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Dear Reviewer,

We would like to thank you for the careful and constructive assessment of our manuscript (hess-2022-313). We are also grateful to you for your insightful and valuable comments. Following these suggestions, we have revised the manuscript as detailed in the next pages. We thank you and also welcome your further questions and comments.

Sincerely,

Reviewer comment (italicized) is followed by a response.

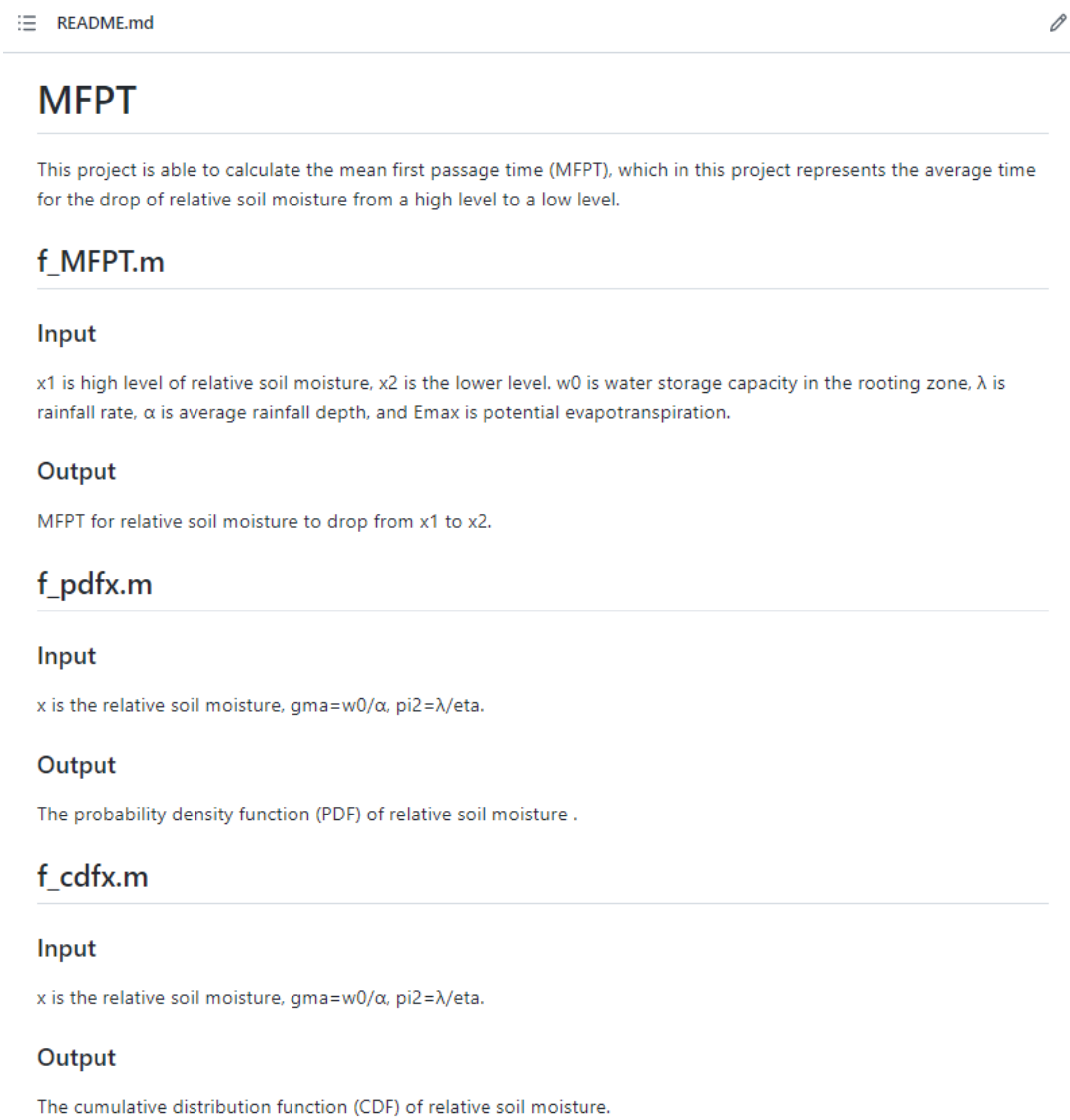
General comments:

The manuscript is written in good English and overall is well structured. The authors provide extensive literature review and good methodological description

We thank the reviewer for the positive comments and encouragement.

- *Please improve your code documentation and comment.*

The code documentation has been revised. A screenshot of the documentation is reported below and further information can be accessed from “github.com/yxshot/MFPT”.



README.md

MFPT

This project is able to calculate the mean first passage time (MFPT), which in this project represents the average time for the drop of relative soil moisture from a high level to a low level.

f_MFPT.m

Input

x1 is high level of relative soil moisture, x2 is the lower level. w0 is water storage capacity in the rooting zone, λ is rainfall rate, α is average rainfall depth, and Emax is potential evapotranspiration.

Output

MFPT for relative soil moisture to drop from x1 to x2.

f_pdfx.m

Input

x is the relative soil moisture, gma=w0/α, pi2=λ/eta.

Output

The probability density function (PDF) of relative soil moisture .

f_cdfx.m

Input

x is the relative soil moisture, gma=w0/α, pi2=λ/eta.

Output

The cumulative distribution function (CDF) of relative soil moisture.

Figure 1 The screenshot of the documentation.

It is my opinion that the manuscript has no major technical flaws. Nevertheless, our recommendation is for Minor Reviews.

Specific comments：

Fig 4. Please improve the colour scheme, as the points in New York and Heyuan are barely visible.

Thank you for pointing this out. We used a new color scheme and also provided two insets for New York and Heyuan. The new map will be updated in the revised manuscript and is reported below.

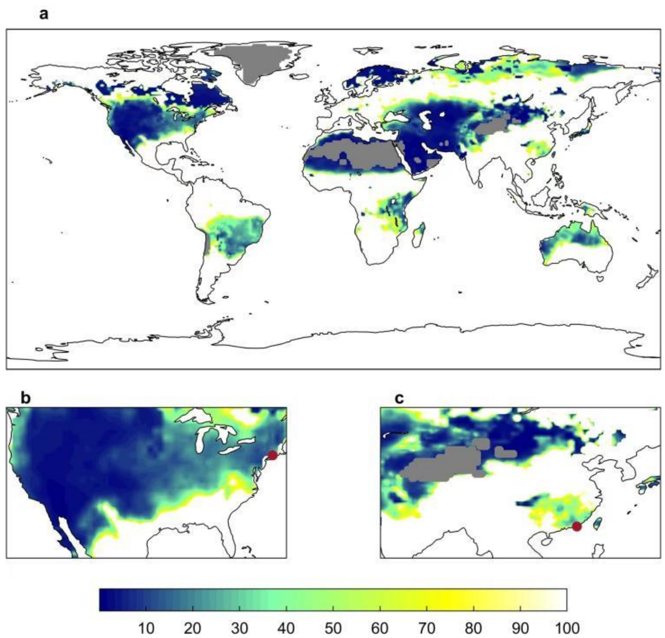


Figure 2 Global distribution of mean first passage time (MFPT) in summer. The two points marked in red are New York State, USA, and Heyuan City, China. The gray areas are hyper-arid regions, other colored areas are those where the MFPT of soil moisture drops from 40 to 20 percentiles in less than 100 days. Desert regions (grey areas) are excluded from this analysis.

Fig 4. Why did you use a limit of 100 days in the scale? Normally flash droughts intensification period is limited to up to 30 days (Osman et al, 2021; Ford and Laosier, 2015, Lisonbee et al, 2021).

Good point. We cited these references to clarify that flash drought is usually up to 30 days.

However, it is still possible to have a flash drought for large MFPT, which only tells the long-term averages of the intensification period. To address this point, we also derived the variance of the first passage time (VFPT) as

$$\sigma^2_{x_1\downarrow x_2} = \int_{t_{\min}}^{\infty} (t_{x_1\downarrow x_2} - \bar{t}_{x_1\downarrow x_2})^2 f(t_{x_1\downarrow x_2}) dt_{x_1\downarrow x_2}$$
$$= (t_{\min} - \bar{t}_{x_1\downarrow x_2})^2 e^{-\lambda t_{\min}} + (1 - e^{-\lambda t_{\min}}) \left[2\beta^{-2} + (t_{\min} - \bar{t}_{x_1\downarrow x_2})(t_{\min} + 2\beta^{-1} - \bar{t}_{x_1\downarrow x_2})\right].$$

As shown in Figure 3 below, VFPT has similar spatial patterns as MFPT. The limit is set to 100 days in order to show as much as possible the areas where flash droughts are likely to occur. We will incorporate these results in the revised manuscript.

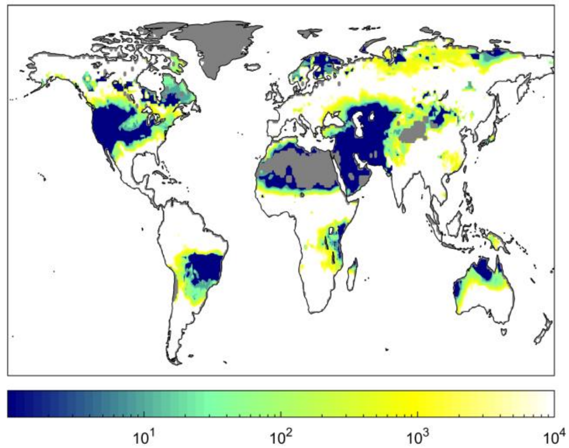


Figure 3 Global distribution of the variance of the mean first passage time (VFPT) (units: day^2).

Fig 4. By using the metric of Mean First Passage Time (MFPT), some areas end up showing no actual flash droughts. Please consider showing the 10th percentile of first passage time, that would show the expected occurrence in more areas.

Thank you for the suggestion.

Similar to the VFPT as shown in Fig. 3, the 10th percentile suggested by the reviewer could also be a useful indicator to quantify the uncertainties of the drought intensification period. However, there is one technical problem regarding the atom probability of this first passage time. As shown in Fig. 2c in the manuscript and also reported below in Fig. 4, the whole distribution is neither continuous nor discrete but a mixed one. The atom probability is associated with the condition where there is hardly any rainfall before the soil moisture drops to the threshold. It is possible that the 10th percentile just falls into this atom probability and ends up as t_{min}. To provide a more accurate quantification of the drought intensification period, we will include both MFPT and VFPT maps in the revised manuscript.

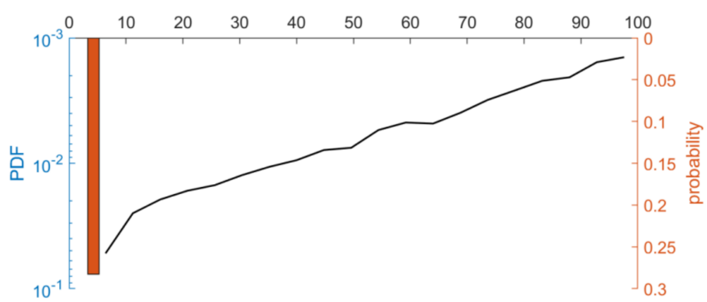


Figure 4 The corresponding distribution of first passage time (sample size of 1000).

Fig 4. Please justify the very low MFPT in semi-arid regions, such as southern India, northern Namibia/Botswana and northeast Brazil.

We are not quite sure if we understand this comment correctly.

As shown in Figure 2 above, the MFPT in southern India, northern Namibia/Botswana, and northeast Brazil are quite high (i.e., close to or higher than 100 days, see). Aside from climate conditions, the long crossing time in these regions may be associated with deep rooting depths (see root-zone storage, w_0, in Figure 5 below), which acts as a buffering zone to reduce the variation of soil moisture and thus increase the time for drought intensification (e.g., Laio et al. 2001). We will clarify the role of rooting depths in the revised manuscript.

Please feel free to correct us if we misunderstood your comment. Thank you again!

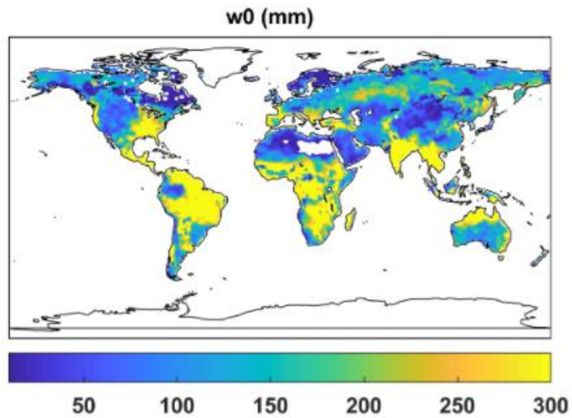


Figure 5 Global distribution of soil water storage capacity (units: mm), which is used to calculate global MFPT.

References

Laio, F., A. Porporato, C. P. Fernandez-Illescas, and I. Rodriguez-Iturbe, 2001: Plants in water-controlled ecosystems: active role in hydrologic processes and response to water stress IV. Discussion of real cases. Adv. Water Resour., 18.