5,5%	3,1;10,2	-63,7%	-4,2%	9,4	-51,7%	-10,7%
13-mars	6,9	-59,8%	-50,9%	6,0;8,4	-56,5%	-43,7%	10,7	-46,9%	-36,7%
15-mars	2,9	-86,1%	30,4%	2,8;8,3	-84,6%	15,0%	8,2	-84,9%	3,4%
19-mars	-4,0	-84,1%	-35,4%	-4,6;-1,8	-83,7%	-34,2%	-3,8	-84,2%	-28,6%
11-avr	5,1	-74,9%	-4,8%	5,3;2,2	-56,6%	-21,8%	1,6	-45,8%	-19,3%
28-avr	0,3	-0,7%	5,3%	0,0;1,1	-51,8%	19,0%	1,1	-72,0%	3,8%
04-mai	3,4	-55,8%	27,0%	3,4;6,1	-36,3%	-10,8%	6,3	-36,3%	-9,4%
16-mai	0,4	-14,6%	21,7%	1,0;12,8	-44,0%	15,7%	11,1	-44,4%	-16,6%
24-mai	4,8	-39,4%	-25,1%	4,4;7,9	-14,7%	-39,0%	6,1	-0,6%	-7,4%
26-mai	4,4	-73,3%	-17,6%	4,4;6,4	-66,1%	-11,8%	6,4	-58,8%	-27,0%

Figure 8. Summary of the 'gain' associated with going from 'walking' to 'running' and 'running' to 'sprinting' for the three paths (1 km along x-axis, 500 m along x-axis followed by 500 m along y-axis, 1 km along y-axis) and 11 studied rainfall events.

3.3. Summary for all events

Figure 8 displays a summary of the results for the 11 studied events and the three types of path tested (1 km along x-axis, 500 m along x-axis followed by 500 m along y-axis, 1 km along y-axis) resulting in a total of 33 scenarios. The average wind velocity in the corresponding axis direction is reported. Three velocities are tested to interpret results: (i) 4 km.h^{-1} , called 'walking' after, (ii) 12 km.h^{-1} , called 'running' after, and (iii) 18 km.h^{-1} , called 'sprinting' after. For each scenario, the change expressed in percentages of total collected water mass when the human shape goes from 'walking' to 'running' is computed. A negative value corresponds to a decrease of collected water (you will be less wet) while a positive one corresponds to an increase (you will be more wet). The same figure while going from 'running' to 'sprinting' are also displayed.

It is always better to 'run' than to 'walk', with a decrease of up to 86% of collected water. In more than 2/3 of the scenarios the decrease in wetness is greater than 50%. It should be noted that for two scenarios the decrease is lower than 1 %.

The situation while going from 'running' to 'sprinting' is much more contrasted. Indeed in 9 scenarios, there is optimum moving velocity lower than 18 km.h^{-1} meaning that you will be more wet if you sprint. In the other cases, there are 14 scenarios with a decrease smaller than 20 %.

4. Conclusion

We have proved that the question whether it is better to walk, run or sprint under the rain is not just a yes-or-no question, but actually depends on many parameters that must be accounted for. These developments enable to quantify some expected results on how fast we should run under the rain. If it looks obvious that at a certain speed we will get less wet, it is interesting to quantify and understand the phenomena while enabling to get familiar with the notion of drop size distribution and wind fluctuations. In our model, we account for actual wind variability, actual size and velocity of falling drops and a more complex shape looking more similar to a human body than in previous

papers. We found that in most cases there is no optimum moving velocity and that you should run as fast as possible to get less wet. However, in light rain and tailwind situation, an optimum may exist. In all the studied scenarios 'running' instead of 'walking' results in a decrease of wetness, which is significant (i.e. greater than 50%) in 2/3 of the cases. On the contrary 'sprinting' instead of 'running' does not always result in less wetness and low gains are generally expected. This suggests that the extra effort required to 'sprint' is not necessarily worth it.

More events should be studied using our model to derive more robust estimates of percentage of gains according to the increase in velocity. In addition future investigations are needed to fully address this daily issue. The idea of Peterson and Wallis [10] of taking into account the fact that running implies leaning forward could be studied. More generally, using a shape that changes while moving and is not simply translating would be more realistic. In addition the size of the shape should also be accounted for, which also results in different velocity in the movement as it was done in [9]. More complex paths than a simple straight line or two perpendicular ones should also be tested. Currently, only the temporal variability of the rainfall is accounted for which is a strong limitation. Accounting for spatial variability will be a challenge. In addition, the effect of studied shape on the local wind around itself which can then affect the drops' trajectories and hence the wetness could also be investigated. This would require the use of computational fluid dynamics models. Even though the final answer is likely to be to run, these exciting opportunities of future investigations show the strong potential of this simple daily life issue to continue exploring various fields of physics, mechanics and geophysics; and introduce complex notions and methods to graduate and undergraduate students. Another issue that was not accounted for is the possibility of a person slipping on a wet ground if he/she runs. Investigating this issue would require to consider the friction between shoes and the wet ground, and also to introduce a notion of risk. This would create a new optimal speed which depends on the probability of the individual of falling based on their speed. The type of ground would then be another determining factor given that the probabilities of slipping on wet grass and on wet concrete are not the same. Such considerations are outside the scope of the current paper, but they should definitely be accounted for in future investigations on the topic.

In this paper, we assumed from scratch that the overall goal was obviously to minimise the amount of rainfall collected by the human moving outside while it is raining. Developing an approach to implement this strategy enables to dig into some of the mysteries of geophysics which is intellectually satisfying. However, it should be stressed that it is not the only strategy possible and someone can simply choose to enjoy staying under the rain, to feel the drops falling on its skin, dance or sing. The latter approach does not require any computation and corresponds to another way of enjoying rainfall whose complete description is outside the scope of the paper.

5. Acknowledgements

The authors gratefully acknowledge partial financial support from the ANR JCJC RW-Turb project (Grant number: ANR-19-CE05-0022-01).

6. References

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