Answer to referee 1

Dear referee,
Thank you for taking the time to review the manuscript and for your relevant and numerous suggestions. You will find below the answers to your comments.
(Unless otherwise specified, figure numbers cited in this response document refer to the figures in this document and not to those in the original manuscript.)

The system is innovative and allows for targeted process studies under controlled conditions. Its strengths include the ability to monitor the total water balance, pore and seepage water quantity and quality, and soil gas concentrations, as well as the ability to modulate environmental conditions over a wide range. The system's weaknesses are the small size and shallow depth of the lysimeters; the lack of soil temperature control, which prevents a natural vertical soil temperature gradient; the inability to freeze; and a lighting system that provides only about 25% of full sunlight intensity.

Thank you for recognizing the strengths of the system, as well as its weaknesses. Some of the weaknesses that were pointed by you and other referees are, in fact, not mentioned sufficiently in the manuscript. To address this, we propose changing the structure of the discussion section to make it more pragmatic and to focus on the technical aspects of the platform. To do so, the last section ‘Experimental perspectives” was removed and the two new sections should offer a more technical approach.
As result, the new structure is the following one:

- 4.1 “Replication of atmospheric conditions and ecosystems”.
- 4.2 “Replication of soil ecosystems with mesocosms”
- 4.3 “Combination of mesocoms and ecotron”

The 4.1 section now allows for a more technical discussion on the limits of the atmospheric conditions replication that are already scattered in the manuscript or that were raised by yourself and the other referees. It addresses the following points:

- The maximum atmospheric conditions boundaries (temperature, relative humidity, light intensity and vertical distribution) / type of experiments
- The absence of wind
- The absence of pressure control
- Irrigation (intercept evaporation; flow rate)

The 4.2 section is rearranged to discuss more specifically the limits of replicating a soil ecosystem in mesocosms. It addresses the following points:

- Size of the mesocosm
- Lower boundary conditions / Upward water flow
- Wall effect
- The insulation of the mesocosm

The 4.3 section will discuss the main advantages of this facility compared to CZO or field experiments. It will also address the complementarity of the data.

We provide later in the answers a more detailed discussion to the limits that you pointed out, such as the absence of a natural vertical soil temperature gradient.

a lighting system that provides only about 25% of full sunlight intensity.

Our maximal light intensity is indeed too low (450 µmol m^{-2} s^{-2}). To tackle this, we added LED bars. We now have 29 bars, compared to 13 in the initial version. The maximal light intensity ranges now from 1114 to 1491 µmol m^{-2} s^{-2} for the least and most illuminated mesocosms, respectively. We should be able to provide a mapping of light intensity in the revised version of the manuscript.

The data presented in the Results section seem somewhat arbitrarily selected. It would be helpful to include example data from different climatic conditions.

Indeed, we intended to select results that we considered demonstrative. We recognise that this does not facilitate reading and may raise doubts about the robustness of the system. To address this, we have completed the results section with the following informations:

- **A simulation of real atmospheric conditions**

In the initial manuscript, we arbitrarily created an artificial climate that allowed strong variations that are not necessarily present in a real climate. Therefore, we chose now instead to simulate a real french climate from meteorological data, that still offers substantial daily variations. We propose to show in the results the following Fig. 1 displaying the temperature and hygrometry simulations.

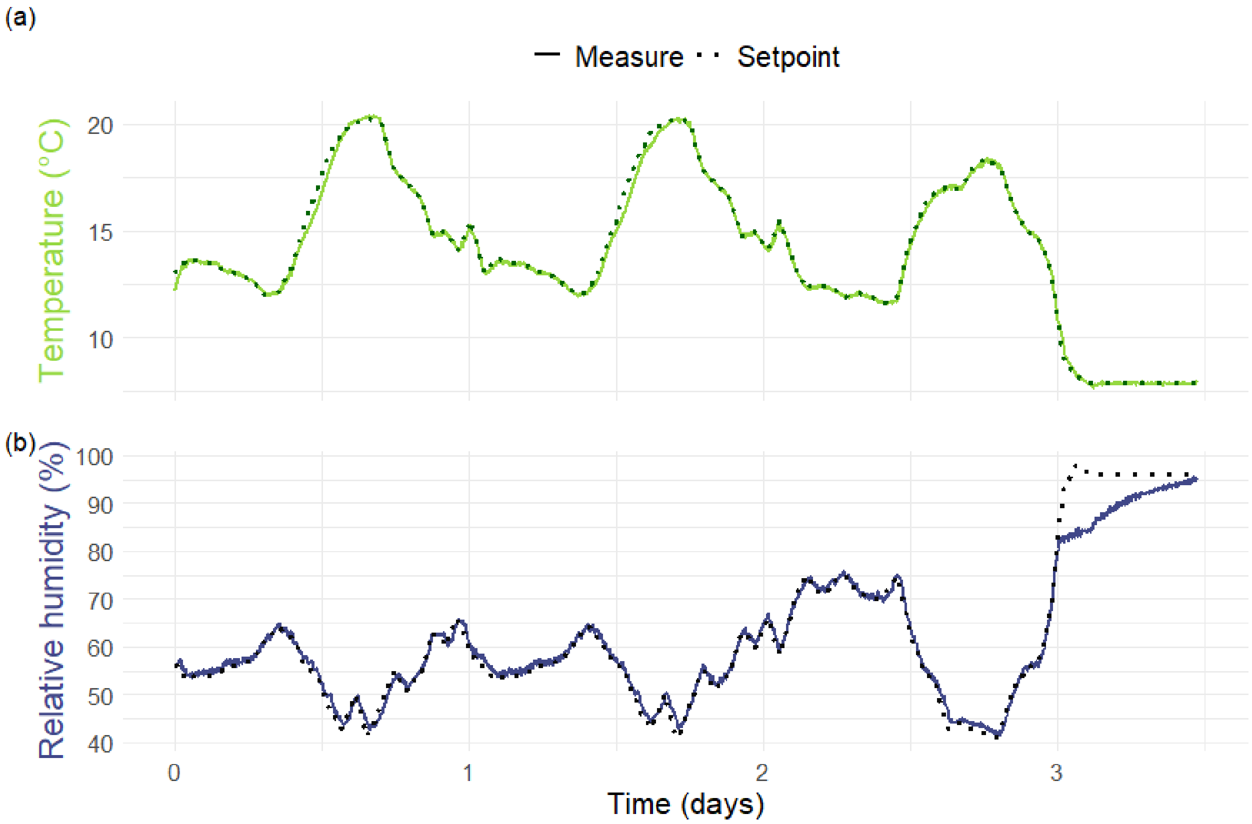


Figure 1: Temperature and relative humidity results of a simulation from french spring meteorological data. Data were recorded in Lons-le-Saunier (46°41'34" N, 5°31'04" E) from 20 to 22 March 2025.

Regarding the CO_2 atmospheric concentrations, we still think that it is relevant to show arbitrarily selected data, as it highlights the potential of the ecotron to simulate an atmospheric CO2 increase. We propose to keep the following Fig. 2 showing atmospheric CO_2 concentration, but to move it to the supplements to facilitate reading.

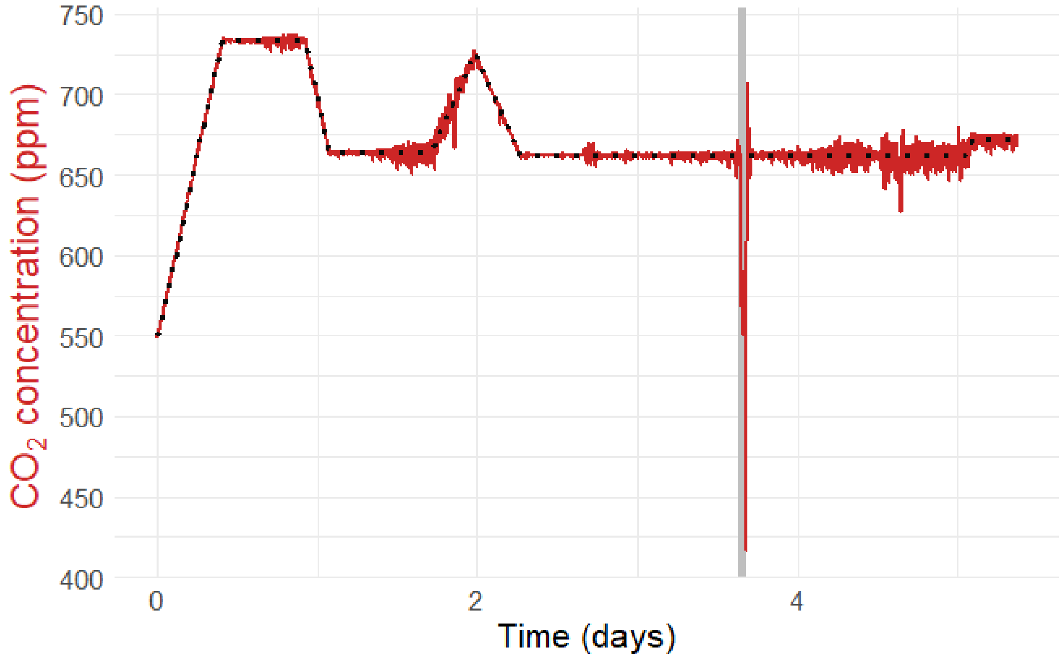


Figure 2 : Atmospheric CO_2 simualtions. The setpoint was selected to demonstrate the cell's potential to increase and then maintain high CO_2 concentrations

We also add in the supplements the following Fig.3 showing the min and max temperatures that we tested.

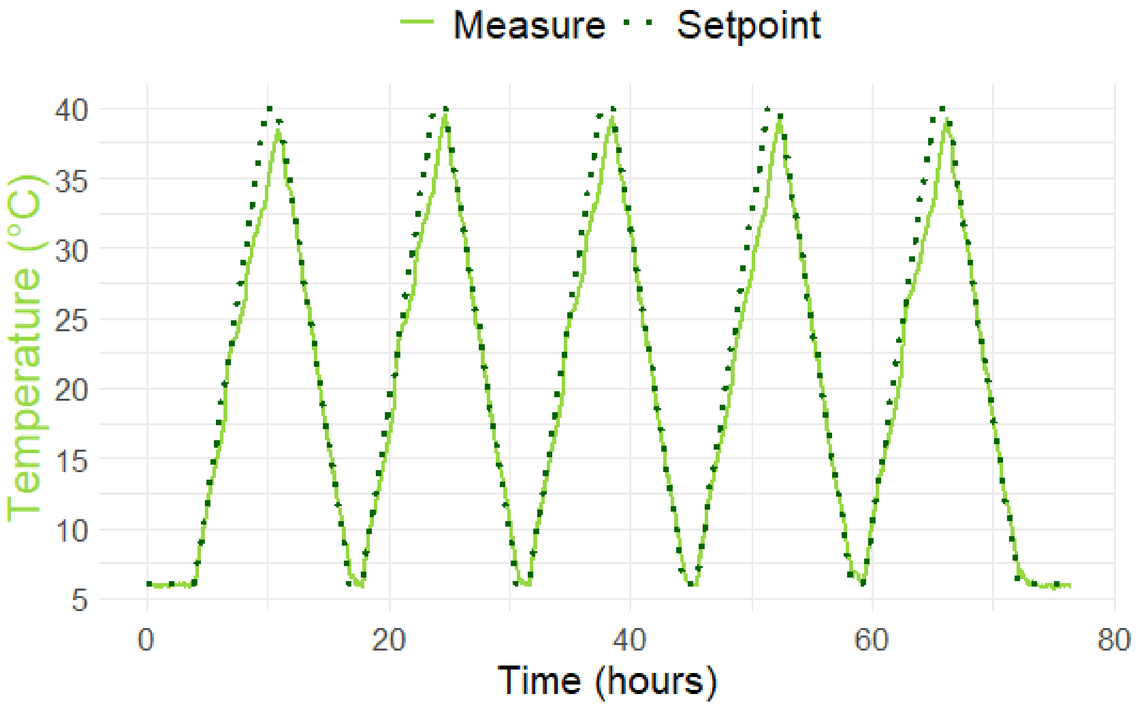


Figure 3: Temperature simulations. The setpoint ranged from 6 to 40 °C.

- **An evaluation of the drippers**

We calculated the amount of irrigation water with the mass data and compared it to the setpoint, that we estimated with the drippers rate, as shown by the following Fig. 4.

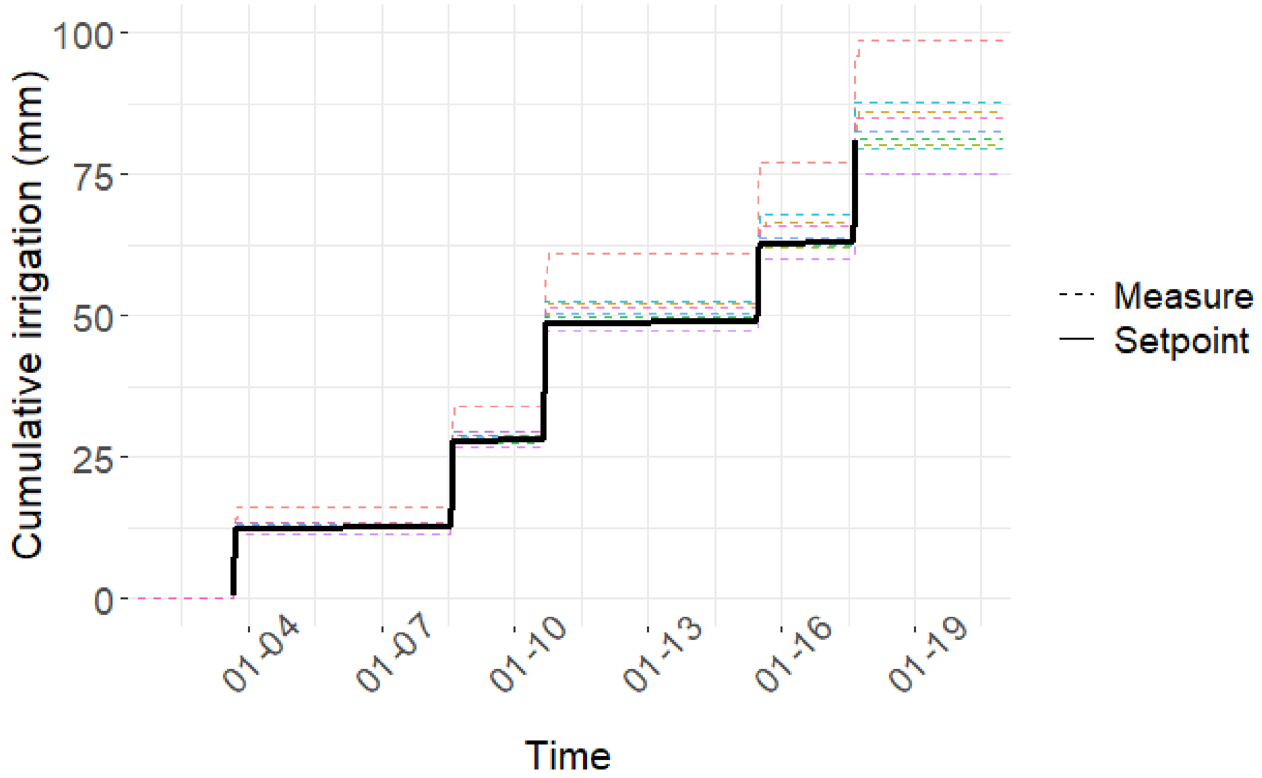


Figure 4: Evaluation of the drippers. The dotted lines (measure) represent cumulative irrigation calculated with mass data. Each colour represents one mesocosm.

- **A table summarising the upper and lower limits of the ecotron**

Table 1: Minimum and maximum values of the parameters controllable by the atmospheric conditions simulator.

Variable	**min**	**max**
Atmospheric CO2 (ppm)	Ambient value	2500
Temperature °C	6	39
Relative humidity (%)	41	95
Light intensity (µmol m^{-2} s^{-2})	0	1114
Rate of T change (°C /min^{-1})	0	0.09

- **more detailed results on the evaluation of lysimeters**

Rather than a single graph showing the cumulative ET, we included Fig. 5 showing the raw mass data from the lysimeters together with the data processed using a filter routine (Peters et al., 2014). Therefore, we propose to reshape our method section and not use use any more the equation from Pütz et al. (2018). The method is the following:

We make the assumption that ET during irrigation is negligible.

We used the mass M of the system:

$M= M_{lys} + M_{out\_cum}$

with M_{lys} the mass of the lysimeter, transformed in mm, given by the scales, and M_{out_cum} the cumulated mass, also in mm, given by the tipping buckets.

We then used the AWAT filtering routine to process the M raw data. First, we calculated the signal strength by fitting a polynomial to each data point. The maximum polynomial order was set to four. The data were then smoothed using a moving average algorithm. The window size for this algorithm varied according to the signal strength. We defined the minimum and maximum window values as 76 seconds and 1920 seconds, respectively. Finally, we filtered out non-significant M changes by applying a thresholding routine. All cumulative changes smaller than the threshold were discarded. We set the minimum and maximum threshold values to 1 mm and 3 mm, respectively.

The whole method is described in Peters et al. (2014) and we provide our R code for the AWAT function at the end of the document, and we will add it to the supplements.

We then derive irrigation from positive changes of M, and ET from negative changes of M, as suggested by Schrader et al. (2013).

In a revised manuscript, we will also show cumulative ET for nine lysimeters, calculated with the processed data, as well as a temporal zoom on ET so that the readers can have a broader overview of the results produced by the lysimeters (Fig. 6).

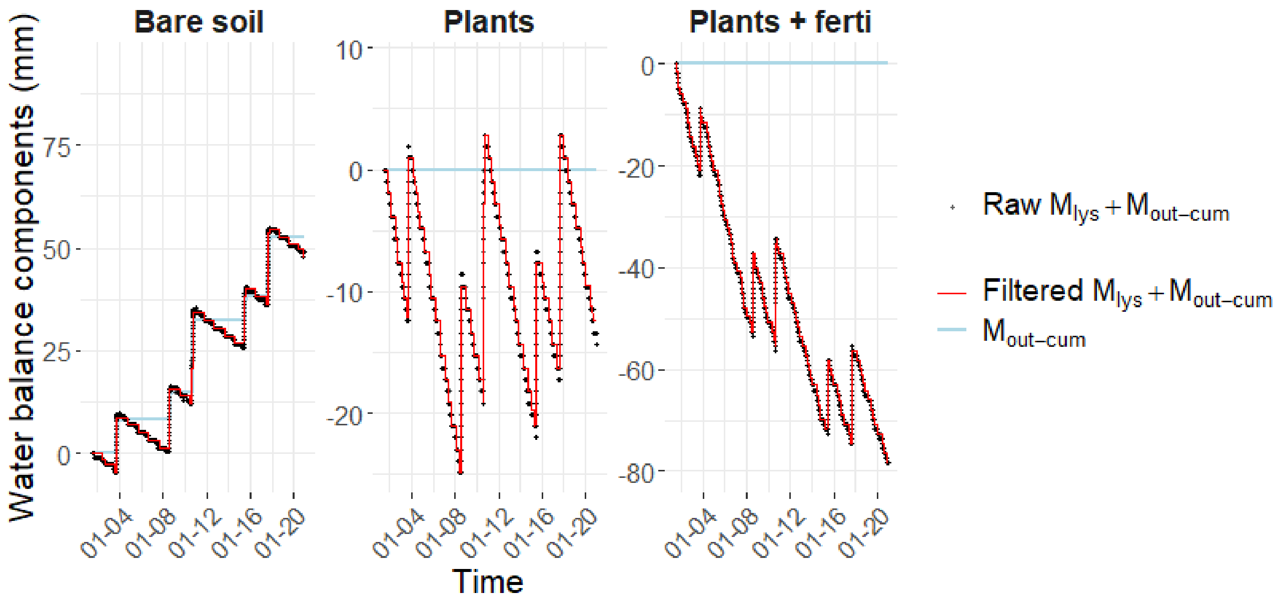


Figure 5: Comparison of raw mass data with data filtered using the AWAT filter routine. We also report M_{out_cum} corresponding to the drainage, measured with the tipping buckets.

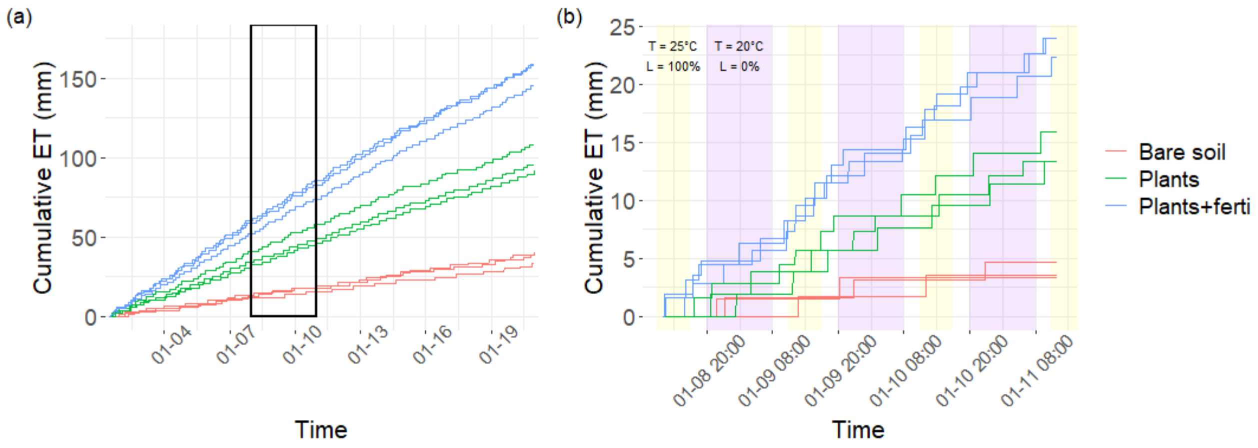


Figure 6: a) Cumulative ET over a 20-day period and b) zoom on three diel cycles.The yellow areas represent daytime, while the purple areas represent nighttime. In between, the sunrise and sunset periods are defined, with a linear increase or decrease in temperature and light intensity, respectively. Please note that the RH was set to 50 % throughout the experiment.

Besides, we also propose to show in the results section a graph showing diel cycles of temperature and moisture for a bare soil and a planted lysimeter. (See below, Fig.7)

Lastly, we selected data (for ET, CO2, soil temperature and water content) obtained in the same 20-day period of the launching experiment (from 1 to 20 January 2025), once the plants were sufficiently developed. We will clarify this in the 2.4 methods section. Therefore, the graphs in the revised manuscript will present different data, but the reader should have a clearer overview of the data acquisition strategy.

The discussion highlights the system's potential and limitations. However, it also includes a section about perspectives that is a bit far-fetched.

Your comment echoes that of the referee 3. We decided to remove this section.

Overall, this is an interesting paper, but it requires revision before publication can be recommended. I have made specific comments and edits in the attached annotated manuscript.

Thank your for your positive comment, and for all the very useful annotations that you made on the manuscript. We accepted your suggestions regarding the grammar, spelling and phrasing. Please see below the answers to your specific comments of the attached annotated manuscript.

How is the temperature of the soil columns controlled? Are the columns insulated? Is there a vertical soil temperature gradient like under natural field conditions?

Unfortunately, the temperature of the soil is not controlled and the columns are not insulated, even if the latter point is an improvement of the platform that we consider for future experiments.
However, we recognise that this is a critical point that was not sufficiently covered in the manuscript. We propose to show in the results section the following Fig.7 that shows diel cycles of temperature and moisture for a bare soil and a planted lysimeter.

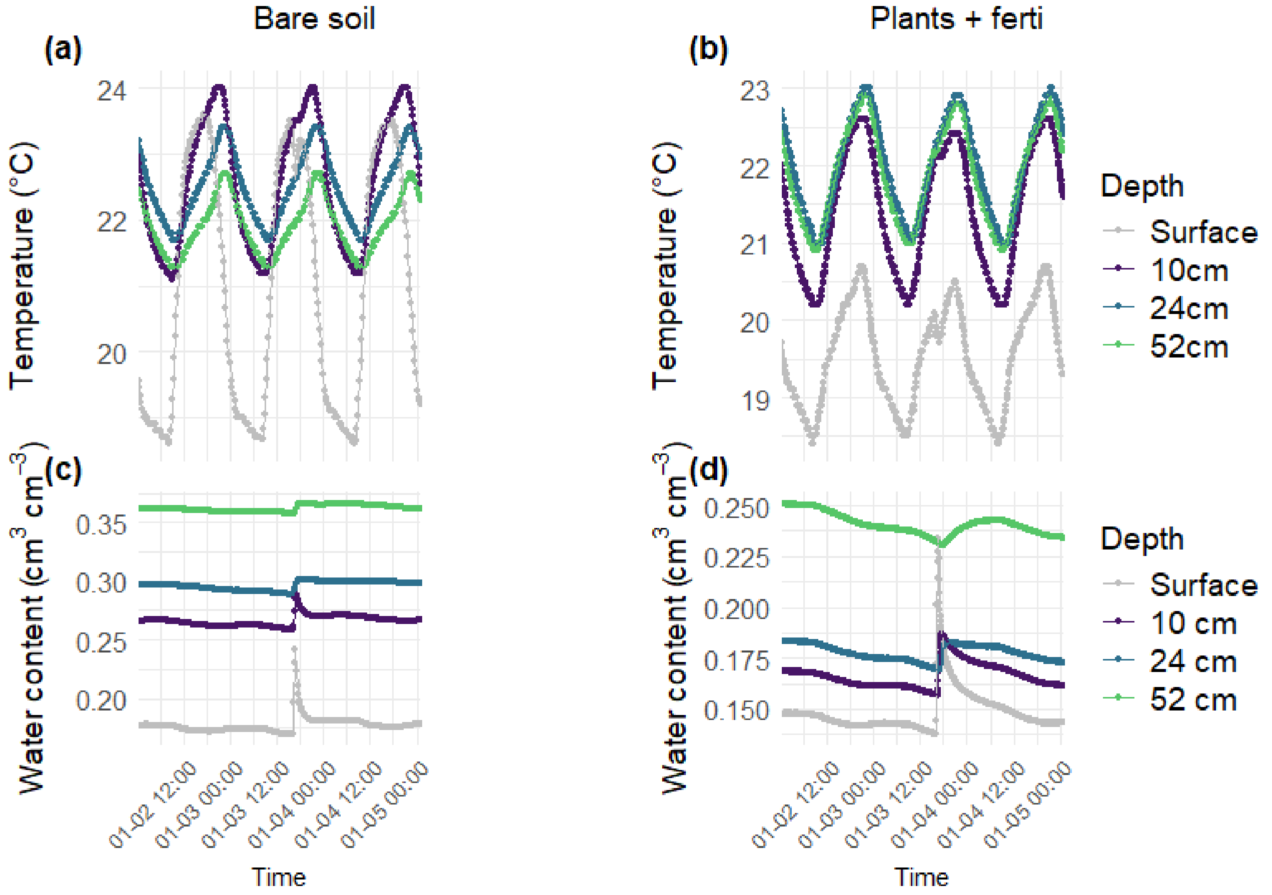


Figure 7: Diel cycles of soil temperature and water content, observed in two mesocsosms, at the surface and in three horrizons.

We will add this result section: “We see in the bare soil, which is saturated with water at the bottom, that the daily temperature range decreases with depth. Soil temperature varies by 3 °C at a depth of 10 cm in this three-day period: from 21 to 24 °C, compared to 1.5 °C at 52 cm: from 21.2 to 22.7 °C. For the planted lysimeter, the difference between horizons is less pronounced. Temperature varies by 1.8 °C at a depth of 10 cm: from 20.1 to 22.9 °C, compared to 2.2 °C at 10 cm: from 20.9 to 23.1 °C.

We thus see that there is a temperature gradient. We compared that with cycles of temperature observed in the Landscape Evolution Observatory, which is an experimental platform featuring artificial watersheds with a surface area of 330 m^2 made of the same basaltic substrate as in our experiment (Pangle et al., 2015). At a depth of 50 cm, in the latter platform, the daily temperature range is less than 1 °C whereas it can reach up to more than 10 °C at a depth of 5 cm for the same climatic conditions. Even though we did not use the same climatic conditions as Pangle et al. (2015), this comparison shows that the buffering effect of soil is more pronounced in the artificial watersheds than in the lysimeters.”

What does semi-manual mean? Please specify.

We used this term because the irrigation is launched manually, but the water is delivered through drippers. We changed to “The irrigation system is switched on and off manually”. The subsection “Irrigation” provides more detail (see below).

What is the maximum temperature range that can be run with your ecotron?

From 6 to 39 degrees. We added it to the results in the Table 1 and we will add the Fig. 3 showing the max and min in the supplements, as mentioned above.

“It is continuously measured by a sensor (ROTRONIC - HC2-SH)
Here and for all following devices/materials: Please provide full information about the device/material (type and/or number) and manufacturer (company name, city, [state], country).

Here Rotronic is the company and HC2-SH the reference of the sensor. Throughout the manuscript, we had followed this naming convention, except for the tipping bucket where we just provided the company. We now changed for all devices and we will follow the following convention: (HC2-SH, ROTRONIC AG, Bassersdorf, Switzerland).

Which pump are you using?

We modified the sentence: “The water is pumped from a 300 L stainless steel tank with **a boost pump (ECOP 140/20, Spid'O, Saint Quentin Fallavier, France).**”

How is the amount of irrigation water controlled?

We clarified in the text: “To launch irrigation, a mecanic garden timer (PNR11, SFC Jardibric, Boigny-sur-Bionnne, France) is switched on to open the valve and allow water to flow to all the drippers. The boost pump then starts up if necessary. The amount of irrigation is set by the flow rate of the drippers and the number of drippers per mescosom. Besides, the garden timer allows fractionation of the irrigation time to avoid excessively high rates. For instance, with six drippers with a 2 L.min^{-1} irrigation rate, the valves open for 30 seconds every three minutes during a rain event to maintain a 2 L.min^{-1} rate in average.”

How many channels do the LED panels have? Do they allow for control of the red/far red ratio?

They have 2 channels: one for the visible wavelengths, and one for the near-infrared wavelengths. It is specified in the text, and we clarified that it allows a control of the R/FR ratio: “Each source is controllable in 10 stages, from 0 % (off) to 100 % of the maximum intensity, which allows a control of the Red:Far-Red (R:FR) ratio. Light intensity can be updated every 30 seconds at most. ”

“The substrate is filled in manually.”
Which substrate do you use? How do you ensure realistic bulk density and homogeneous packaging?

In the first experiment, we used ground basalt. We used the scale to adjust density. We propose to clarify in 2.3.1 section (Mesocosm description) with the following sentence: “The substrate is filled in manually, **directly inside the chamber. The scale below the mesocosm is used to adjust the density during packing**”
We also added in the 2.4 (design evaluation) section the following sentence. “To do so, the ground basalt was packed in five successive layers. For each layer, a bulk density of 1.5 g cm^{-3} was achieved by adding the appropriate mass of basalt for the corresponding volume.”

At which depth(s)? How long is the loop in the soil/substrate?

The depths are shown in Fig. 2 of the manuscript. Initially, the membrane loops are located at 13, 27 and 55 cm from the mesocosm’s surface. However, it is adjustable according to the needs of the experiment.

We completed the text: “an automated gas circuit is deployed in all 15 mesocosm **at three different depths (Fig.2). Soil gas phase is sampled through a 25-cm-long hydrophobic microporous polypropylene capillary membrane (Accurel® PP V8/2 HF, Membrana GmbH - 3M, Wuppertal, Germany) installed as a loop within the mesocosm** .”

”Air flow is provided by a pump.”
At which flowrate ?

We clarified in the text: “The circuit consists of a closed loop connected to the gas analyzers, allowing the sampled gas to be continuously recirculated back into the mesocosm. Gas flow is maintained by the internal pump of the CO$_2$ analyser at a flow rate of **0.75 L min^{-1}**.”

“ Measurement time was set to 4 minutes for each channel. Only the last data point from this interval is preserved to avoid alteration induced by the channel change”
Which period of time does this last data point represent?

We keep the last point of the nine data points obtained in a 4-minutes interval. The time associated to the value is the exact time of the measurement.
We have provided a full asset dedicated on the manifold that we constructed in an open source repository: https://doi.org/10.5281/zenodo.16928632. We propose to include the following figure (similar to the one in the asset) in the supplements for more clarity. The figure will be cited in the results.

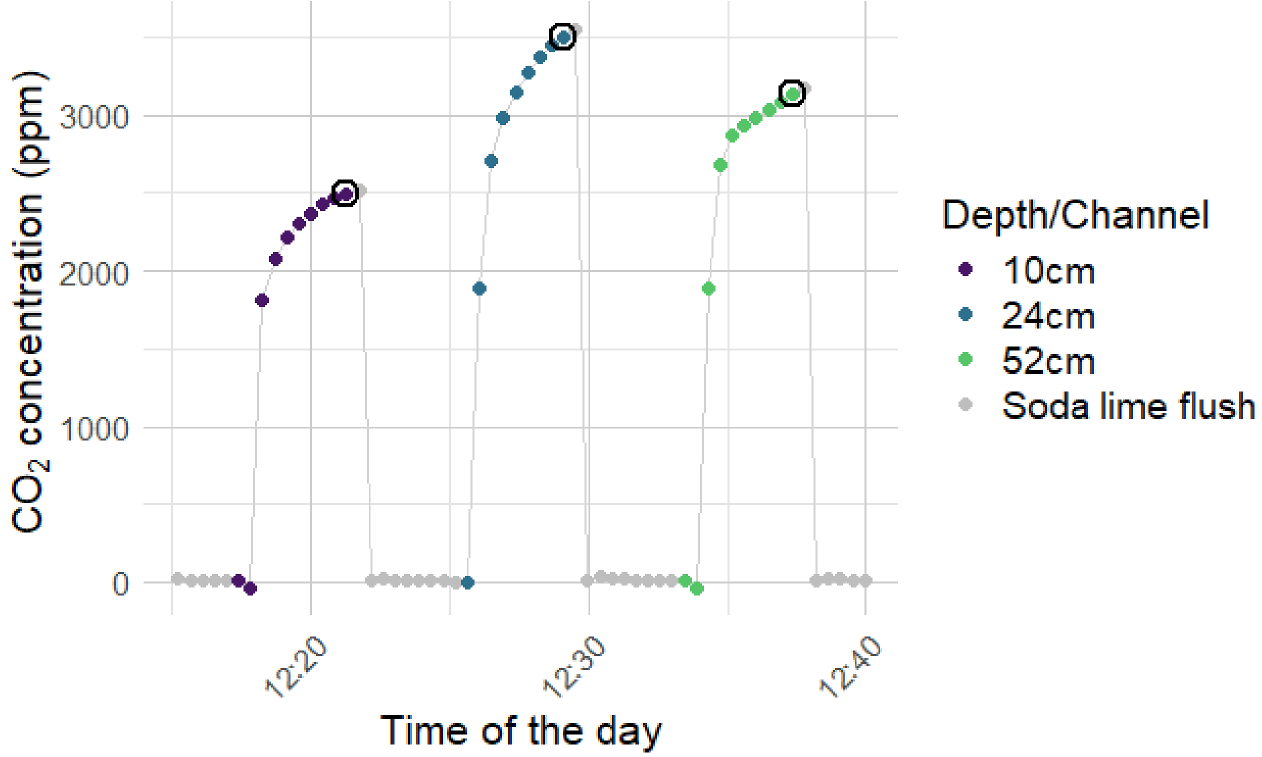
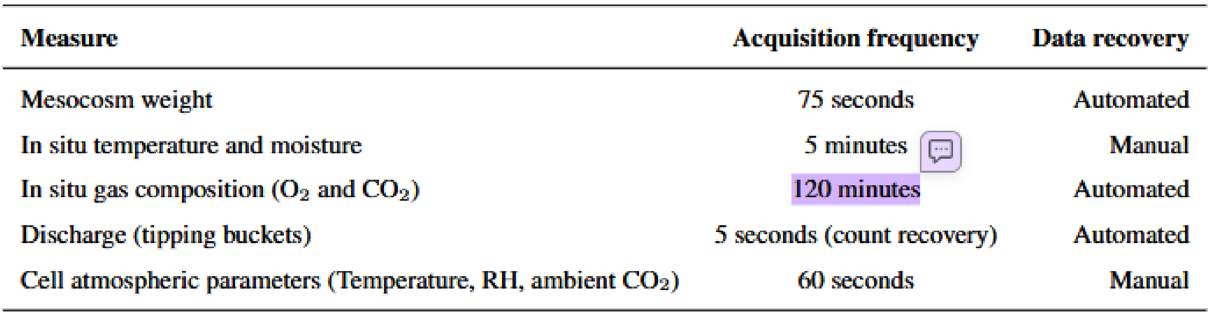


Figure 8: Raw CO$_2$ data before post-process showing pore CO$_2$ concentrations for three different depths in the mesocosm and for the flush channel. All data points are acquired with the same analyser. Each color represents one channel. Each measuring timeslot is 4-minute long. Only the last point of each series, circled on the plot, is kept.



Measure	Acquisition frequency	Data recovery
Mesocosm weight	75 seconds	Automated
In situ temperature and moisture	5 minutes	Manual
In situ gas composition (O_2 and CO_2)	120 minutes	Automated
Discharge (tipping buckets)	5 seconds (count recovery)	Automated
Cell atmospheric parameters (Temperature, RH, ambient CO_2)	60 seconds	Manual

If you measure 45 channels 4 min each, this amounts to 180 min return time.

It is indeed 120 minutes. We have three manifolds with 16 channels each. One channel is attributed to flushing and 15 to measuring. As there is a flush between each measurement period, it takes 15 * 2 * 4 minutes until we come back to the same channels, which equals 120 minutes.
We propose to reformulate the whole section for more clarity.

“. To do so, we grew alfalfa (Medicago sativa) on ground basalt for 6 months. We used 3 treatments: bare control without alfalfa, alfalfa without fertilisation and alfalfa with fertilisation.”
How many replicates did you use?

We added the following sentence: “We used nine lysimeters to have three replicates for each treatment.”

“Secondly, we measured in situ CO2 concentration during the growth of the plants at 3 different depths in a planted mesocosm without fertilisation”
Why only in this one mesocosm?

We did not want to show too much data, but you are right, it is relevant to show several mesocosms.
Please find the new graph below (Fig. 9):

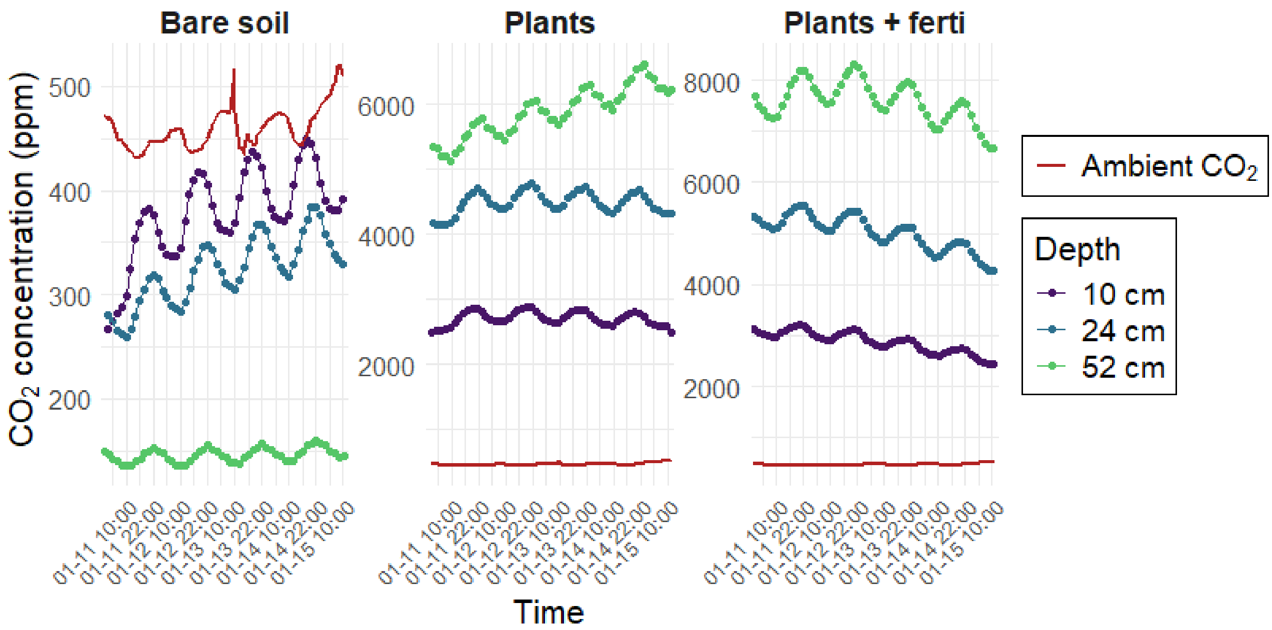


Figure 9: Example of in situ pore CO_2 concentration curves for three mesocosms. The red curve shows the atmospheric concentration in the ecotron cell. Each point displays the last measurement of a 4-minute acquisition time.

Note that we did not take the same dates, as we wanted to group all the measurements (ET, water content, gas) within the same interval of days. We chose a period without rain for CO_2 meaurements.

"To do so, seepage was recorded with tipping buckets, ΔW with scales and irrigation rate was deduced from irrigation time and drippers flow rate"

How precise was this deduction? Wouldn't it have been more precise to use the increase in weight to determine the irrigation amount?

Indeed, as discussed above, we propose to deduce now irrigation from the masses to calculate ET (Fig. 4). This whole methods section will be restructured to detail our procedure, notably the use of the AWAT filter routine (Peters et al., 2014) to analyse mass data.

"However, negative rates are rapidly compensated and therefore do not prevent the reading of a longer trend."

What is meant with this statement?

The negative rates were due to noise in the data. In the revised version, we applied the AWAT filtering routine (Peters et al., 2014). It allowed to remove the negative rates. This sentence will not appear anymore in the manuscript.

"Nevertheless, the chamber's temperature range limits simulation to warm climates, where many countries have high vulnerability to climate change (Birkmann et al., 2022)."

Please specify the temperature range in the Materials and Methods section.

As mentionned above, we inserted it in a table (Table 1).

"Comparing the results with laboratory, field and natural experiments, which all have advantages (Diamond, 1983) still remains beneficial as ecosystem reproduction is always challenging, even though ecotrons limit the gap with outside parameters."

Meaning not fully clear to me. Do you mean ecosystem replication? Check wording of the whole sentence.

We changed: “Comparing results from laboratory, field, and natural experiments, each of which has its own advantages (Diamond, 1983), remains valuable. This is especially relevant given the ongoing difficulty of replicating whole ecosystems, despite advances such as ecotrons that reduce the gap with natural conditions.”

Awkward title. Please revise.

We changed the discussion structure for more clarity. The informartion of this section will be rearranged in the section “Combination of mesocosms and ecotron”.

“heat exchange between the soil and the atmosphere is biased by the exposition of the lysimeter wall”
This is a really critical point. If the lysimeter walls are not insulated, then the soil will become unrealistically warm. Furthermore, under natural conditions there is usually a vertical temperature gradient in the soil which has a strong influence on root growth and soil biogeochemical processes because any physical and chemical process is highly temperature-dependent.

As discussed above, we propose to add results on this point (Fig. 7). Besides, we introduced this major limitation in the abstract: “Its main limits are the limited size of the lysimeters and **the exposition of their walls, which influences the heat exchange between the soil and the atmosphere, unlike buried lysimeters.**”

“The automated gas system enabled gas sampling and analysis in 3 layers for each of the 15 mesocosms with a 90 minutes frequency”

It should read "frequency of 90 minutes". However, in Table 1 it says 120 min, and if one does the calculation (4 min x 15 lysimeters x 3 depths), one ends up with 180 min. Please be consistent.

Thank you for pointing out this mistake. We changed: “The automated gas system enabled gas sampling and analysis in three layers for each of the 15 mesocosms with a frequency of 120 minutes.”

“Cross-indexing the data from the two allows us to obtain ratios that can help to distinguish sources from emissions (Sánchez-Cañete et al., 2018)”
What do you mean with "cross-indexing"?

We meant using both variables to calculate a ratio. It has been proposed that CO_2 sequestration through chemical weathering could be quantified with a combination of O_2 and CO_2 measurements (Sánchez-Cañete et al., 2018; Angert et al., 2015). This proposition refers to the Apparent Respiratory Quotient (ARQ), a ratio between CO_2 an O_2 efflux, which is modulated by diffusion coefficients of both gas. The theory is the following: heterotrophic or autotrophic respiration consumes O_2 and releases CO_2, whereas chemical weathering consumes CO_2 without affecting O_2 concentration for the majority of reactions. As a result, the ARQ helps to separate this two biogeochemical processes.

We changed the sentence to: “Combining CO_2 and O_2 measurements allows the calculation of ratios such as the Apparent Respiratory Quotient (ARQ), which can help distinguish between sources and sinks of CO_2 (Sánchez-Cañete et al., 2018).“

I think this whole section is a bit far-fetched. We're talking about comparably small lysimeters that allow for highly targeted process studies. However, claiming that they enable research into nature-based solutions, such as carbon sequestration or groundwater pollution, is, in my opinion, a bit of a stretch, given their small surface area of 0.1 m² and depth of about 0.7 m.

Your comment echoes that of the referee 3. We do agree and decided to remove this section.

“The data variety that it can provide makes it a relevant support to foster interdisciplinarity and to apprehend complex ecosystem”
This would at least require intact soil cores with all lifeforms in it (microorganisms, micro- and mesofauna), realistic soil temperature conditions and operation of the ecotron with real weather data.

We agree that it is far-fetched. We changed it to “The variety of data it can provide makes it a valuable resource for fostering interdisciplinarity in biogeochemical, agronomic, and hydrological studies in the context of climate change.”

References

Pangle, L.A., DeLong, S.B., Abramson, N., Adams, J., Barron-Gafford, G.A., Breshears, D.D., Brooks, P.D., Chorover, J., Dietrich, W.E., Dontsova, K., Durcik, M., Espeleta, J., Ferre, T.P.A., Ferriere, R., Henderson, W., Hunt, E.A., Huxman, T.E., Millar, D., Murphy, B., Niu, G.-Y., Pavao-Zuckerman, M., Pelletier, J.D., Rasmussen, C., Ruiz, J., Saleska, S., Schaap, M., Sibayan, M., Troch, P.A., Tuller, M., van Haren, J., Zeng, X., 2015. The Landscape Evolution Observatory: A large-scale controllable infrastructure to study coupled Earth-surface processes. Geomorphology 244, 190–203. https://doi.org/10.1016/j.geomorph.2015.01.020

Peters, A., Nehls, T., Schonsky, H., Wessolek, G., 2014. Separating precipitation and evapotranspiration from noise – a new filter routine for high-resolution lysimeter data. Hydrol. Earth Syst. Sci. 18, 1189–1198. https://doi.org/10.5194/hess-18-1189-2014

Schrader, F., Durner, W., Fank, J., Gebler, S., Pütz, T., Hannes, M., Wollschläger, U., 2013. Estimating Precipitation and Actual Evapotranspiration from Precision Lysimeter Measurements. Procedia Environmental Sciences, Four Decades of Progress in Monitoring and Modeling of Processes in the Soil-Plant-Atmosphere System: Applications and Challenges 19, 543–552. https://doi.org/10.1016/j.proenv.2013.06.061

AWAT_2014_function

Hulin Baptiste

2026-06-03

Filtering routine to be iterated on lysimeters M data (Mlys +Mout_cum). Based on the recommendation from Peters et al. (2014). https://doi.org/10.5194/hess-18-1189-2014

```
AWAT_filter <- function(y, t,
                        wmin=76,
                        wmax=1920,
                        delta_min=1,
                        delta_max=3,
                        max_degree=4){

  N <- length(y)

  best_degree <- rep(NA,N)
  best_AICc <- rep(NA,N)

  yhat <- rep(NA,N)
  Bi <- rep(NA,N)
  wi <- rep(wmax,N)
  delta <- rep(NA,N)

  ########################
  # STEP 1
  ########################

  for(i in 1:N){

    center <- t[i]

    ind <- which(abs(t-center) <= wmax/2)

    if(length(ind)==0) next

    xw <- t[ind]-center
    yw <- y[ind]

    good <- complete.cases(xw,yw)

    xw <- xw[good]
    yw <- yw[good]

    r <- length(yw)

    if(r < (max_degree+2)) next

    models <- vector("list",max_degree+1)
    AICc_values <- rep(NA,max_degree+1)

    for(k in 0:max_degree){

      n <- k+1
```

```r
      if((r-n-1)<=0) next

      X <- sapply(
        0:k,
        function(j) xw^j
      )

      fit <- tryCatch(
        lm(yw ~ X -1),
        error=function(e) NULL
      )

      if(is.null(fit)) next

      models[[k+1]] <- fit

      SSQ <- sum(residuals(fit)^2, na.rm=TRUE)
      SSQ <- max(SSQ,1e-12)

      AICc_values[k+1] <-
        r*log(SSQ/r)+
        2*n+
        (2*n*(n+1))/(r-n-1)
    }

    if(all(is.na(AICc_values))) next

    best <- which.min(AICc_values)

    best_fit <- models[[best]]

    if(is.null(best_fit)) next

    Sres <- sum(residuals(best_fit)^2)

    Sdat <- sum(
      (yw-mean(yw,na.rm=TRUE))^2
    )

    Bi[i] <- ifelse(
      Sdat<1e-12,
      1,
      Sres/Sdat
    )

    yhat[i] <- coef(best_fit)[1]

    t975 <- qnorm(.975)

    delta_raw <- Sres*t975

    delta[i] <- max(
      delta_min,
      min(delta_raw,delta_max)
    )
```

```r
}

########################
# STEP 2
########################

wi <- pmax(wmin,Bi*wmax)
wi <- pmin(wmax,wi)

########################
# STEP 3
########################

y_smooth <- rep(NA,N)

for(i in 1:N){

  if(is.na(wi[i])) next

  ind <- which(
    abs(t-t[i])<=wi[i]/2
  )

  y_smooth[i] <- mean(
    y[ind],
    na.rm=TRUE
  )

}

########################
# STEP 4
########################

y_threshold <- y_smooth
for(i in 2:N){

  if(is.na(y_threshold[i-1])) next

  if(is.na(y_smooth[i]) || is.na(delta[i])){

    y_threshold[i] <- y_threshold[i-1]
    next
  }

  diff_i <- abs(
    y_smooth[i] - y_threshold[i-1]
  )

  if(is.na(diff_i)){
    y_threshold[i] <- y_threshold[i-1]
    next
  }

  if(diff_i < delta[i]){
```

```
      y_threshold[i] <- y_threshold[i-1]

    } else {

      y_threshold[i] <- y_smooth[i]
    }
  }

  ########################
  # ET + P
  ########################

  dM <- c(
    NA,
    diff(y_threshold)
  )

  P <- ifelse(
    is.na(dM),
    0,
    ifelse(dM>0,dM,0)
  )

  ET <- ifelse(
    is.na(dM),
    0,
    ifelse(dM<0,-dM,0)
  )

  return(
    list(
      yhat=yhat,
      Bi=Bi,
      wi=wi,
      delta=delta,
      y_smooth=y_smooth,
      y_threshold=y_threshold,
      P=P,
      ET=ET,
      P_cum=cumsum(P),
      ET_cum=cumsum(ET)
    )
  )

}
```