<u>Author responses for Egusphere-2026-576</u>

Author responses are in green.

<u>Reply to RC1</u>

Important advances have been made in the development of field-deployable analysers and sensors that enables in-situ, high-temporal-resolution measurements at a reasonable cost without the requirement involving sample collection, transport and analysis to and in the lab. Such continuous measurements using either deployable sensors to look at for example nutrients and/or dissolved organic matter, or semi-continuous measurements using devises that pump water to the analytical instrument for biogeochemical, physical and stable water isotopes analysis are increasing our ability to provide process-based understanding. Hence, the further development of such lab-in-the-field devices will be important in the years to come.

The manuscript provides another dimension of this such a lab-in-the-field approach, namely being mobile. While this is a rather obvious development, it has to my knowledge not previously been formalized into a paper. This is an advantage since others can more easily follow by using the detailed instructions or coming up with new ideas on how to improve it further.

The mobile laboratory allows for relatively advanced measurement, while the authors also are honest with not only the pros, but also the cons for others to develop alternative solutions.

While I generally applaud this, I think that the data presentation could be improved. It is difficult to make much sense of the data. Perhaps use better colour scheme, try to help the reader with some lines between points and make clear what data is what. But these are minor issues.

We are very grateful to the reviewer for their positive assessment of our manuscript and recognition of the efforts we made to present a balanced perspective on the WATER and its capabilities.

To address the data presentation issue, Fig. 4 and Fig. 5 have been reformatted into matrices of subplots. Water sources and water quality parameters have been organised by rows and columns, respectively. Consequently, only one data series is plotted per subplot, improving clarity. In addition, colours used for each water quality parameter now match the colour used for the appropriate measurement device in Fig. 1a.

Reply to RC2

This new manuscript is a strong and valuable contribution to water quality monitoring research. It combines technical innovation with practical field validation and addresses an important challenge in hydrology by obtaining reliable, high-frequency and multi-source water quality data. The article is well-structured but the choice of the colours and symbols in the graph could be improved for the reader's understanding. Despite some minor limitations, the study demonstrates real potential for advancing catchment science and management of water quality in mixed structured landscapes.

We are very grateful to the reviewer for their positive assessment of our manuscript and recognition of the potential offered by the WATER. To address the data presentation issue, Fig. 4 and Fig. 5 have been reformatted into matrices of subplots. Water sources and water quality parameters have been organised by rows and columns, respectively. Consequently, only one data series is plotted per subplot, improving clarity. In addition, colours used for each water quality parameter now match the colour used for the appropriate measurement device in Fig. 1a.

The manuscript focuses primarily on technical implementation rather than on the scientific interpretation of the collected data. Although this is acceptable for a technical note, additional examples of hydrological insights derived from the measurements would have given some added value to the manuscript. Strongest interpretations on the relationship between hydro-climatological records and water isotopic or nitrate composition could have been done.

Thank you for this suggestion. Being mindful of the length of the manuscript and in response to earlier suggestions by the editor, we have respectfully decided that additional quantitative analysis of the relationships between hydro-climatological records and water quality parameters is beyond the scope of this Technical Note. Here, we wish to focus on showing one or two exemplar results from the WATER to highlight how the collected data has the potential to advance process understanding. Formal process-based analysis will, however, be the focus of later manuscripts.

I think that the economic dimension would require more details that could be valuable for research institutions or public authorities interested in this recent way of monitoring water quality. Additional explanations and estimations about installation costs, operational expenses and long-term maintenance would have been welcome.

To assist with understanding the economic dimension, we have calculated the cost of constructing the WATER (~ €310,000) and also provided estimates of monthly operational costs for an average month (€208), as well as months requiring heating (€283) or cooling (€143) of the trailer. All costs were corrected for inflation to the year 2025. Full details of *the construction cost breakdown and assumptions made for the monthly costs are provided in a Supplement. In the manuscript itself, the construction cost was added to the start of Sect. 2 (L98-101), while monthly costs and additional considerations for longer-term (> 1 year) deployment were added to Sect. 3.3 (L436-441).*

Despite the nice presentation of the considerations when operating the WATER system, showing flood event cases for which the results were not as promising would have given more realistic indication of WATER operational limitations. This is of importance because such monitoring tool may not always be as straight forward in its use and in the results it may provide.

The reviewer is correct that in our proof-of-concept, we have not explicitly demonstrated the capability of the WATER to sample in extreme events such as floods. To address this, we remove the reference to the rapid response use case from the Abstract and Introduction and instead added the line "It may also be possible to rapidly deploy the WATER for analysis of extreme events (e.g., floods) or pollution incidents, subject to safe site access; this will be explored in future work" to the conclusion (L512-514).

Finally, I wonder about the 5 µm threshold of the filter selected in this analytical chain. I do not really see its relevance according to the standard filtration scheme that are generally used by environmental agencies and research institutions: 1 µm to separate suspended particles from colloids and real dissolved fractions; 0.45 µm for water quality assessment. How the data collected with WATER could be used as a comparison in places where historical data already exist if the filtration is so different? More detailed information for the selection of the filter system could be done as well.

In this iteration of the WATER, only the water drawn by the Continuous Water Sampler (CWS) for stable water isotope analysis is filtered. The 5 µm filter is positioned upstream of the sampling reservoir, from which the CWS draws its water, and its sole purpose is to remove particulates that would otherwise reduce the lifespan of the membrane cassette used by the CWS and does not affect the resulting isotope data. Water sampled by the YSI 600R and ProPS for water quality is unfiltered. Depending on which measurement devices are to draw water from the sampling reservoir, other filter thresholds could also be used. This explanation was added to Sect. 2.2 (L152-156).

Reply to RC3

This manuscript is a relevant contribution presenting a new lab-in-the-field set-up for high frequency natural water analysis and its application over a 6-month period in a research observatory. To my opinion this original set-up is promising and presents several relevant specificities: 1) it analyses water stable isotopes that are not possible to analyze with in situ probes , 2) it allows for analyzing several different water sampling points which is of major interest, and 3) it sounds easy to move from one catchment to another.

We are very grateful to the reviewer for their time in reviewing our work and recognising the potential in our setup.

I think the authors should detail several aspects so that readers can fully understand:

- i) about multiple water sampling locations:
  - how far could be the sampling locations from the WATER? How deep? Are there any constraint for the pumping ? for example, would it be possible to sample deep groundwater? What if the well gets dry or if the stream gets frozen?

    The horizontal distance is constrained by whether the flushing and reservoir filling time can be accommodated within the desired sample throughput time, which here is 20 minutes. In the proof-of-concept application, the sampling line to the most distant source from the WATER (145 m) could be successfully flushed within 10 minutes. Meanwhile, the vertical depth of sampling is constrained by the power of the peristaltic pump and hydraulic gradient. Again, in the proof-of-concept application, drawing water up from 3 m below the WATER was possible. This information was added to Sect. 2.2 (L142-146).

    If no water is available from a source due to a well running dry or a sampling line becoming obstructed, this would be detected via the sampling reservoir load cell during the Fill-Empty-Fill component of a Measurement Task, and the measurement would be skipped. This is now noted to Sect. 2.5 (L276). Meanwhile, if ambient temperature falls below a defined threshold, the WATER pauses sampling to prevent sample acquisition and measurement issues that could be caused by freezing conditions. This is now stated in Sect. 2.4.1 (L250-251).

  - would it be possible to manage multiple event-triggered sources? e.g. to capture rain + stormflow dynamics or to investigate the spatial variability in rainwater composition with multiple collectors?

Yes, multiple event-triggered sources are possible and could be triggered by a variety of data streams depending on the measurement devices connected to the WATER (e.g., load cell for rainfall, water level, soil moisture, etc.). This has been clarified in Sect. 2.4.1 (L222-224).

- ii) time recording:
  - how long does it take to the water to travel from sampling point to the WATER? and to the reservoir to be rinced and filled?

    In an earlier iteration of the manuscript, we provided the following example for calculating the flush time of a given source but later removed it for brevity: "The flush time is set for each source separately based on an assigned flow rate and the volume of water in the line (dependent on length and diameter). For example, a 50 m line with an inner diameter of 4 mm would hold 630 ml of water. To flush the line twice with a flow rate of 500 ml min^{-1} would require 2.5 minutes." This has been returned to L268-271. We have also added that the time needed to rinse and fill the reservoir after flushing is approximately 25-30 seconds (L274-275).

  - what it the time associated to the recorded analysis values? is it sampling time + 20 min for isotopic results? is it less for NO3 and EC?

    The time associated with the analysed values is the UTC time at which the "fill-empty-fill" function of a Measurement Task successfully completed. Therefore, all measurements for a sample receive the same timestamp. This is now explained in L242-247, together with the structure of the SQLite database.

  - Did you compare with in situ EC probes in stream sources and piezometers?

    We have not specifically compared measurements taken by the WATER to in-situ *EC probes. However, data were quality checked and calibration of measurement devices was undertaken at routine intervals.*

Specific comments:

No detail about filtration is given in the abstract, would it be difficult to have stronger filtrations (e.g. 0.45 µm)? Is this threshold of 5 µm resulting from preliminary tests or any other strategy?

We have added the filter threshold to the abstract together with a brief description of the two analytical pathways (Throughflow and Reservoir) provided by the WATER. The 5 µm threshold of the filter upstream of the sampling reservoir reflects the need to remove particulates from water sampled by the Continuous Water Sampler (CWS) during stable water isotope analysis. This is to preserve the lifespan of the membrane cassette used by the CWS and does not affect the resulting data. Depending on which measurement devices are to draw water from the sampling reservoir, other filter thresholds could also be used. This explanation was added to Sect. 2.2 (L152-156).

lines 101-104: temperature fluctuations (+/- 5°C for low temperature, +/-1° with air conditionner) : what is the range of temperature for which these ranges of fluctuations are guaranteed?

A detailed explanation of the systems involved in temperature regulation of the trailer and the conditions under which they can operate has been added to Sect. 2.1 (L105-115). If the internal temperature is too cool (warm) whilst outside temperature is warmer (cooler), the Maico Eat 6 G/1 passive ventilation system draws in outside air to maintain the internal temperature to within +/- 5°C of a set temperature. If the internal temperature is too low whilst the outside temperature is cooler, a diesel heater provides additional warming. The only condition where further temperature regulation is not possible is if the internal temperature becomes too warm whilst the outside temperature is warmer. To mitigate this issue for particularly sensitive measurement instruments, the climate-controlled server cabinet is available for heating and cooling to within ±1 °C of a specified temperature for ambient temperatures between -30 and 55 °C.

line 153: please explain the different parameters proposed as measurement of organic content

The parameters CSBeq (Chemical Oxygen Demand equivalent) and BSBeq (Biochemical Oxygen Demand equivalent) were mistakenly given with their German acronyms. They have been corrected in the revised manuscript.

line 175 : Why do you mean by "code aligns with FAIR principles"? is that because the code is open? or is the code directly reusable by algorithms and based on interoperability standards?

Here we meant that the code is open source and based on a free software stack. However, we realise that this is not the full definition of "FAIR principles". Therefore, we have adjusted this description of the code in L211-212 accordingly.

Section 2.4: If someone had to be autonomous for changing acquisition parameterization or adding new devices: what skills will it required? My understanding is that it is implemented in the PLC software, then it should be modified in the CODESYS scripts, is that right? Same question for changing sampling locations or measurements actions: my understanding is that this part required "only" to know Python coding, is that right? this needs to be clearer.

Since the PLC largely controls the Sample Acquisition System, adding new measurement devices would not normally require changes to the CODESYS scripts. An exception would be if adding, for example, additional tank electrodes for precipitation-triggered sampling, as these interface with the WATER via the PLC. Adding measurement devices would instead usually require writing a Python script defining the functions specific to the operation of the device and then modifying the measurement.py script to include a call to the measurement function of the new device. The device would also need to be added to the general configuration file (.yaml) of the WATER. Adding or changing sampling sites would involve positioning the physical sampling line and then making any necessary adjustments to the sampling order in the schedule. Metadata for the site (e.g., flushing time) would also need updating via the web app.

To explain this in the manuscript, additional details regarding the setup files and process of assigning source metadata were added to the first paragraph of Sect. 2.4.1. A short section (Sect. 2.6) was then also added to explain how to add or change water sources and measurement devices.

Lines 225-229: there is no additional time for filling reservoir and pumping from sources?

There is no additional pumping or filling time required as once measurements have been made by instruments on the Throughflow Pathway (i.e., ProPS and YSI 600R), pumping of the next sample and flushing of the sampling line can already begin whilst the isotope measurements are still ongoing. Once the isotope measurements are complete, the reservoir can immediately be rinsed and filled with the next sample. This detail was omitted in the manuscript and has now been added to Section 2.5 (L263-266 and L284-286). Figure 1d has also been modified to reflect that a new measurement task can begin whilst the current one is still awaiting the isotope measurements.

lines 277-278: does it need someone in charge of watching the alarms and solving eventual issues?

Alarm notifications can be sent to a list of persons responsible for the WATER via email or SMS so they are immediately made aware of any issues and can respond in a timely *manner to minimise potential data loss. This has now been stated in L247-250. This feature is made possible by a GSM modem, details of which are now given at the end of Sect. 2.1. Some other minor changes to the basic infrastructure have also been made for clarity.*

Line 286: pumping set-up for Groundwater is not described. What is the range of water table depth that is supported by this set-up?

Groundwater is pumped to the WATER by the onboard peristaltic pump (P1); there are no additional pumping mechanisms at the piezometers themselves. Confusion may have been caused by mentioning the potential to use additional pumps to facilitate sampling of deeper GW; however, this is not something we have tested, and we have removed this possibility from Sect. 2.2. In L145-146 we now provide the maximum tested horizontal and vertical pumping distances and in L333-334 also clearly state that GW samples were pumped by the onboard peristaltic pump with no additional pumps installed at the piezometers.

line 328 : can you explain what is your criteria of quality? (high NO3 concentration? high turbidity? others?)

Here we mean if a high particulate load was expected in the sampled water due to, for example, a heavy rainfall event. We have clarified this in the revised manuscript.

line 339: It would be helpful to know how often consumables need to be replaced or the approximate monthly costs associated with this.

To assist with understanding the economic dimension, we have calculated the cost of constructing the WATER (~ €310,000) and also provided estimates of monthly operational costs for an average month (€208), as well as months requiring heating (€283) or cooling (€143) of the trailer. All costs were corrected for inflation to the year 2025. Full details of the construction cost breakdown and assumptions made for the monthly costs are provided in a Supplement. In the manuscript itself, the construction cost was added to the start of Sect. 2 (L98-100), while monthly costs and additional considerations for longer-term (> 1 year) deployment were added to Sect. 3.3 (L436-441).