Replies to RC2: Anonymous Referee #2, 28 Dec 2023

This study investigates the ability of surface and root-zone soil moisture from multiple reanalysis and remote-sensing products in representing drought events in recent 20 years globally, and compares their differences in describing various drought metrics. Overall, this paper provides a comprehensive reference for selecting datasets for drought study. But the structure and conclusions of this article are not clear enough for including too many datasets and drought events, so I suggest a major revision before publication. The main suggestions are as follows.

General comments:

The authors should be more familiar to Europe, and nearly half of the 18 selected events occurred over Europe. So why not just focus on the ability of multiple datasets in characterising seasonal drought events in Europe? In Figures 6—7 and 10, the drought metrics show remarkably discrepancies between seasonal and multi-year events. Thus I suggest the reconsideration of the clarification.

We thank the reviewer for the valuable feedback. Based on the comments of Reviewer #1, we decided to reframe the study and focus on the potential of long-term satellite observations for characterising soil drying. This includes i) long-term negative changes in soil moisture, and ii) agricultural drought events.

Thus we will first focus on the global soil moisture trends, which will be based on the full year instead of dry season only. Using the ACTIVE, PASSIVE and COMBINED satellite products, we will identify regions with soil moisture trend direction agreement and those with trend disagreement (products deviate) in order to identify the areas where the agreement leads to higher confidence in satellite observed trends. We will confront this with a similar analysis based on the reanalysis products.

In a new “Discussion and synthesis” section, we will then provide a synthesis of the global trends based on the “best-estimate” products from both remote sensing and reanalysis data. This synthesis will be based on the analysis of the areas with trend agreement and disagreement and will consider the adjusted area fractions of positive and negative trends (cf. Table A1 of the current manuscript).

We will further investigate seasonal drought events as a use case to show how the diverse trend representation also affects the drought detection capabilities of the products. For this, the product intercomparison of the drought metrics (e.g., magnitude, severity), particularly regarding the relation of product deviations in these metrics and soil moisture trends, will be stratified by separating the drought regions in areas with trends agreement and in those without agreement. This stratified analysis based on the trend agreement will allow to generalise the product intercomparison. We will consider seasonal events only in the drought analysis (and neglect the few multi-year events) in order to not overload the paper and to allow better comparability of the events.

Specific comments:

1. The description of data and methods (section 2 and 3) are too long. Although the detailed information may be helpful to readers, it is not suitable in a scientific paper.

   We will shorten the description of the datasets. In particular, we will not consider the C3S soil moisture product anymore, since it is based on a precursor version of the processing algorithm of ESA CCI and thus does not represent the latest product achievements of merged satellite products. Also, as a suggestion from Reviewer #3, referenced literature on the validation of the products will be moved and only considered in the discussion section to better link the findings of the analysis.

2. The figures and tables are not well organized in the paper structure. The quantitative results in tables can be integrated to the respective figures, which can make it more clear and comparable to readers. For example, the area mean of severity, magnitude and duration in Table 2 can be added to Figure 1—3, and the maximum of spatial extent of the events to Figure 5. In addition, Figure 4—5 can also be integrated in a Figure as (a) and (b), respectively.

   We thank the reviewer for the detailed suggestions on the organisation of the figures and tables. We agree that the numbers of Table 2 can be integrated into the corresponding Figures 1–3 and will adjust the manuscript accordingly. We will also combine Figure 4 and 5 as suggested.

3. In term of the evaluation for the selected drought events, more statistical metrics can be included, such as pattern correlation, RMSE, and so on. Figures 6—9 are displayed only in bars, which is not concise and explicit enough. I recommend the Table graphic type to present each evaluation result for all events and all datasets. The detailed procedure can be seen at https://www.ncl.ucar.edu/Applications/table.shtml.

   Indeed, the presentation of the drought response as barplots may be overwhelming. We will consider the proposed presentation of these results in a revised manuscript.

4. The analysis of dry-season soil moisture is less related with the research objective. I think it is more reasonable to further compare the soil moisture during drought events after presenting the results for multiple drought events.

   As indicated in the replies to Reviewer #1, the dry-season trends will no longer be used and we will refocus the study on soil moisture trends based on the full year (but excluding the soil frost period).

5. As for the long-term trend, the analysis may be better to be conducted for the drought events rather than another indicator.

   We do not think that trends based on the events are meaningful in this case since the events are scattered in space and time. But as mentioned, we will restructure the analysis and first focus on the global soil moisture trends.

The discussion section is not convincing and substantial. In 5.1, For drought metrics and dry-season SM trend were derived from the same variable, they must be related. In 5.2, the attribution method is too simple and no quantitative results are shown.

By reframing the study and focussing on the potential of long-term satellite observations for characterising soil drying, we will investigate seasonal drought events as a use case to show the impact of the diverse trend representations on the drought detection capabilities of the products. As mentioned, the product intercomparison of the drought metrics (e.g., magnitude, severity) will be stratified by separating the drought regions in areas with trends agreement and in those without agreement. Hence, the aim will be to quantify the impact of the trend-drought relation rather than point to its existence. Furthermore, this stratified analysis based on the trend agreement will allow to generalise the product intercomparison.

As for 5.2, we will add statistical metrics (e.g., pattern correlations between the different variables) to better attribute the differences in soil moisture trends to the driving variables.