Reply to reviewers - Second round

Review of HESS 2024-110

Observation-driven model for calculating water harvesting potential from advective fog in (semi-)arid coastal regions.

By Felipe Lobos-Roco, Jordi Vilà-Guerau de Arellano, and Camilo del Río.

Reply to Editor

Editor decision HESS-2024-110

Dear authors, two referees have assessed the revisions you made to the manuscript, one of them being mostly satisfied except a couple of remaining remarks, the other not entirely. When reading the revised manuscript myself I ran into a couple of issues that made it hard to understand the reasoning. I ask you to address the comments and suggestions made by reviewer #1 and address additional comments as follows (line numbers refer to manuscript version with tracked changes):

Dear editor, we appreciate very much that you took the time in reading and reviewing the paper. We have read the comments of reviewer #1 and your own comments and we have carefully addressed all of them, and we have modified the paper accordingly. Below, in blue font, you will find our responses, including the line numbers where changes were made in the revised version of the manuscript.

- Line 51: "one of the main physical involved in.." : noun missing after physical

We have modified the sentence as follows: "Here, one of the main physical **processes** involved in stratocumulus formation is the microphysical properties of cloud droplets,".

- Line 53: <50cm^{-3} 50 cm^{-3} …Is there a typo here?

Agree, the misspell have been corrected.

- Line 56-57: please explain why the MBL has to be well mixed for advective fog formation? You provide a very strict limit for well-mixed versus stratification (<3.1 10^{-3} K/m) – how accurate and how generally valid is this limit? Please clarify.

The sentence on lines 56-57 indicates that stratocumulus formed and maintained over the ocean, move (advect) over land and lead to fog formation. Since conserved variables are well-mixed below the stratocumulus deck, we assume the same condition over land. Regarding the thresholds mentioned ($\partial\theta/\partial z$ and $\partial q/\partial z$), Lobos-Roco et al. (2018) studied these in the Atacama region based on observation of fog collection and meteorological data on a topographic transect. In the study, the authors define two MBL layer regimes related to fog formation and dissipation when MBL is either well-mixed or stratified. These thresholds were calculated during nine advective fog events in the Atacama region during all seasons in 2015 and validated using fog collection observations.

- Iine 60-61: you state that liquid water content peaks at the cloud top at ~0.7g kg^{-1} Same question here: please clarify how generally valid is this statement

0.7 g kg^{-1} is the maximum mean liquid water content observed on a vertical profile over marine stratocumulus in several studies. For example, Duynkerke et al. (1995) in the north Atlantic and recently Schween et al. (2022) in the coastal Atacama region. To clarify the sentence we have modified it as follows:

"From the lifting condensation level to up, the measured liquid water content progressively rises. Based on observations in the same region, we take 0.7 g kg^{-1} at cloud top as the maximum value (Schween et al., 2022)"

- In section 2 (lines 85-90): please explicitly state the aim of the model here.

We have modified the sentences in line 85-90 as follows:

"The AMARU reproduces the fog that can be potentially harvested using standard fog collectors, estimating the liquid water content of the air. A particular aspect of AMARU is to apply the available routine meteorological observations to obtain this liquid water content. The model is based on the evolution of time and the height of marine stratocumulus adiabatic liquid water content moving towards land characterized by complex topography."

- For the equations: make sure to explain all symbols used in the equations and clarify their units

Thanks, we have checked and made small changes to clarify.

- The term "fog occurrence" is used a lot without explaining the reference time period for which the frequency is calculated (frequency is typically defined as nr of occurrence per time period). Please provide a clear definition of fog occurrence

We understand the Editor's concern to make it clearer, we have added the following sentence at line 140-142:

"We define fog frequency as the number of counts when fog is present over a timestep (in an hour), expressed in percentages. For example, 50%'s fog frequency means that fog occurred during 30 min over an hour. "

- Figure 3: clarify what data (and model outputs) are behind the statistics shown in the Taylor diagram, incl the number of data points used. In the figure caption clarify which "line" you mean in "Note that … placing behind the line and …."

Agree, we have modified the caption of Figure 3 as follows:

"Figure 3. (a) Taylor diagram comparing the proposed criteria and thresholds for estimating fog frequency (%). The diagram deploys correlation (r), standard deviation (in FF units, %), and root mean square error (RMSE in FF units, % %) between the criteria-thresholds and observations. The number of data points used is 8760, which corresponds to hourly data over a year. (b) Comparison of the annual diurnal cycle of fog occurrence between observations (SFC) in blue and the best-performing criteria in black. Every black/blue mark represents the presence (100% of frequency) at every hour during 2018. Note that numbers 11 and 12 have a slightly negative correlation, placed behind (left) to the Taylor diagram y-axis."

- Section 2.1.1 Fog cover fraction frequency. Consider using a different term. What is a "fraction frequency.."?

The term "fog cover fraction frequency" was thought to be like cloud cover fraction. However, we agree it can induce confusion, so we have modified it simply as "fog frequency".

- In 2.1.1. percentages are used to for occurrence (In line 156: fog occurrence (in %) – why not frequency as before? Especially because you % a lot in section 3 to discuss disagreements between observations and model. It can be confusing..

We agree, we have defined fog frequency to avoid this confusion.

- Equations 9 and 11: are you sure these constants are accurate enough to use so many digits? Also, make sure to explain how these constants were determined.

The constants result from the linear regression model obtained from the relation between the observed cloud base and top during the GOFOS experiment. We decided to use the full decimals to be more accurate. To be more explicit, we have modified the following sentence in line 229-230:

"Equation 9 shows a linear regression model in which CT [m] solely depends on CB [m], where constants are determined from the relation between observed CB and CT during the GOFOS experiment.".

- Section 3, line 356: “disagreements with observations by 1% to 20%. The units in the figure are not %, so these percentages refer to what, exactly..?
-

In section 3 line 356, the percentages between 1% to 20% refers to the differences of annual daily rates of fog collection between model and observations. This is explained in the lines after, where, for example, observations in site a is 5.5 L m^{-2} and model 5 L m^{-2}, then the model disagrees by 10%. To avoid confusion with frequency and efficiency, which are also in %, we decided to leave the comparison here in L m^{-2}.

- line 361, 362: errors around 0.39 $lm^{-2}d^{-1}$(20%), (…) errors of 2 $lm^{-2}d^{-1}$ (18%). Where exactly do these values come from? What do the %-s mean, % of what?

To avoid confusion, we will remove the comparison in % and only leave the ones in L m^{-2}. These numbers refer to the differences between monthly averaged fog collection daily rates (L $m^{-2}d^{-1}$), shown in Figure 7. The 0.39 L $m^{-2}d^{-1}$ is the mean difference between model and observations for summer months (January and March), whose difference is about 20%. .

- Line 364: observed rates 4 to 9 (..) – I can’t relate this range to the figure, for site A? How did you find the range that you’re reporting here?

These numbers 4 to 9 and 6 to 10 L $m^{-2}d^{-1}$ refer to the error bar length (black vertical line over the plot) during spring (September to November).

By reading to the last three comments, we have introduced several changes in section 3.1 to explain the comparison between observations and modeling clearer and more explicit.

General comment: make sure to check spelling and grammar throughout the document. There are many instances where plural is used instead of singular and vice versa, in some sections past and present tense are mixed.

Agree. To improve the readability, we have re-checked the entire manuscript looking for spelling errors with a native English language editor.

Reply to Reviewer #1

General comments.

Most of my concerns with the initial version have been addressed and the AMARU model appears to be useful for practical estimation of water harvesting. There are some places in the revised manuscript where minor changes could be made to improve clarity and some suggestions are given below.

We are grateful to have addressed most of the reviewer's initial concerns and thank him for his valuable contribution to improve our manuscript through the alternative analysis. Regarding the new minor comments, we have accepted all the reviewers' comments, corrections, and suggestions, resulting in the corresponding changes in the manuscript. Below, in blue font, you will find our responses, including the line numbers where changes were made in the revised version of the manuscript.

Detailed comments

- line 8 "is ≤50 cm −350 cm −3 " repetition.

Agree, the misspell have been corrected.

- line 56 "how well-mixed (<3.1 x 10 -3 K -1) the MBL.." Make it clear that this is ∂θ/∂z, and introduce "potential temperature".

Agree, we have modified the sentence as follows:

"Formation and maintenance depend on how well-mixed the MBL is in terms of potential temperature ($\partial\theta/\partial z < 3.1 \times 10^{-3}$ K m^{-1}) the MBL is, while the dissipation is influenced by its stratification ($\partial\theta/\partial z > 3.1 \times 10^{-3}$ K m^{-1}) (Lobos-Roco et al., 2018)."

- line 59 "As the latter increases, the liquid water content progressively..." The LCL or just height?

The way the phrase is written results in confusion, we decided to modify as follows:

"From the lifting condensation level to up, the measured liquid water content progressively rises. Based on observations in the same region, we take 0.7 g kg^{-1} at cloud top as the maximum value (Schween et al., 2022)"

- line 90 If F in is a flux it should be per unit area"

The unit of the flux is g kg^{-1} m s^{-1}, which after multiplied by air density it ends as L m^{-2} s^{-1}, as is explained in line 103.

- line 97 Why add in std?

We understand the reviewer's concern. Mathematically, we should use the perpendicular mean wind ($\overline{u_x}$). However, in reality, fog can also be collected with a tilted wind respect to the perpendicular. To include this effect, we add the standard deviation to amplify the range of fog influx.

- line 119 "through"

Agree, corrected.

– line 124 "devices"

Agree, corrected

– line 140 maybe ".. the potential temperature gradient (∂θ/∂z)" ...

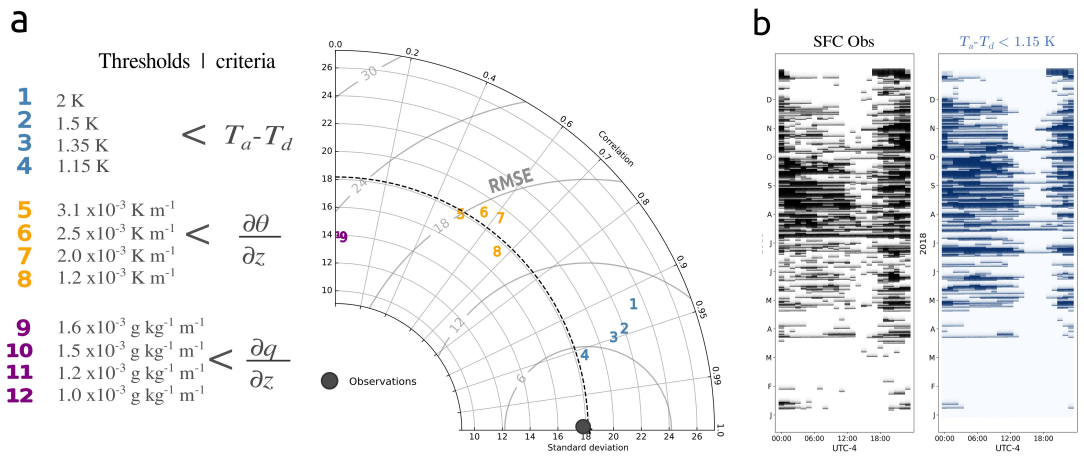
Agree, corrected

– line 142/3 Is q the (water vapor) mixing ratio or specific humidity? Virtually the same but best to be consistent. Also well mixed potential temperature.

Agree, corrected

– Figure 3 Units for ∂θ/∂z and ∂q/∂z thresholds.

Agree, The unit thresholds have been included



– line 150 Case 4 is a dewpoint depression of 1.15K, not 1.5 K?

Agree, corrected

– line 159/160 If there is no fog ∂q/∂z could have any value and once fog is formed q = qs (saturation mixing ratio), but T dependent and not well mixed. I am nor sure what to read into +not contingent"

We agree that this sentence leads confusion. We decided to delete it to improve the paragraph readability.

– line 179 I suspect a typographical error in Equation (8), One of the "1-" expressioins should probably be removed!

Agree, the equation has been corrected as it is in Lobos-Roco et al., (2018)

– line 189/190 the "uplifting" in Fig 2C will depend in part on the topography - airflow over the mountain or through gaps? Is the 3D terrain structure taken into account?

The uplifting shown in Figure 2C depends on the topography where the z_2 station is located. In the manuscript, we test the model over three sites where the z_2 station is located over the mountain and

not through gaps (valleys). Then, the uplifting results from the combination of potential temperature between z_1 and z_2. Here, if z_2 is warmer than z_1, then the combined potential temperature of MBL (z_1 and z_2) will also be warmer, and consequently, LCL will be reached at a higher height. For calculating the vertical profiles of r_l or W_h, the model do not take into account 3D topography. However, as explained in section 2.3, we combine vertical profiles of r_l or W_h with topographic 3D model and the GOES fog and low cloud algorithm to approach to represent fog collection in the space.

– p10,11 CB estimates seem better than CT. CT will depend on many factors, such as the initial humidity profile when the stratus clouds were forming.

We agree with the reviewer that CT will depend on many factors. However, for simplicity, in this model, we opted to estimate the cloud top based on the relation between observed CB and CT (equation 9), which we have improved by including two factors: fog frequency (equation 10) and potential temperature gradient (equation 11). We are aware that CT calculation needs to be improved in further research with more accurate CT measurements, which is discussed in section 4 (model limitations and challenges).

– One concern would be Equation 12. Once cloud or fog has formed I would expect 100% relative humidity and, with $r_v = r_s$, Eq (12) would give zero liquid water mixing ratio. I think we are to assume that r_v is the surface level (z_1) mixing ratio and represents the mixing ratio of the air before the stratus cloud had formed.

– line 242 Need more explanation of the basis for Equation(12).

Equation 12 is only applied above the LCL. LCL is defined by RH=100 (r_v-r_s=0). As a first approximation (r_v is not a conserved variable, but very close to a conserved variable specific humidity), r_v is constant with height. Between LCL and cloud top, any excess of r_v with respect the change of r_s (T) results in r_l.

We have introduced the following changes in line 253-256 as follows:

"where r_v is the mixing ratio between grams of mass water vapor by kilogram of dry air, r_s is the saturated mixing ratio, and z represents the vertical level between CB and CT (Fig. 2a). Here, since r_v is very close to be a conserved variable (r_v~q_v), it is assumed as constant over the cloud layer. Therefore, any excess of r_v with respect the change of r_s (T) will result in r_l."