

## Response to RC1

This manuscript presents a timely and valuable global long-term dataset of optimized SMOS 40° brightness temperatures (TB), together with the corresponding soil moisture (SM) and vegetation optical depth (VOD) retrievals. It is also the first study to provide SM and VOD products derived from SMOS single-angle information. This represents an important advance, as it complements currently available multi-angular products and facilitates cross-comparison and potential fusion with SMAP-based datasets. Overall, the study is interesting, and the manuscript is well written. The dataset is publicly available, and the validation is extensive, including in situ observations as well as independent satellite and reanalysis products, which fits well within the scope of ESSD. I am positive about the overall contribution; however, before considering publication, several points could be clarified to further strengthen the manuscript:

**Response:** We sincerely thank the reviewer for the careful reading of our manuscript and for the encouraging feedback. We are deeply appreciative of your overall positive assessment. We have carefully considered the points where you suggested clarifications and these suggestions have been extremely helpful in improving the presentation quality of our work. We have addressed them point-by-point below to strengthen the manuscript.

1. There are too many acronyms throughout the manuscript. Acronyms like IB\_HR\_mono\_SMOSIB, IC\_multi\_SMOS, etc., are essential but can be challenging for readers to track. Please consider adding a small glossary table in the supplement defining these key acronyms.

**Response:** We totally agree with you that adding a table in the supplement defining these key acronyms improves the overall readability of the manuscript. Following your suggestion, a table was added in the revised supplementary document. The added table is as follows:

**Table S2 List of key abbreviations.**

<b>Abbreviation</b>	<b>Definition</b>
SMOS	Soil Moisture and Ocean Salinity
SMAP	Soil Moisture Active Passive
SM	Soil Moisture
VOD	Vegetation Optical Depth
TB	Brightness Temperature
SMOS-IC	A multi-angular SMOS algorithm developed by INRAE Bordeaux
SMAP-IB	A mono-angular SMAP algorithm developed by INRAE Bordeaux
$IB_{mono}^{SMOSIB}$	SM and VOD products retrieved by applying the SMAP-IB algorithm to the fitted SMOS L3 40° TB and updated soil roughness map
$IB_{mono}^{SMOSIB}$	SM and VOD products retrieved by applying the SMAP-IB algorithm to the fitted SMOS L3 40° TB
$IB_{mono}^{RawSMOS}$	SM and VOD products retrieved by applying the SMAP-IB algorithm to the SMOS L3 40° TB
$IC_{multi}^{SMOS}$	SM and VOD products retrieved using the processed multi-angle SMOS-L3 TB dataset with quality filtering provided by the Centre Aval de Traitement des Données (CATDS) using the SMOS-IC version 2 algorithm
$IB_{mono}^{SMAP}$	SM and VOD products retrieved by applying the SMAP-IB algorithm to the 25km SMAP-L3 TBs

2. Lines 179-180 state: “The GLDAS SM ( $\text{kg}/\text{m}^2$ ) was also transformed into volumetric unit ( $\text{m}^3/\text{m}^3$ ), with daily average SM computed for analysis”. Please correct “GLDAS SM” to “GLDAS-Noah SM” for precision. Furthermore, please specify the method used to convert the units from  $\text{kg}/\text{m}^2$  to volumetric SM ( $\text{m}^3/\text{m}^3$ ).

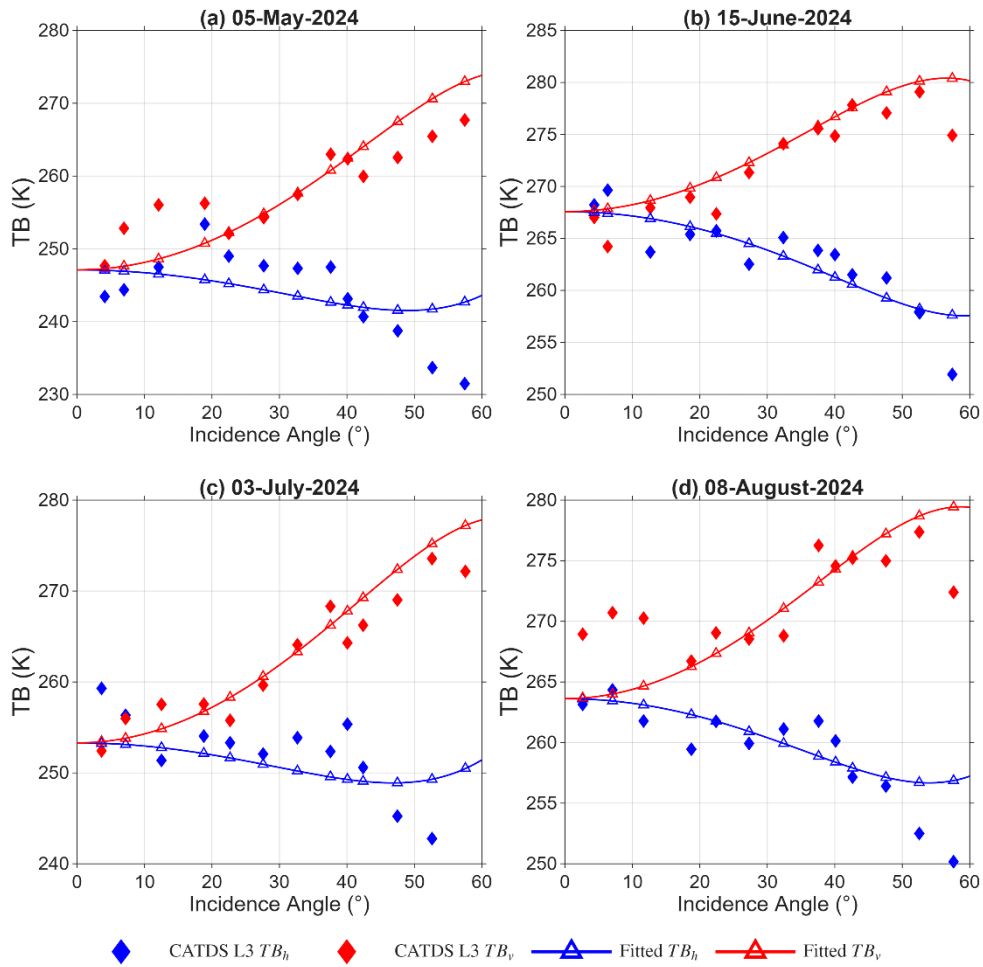
**Response:** Thanks for pointing this out. In the revised manuscript, the “GLDAS SM” has been corrected to “GLDAS-Noah SM” throughout the manuscript.

We also agree that specifying the conversion method is important for transparency. Regarding the unit conversion, the sentence was revised in the updated manuscript to specify that we followed the method established by Cui et al., (2018). The revised sentence is as follows in L175-177:

*“ The GLDAS-Noah SM ( $\text{kg}/\text{m}^2$ ) was then converted to volumetric unit ( $\text{m}^3/\text{m}^3$ ) following the method of Cui et al., (2018) by dividing by the water density and the corresponding soil layer thickness, with daily average SM computed for further analysis ”*

3. Please add labels (e.g., a, b, c, d) to each subplot in Figure 3 for easier referencing and to ensure consistency with the figure caption descriptions.

**Response:** Thanks for the suggestion. The labels have been added in Figure 3. The revised figure is as follows:



**Figure 3: Examples of L-MEB model fitting to CATDS L3 TB at a SMOS pixel located at 83.646°E, 31.661°N. Panels (a) – (d) correspond to May 5, June 15, July 3, and August 8, 2024, respectively.**

4. Table 2: The “Scene\_Flags” layer is a useful inclusion. For greater clarity, please reference or briefly describe the specific criteria for flags like “moderate Topography” (e.g., stating the specific slope range used) in the supplement or somewhere. Besides, the soil roughness map is very important for this manuscript; was that included in the published dataset?

**Response:** Thanks for this insightful suggestion. We entirely agree that providing clear definitions for the flags is crucial for data transparency and user clarity.

Regarding the topography flags, the classification criteria for “moderate” and “strong” topography in our dataset are not based on simple slope ranges. Instead, we followed the pixel-based approach developed by Mialon et al. (2008) specifically for SMOS. Briefly, this method quantifies the topographic impact using a parameter “a”, which is derived from fitting the semi-

variogram of the Digital Elevation Model (DEM). The classification is determined by comparing this parameter against specific thresholds defined by a confidence interval related to radiometric uncertainty (as detailed in Mialon et al., (2008)).

To make this clear, we have added a footnote to Table 2 in the revised manuscript that explicitly references Mialon et al. (2008) for the definitions of these flags. The revised table caption/footnote is as follows:

**Table 2: Overview of the gridded data layers included in the IB\_HR<sup>SMOSIB</sup><sub>mono</sub> dataset.**

<i>Data layer</i>	<i>Description</i>	<i>Units</i>
<i>CRS</i>	<i>Coordinate reference systems (CRS) include spatial reference information and geographic transformation parameters</i>	<i>/</i>
<i>lat</i>	<i>The latitude of the center of each grid cell</i>	<i>degree</i>
<i>lon</i>	<i>The longitude of the center of each grid cell</i>	<i>degree</i>
<i>Incidence_Angle</i>	<i>Pixel-based Incidence Angle</i>	<i>degree</i>
<i>TIME.UTC</i>	<i>Year information starting from 2010</i>	<i>/</i>
<i>BT_H</i>	<i>Optimized brightness temperature at H polarization</i>	<i>K</i>
<i>BT_V</i>	<i>Optimized brightness temperature at V polarization</i>	<i>K</i>
<i>Soil_Moisture</i>	<i>Soil Moisture (SM) retrievals</i>	<i>m<sup>3</sup>/m<sup>3</sup></i>
<i>Soil_Moisture_StdError</i>	<i>Error on the derived Soil Moisture</i>	<i>m<sup>3</sup>/m<sup>3</sup></i>
<i>Optical_Thickness_Nad</i>	<i>Vegetation Optical Depth (VOD) retrievals</i>	<i>/</i>
<i>Optical_Thickness_Nad_StdError</i>	<i>Error on the derived Vegetation Optical Depth</i>	<i>/</i>
<i>Soil_Roughness</i>	<i>Global Soil Roughness Map</i>	<i>/</i>
<i>RMSE</i>	<i>Goodness-of-fit between measured TB and modelled TB (Root Mean Square Error, RMSE)</i>	<i>K</i>
<i>Scene_Flags</i>	<i>8-bit flag</i> <i>'00000001': moderate Topography</i> <i>'00000010': strong Topography</i> <i>'00000100': polluted scene (water+urban+ice &gt; 10% of the pixel),</i> <i>'00001000': frozen scene, ECMWF_Surf_Temperature &lt; 273K</i>	<i>/</i>

**Note:** The specific criteria for “moderate Topography” and “strong Topography” flags are defined pixel-by-pixel based on the methodology described in Mialon et al., (2008).

Regarding the soil roughness map: Yes, we confirm that the soil roughness map is considered very important and is included as a data layer in the published dataset, as listed in Table 2 (“Soil\_Roughness”).

5. While using Canopy Water Content (CWC) to validate VOD temporal dynamics is innovative (Section 2.3), the manuscript currently lacks justification for choosing this specific CWC product. Please provide a brief rationale. Besides, please clarify the native spatial resolution of the CWC product. If it is finer than 25km, please explain the aggregation method used to match the SMOS-IB 25km grid.

**Response:** Thank you for the helpful suggestion. In response to this comment, we revised the manuscript to provide a clearer description of the rationale for selecting the CWC product, its

native spatial resolution, and the aggregation procedure used to match the SMOS-IB 25 km grid. The revised text is as follows (L129-133):

*"In addition, this study was the first to use satellite canopy water content (CWC) data from 2016 to 2022 to validate the temporal behavior of VOD retrievals, since L-band VOD has been demonstrated to have a linear relationship with vegetation water content (Wigneron et al., 2024). The CWC product used here was a newly developed global dataset derived from the integration of Sentinel-2, Landsat-8, and MODIS satellites with a spatial resolution of 0.05°. Its good accuracy and reliability have been previously demonstrated, making it a robust reference for large-scale assessment of VOD data (Ma et al., 2025). The dataset was obtained through personal communication but will soon be publicly available via ESA data portal. These four vegetation parameters were standardized by projecting them onto the EASE-Grid 2.0 and spatially aggregated to 25 km using arithmetic mean resampling to match the SMOS grid spatial resolution. This same resampling method has also been employed in several earlier VOD studies (Li et al., 2021; Fan et al., 2019)."*

6. The in-situ validation relies on the ISMN, which exhibits a highly non-uniform global distribution (Fig. 1), characterized by dense coverage in North America and Europe but sparse sampling in other regions. Please include a dedicated paragraph in the Discussion section acknowledging this representativeness bias. Discuss the implications for users and suggest how future validation efforts could complement this global assessment.

**Response:** Thanks for this important comment. We agree that the ISMN stations are unevenly distributed globally, with dense coverage in North America and Europe but sparse sampling across many other regions. This is a real limitation for global validation. We have addressed this issue in the revised manuscript in the following two ways:

1) The Triple Collocation Analysis (TCA) method was employed as a secondary approach for global-scale evaluation of SM quality, owing to its applicability at both the footprint and pixel scales and its independence from ground measurements as the sole reference “truth”. We have explained this motivation in the methodology section as follows in L250-254:

*“The direct validation of the SM retrievals using sparse in-situ networks may not be sufficient to obtain robust evaluation result due to potential representativeness errors associated with the spatial discrepancy between point-based in-situ SM and satellite SM observations (Al-Yaari et al., 2019; Xing et al., 2021). The TCA method was employed as a secondary approach for global-scale evaluation of SM quality, owing to its applicability at both the footprint and pixel scales (Dong and Crow, 2017).”*

2) Following your suggestion, we have added a new paragraph to discuss this representativeness bias and its implications as follows in L384-387:

*“We acknowledge the known non-uniform distribution of ISMN stations (Figure 1), and the validation results in data-sparse regions should be interpreted with caution. This inherent limitation of direct validation motivates the subsequent application of TCA-based comparison and underscores the need for future deployment of denser networks in under-represented regions.”*

7. How were the inherent mismatches handled regarding different satellite overpass times versus observed SM times, and differing native spatial resolutions between products? Please clarify the methodology by detailing the temporal compositing approach, spatial aggregation methods, and the specific temporal windows used for matching different datasets.

**Response:** Thank you for this helpful comment. We agree that the temporal and spatial matching procedures should be described more clearly. We have revised the manuscript accordingly and added the following clarification in the methodology section in L242-245 and L144-145:

*“..., a four-step procedure was applied to retain valid evaluation results and ensure fair comparisons: (1) all datasets were assessed over the common period from 2016 to 2022, (2) maximum 1-hour temporal matching between in-situ data and satellite overpasses, (3) minimum 31 valid observations (i.e., 1 month) per station for statistical robustness, and (4) restriction to the same stations containing valid evaluation metrics for all TB or SM datasets.”*

*“The SMAP-L3 TB observations were quality-controlled based on corresponding quality flags and resampled to 25 km via weighted area averaging for consistency with the SMOS’ grid resolution”*

8. Regarding the Triple Collocation Analysis (TCA) method, SM anomalies were computed using a 35-day moving window. Please clarify the rationale behind choosing a 35-day window. Is this choice based on specific references or sensitivity analysis?

**Response:** Thanks for the comment. We agree that the rationale for using a 35-day moving window should be clarified. In response, we revised the manuscript in L256-257 to specify that this choice follows the validation protocol of Gruber et al. (2020) and Fan et al. (2022) :

*“where  $\theta_{anom}(t)$  is the SM anomalies at day  $t$  and  $\overline{\theta_{(t-17:t+17)}}$  is the mean SM value via a 35-day moving window, following Gruber et al., (2020) and Fan et al., (2022).”*

9. Please explain how the high-frequency TB variations (SDHF) were computed. It is suggested to add a short description in the Methodology section to clarify this process for readers.

**Response:** Thanks for the useful suggestion. We agree and have revised the manuscript to include a brief description of the SDHF calculation in the Methodology section. The revised text is as follows in L232-236:

*“(1) The standard deviation of the high-frequency TB variations (SDHF)*

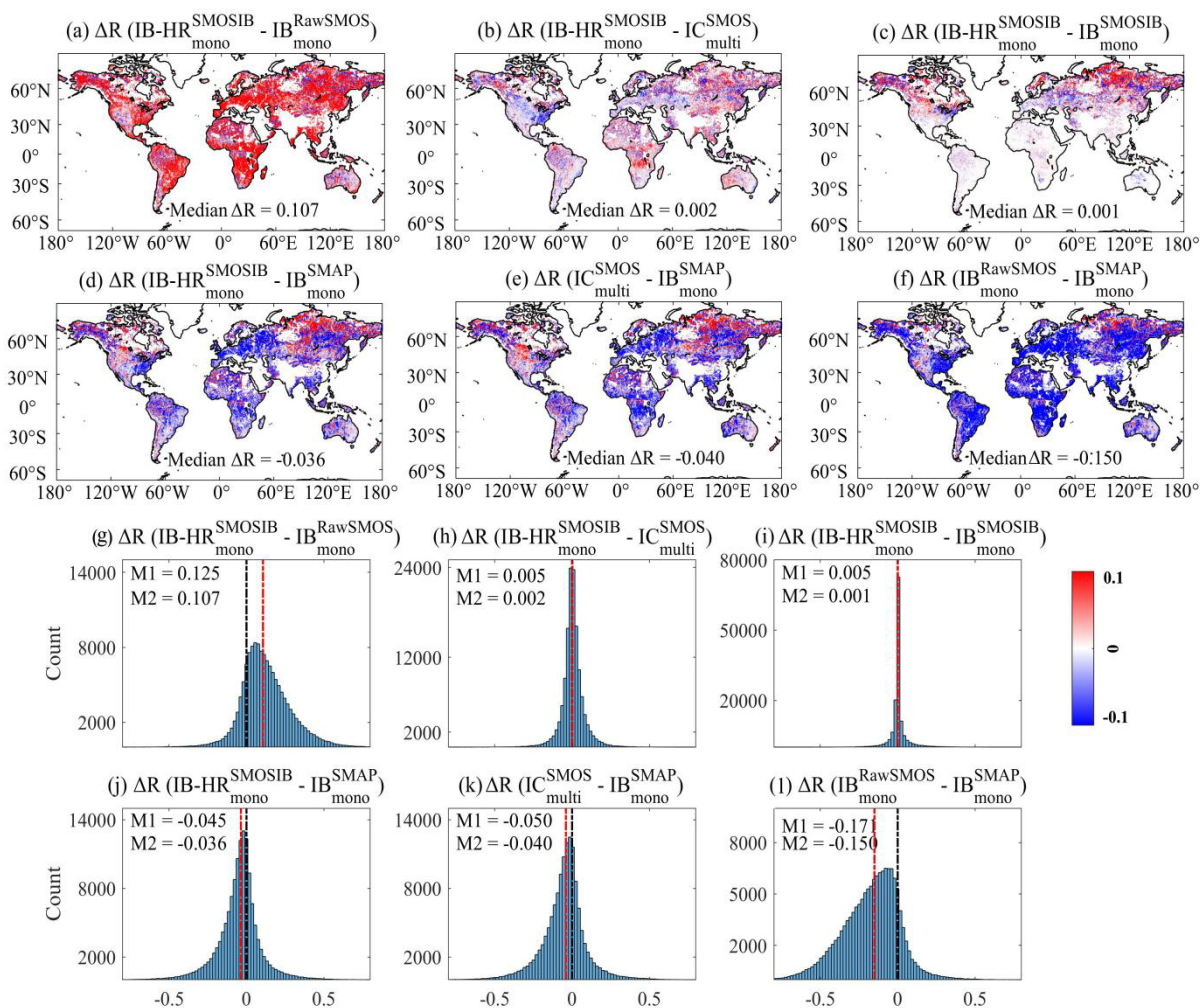
*To characterize the high-frequency variations of TB, SDHF was calculated on a pixel-by-pixel basis (Wigneron et al., 2021). First, the seasonal component of the TB time series was estimated using a 30-day moving average window. Subsequently, high-frequency anomalies were obtained by removing this low-frequency component from the original TB observations. Finally, the SDHF was computed as the standard deviation of these high-frequency anomalies over time.”*

10. In Figure 4, the unit for Kelvin should be capitalized “K”, not lowercase “k”. In Figure 6, subplot (d1), please correct the display of percentages, as the numbers are currently overlapping and unreadable.

**Response:** Thanks for pointing it out. We have corrected the unit notation and improved the readability of the percentage labels in the revised manuscript.

11. Figure 7 requires several corrections. There appears to be a labeling error, as subplot (f) seems to be duplicated; please ensure each panel is uniquely identified. Additionally, the histogram subplots (i), (j), and (k) are currently not cited anywhere in the main text. Please double-check their necessity. Besides, for consistency with other figures in the manuscript, it is suggested to change the legend orientation from horizontal to vertical.

**Response:** Thank you very much for these detailed suggestions. Following your suggestions, we have revised Figure 7, including correcting the panel labels, citing the relevant subplots in the main text, and adjusting the legend for consistency with the other figures in the manuscript:



**Figure 7: Spatial distribution ((a)–(f)) and histograms ((g)–(l)) of TCA-based R differences between paired SM anomaly products.  $m1$  and  $m2$  denote the mean and median (red line) difference value. A black vertical line marks the zero-difference reference.**

12. Please carefully check the reference list for formatting consistency. For instance, some journal names are currently capitalized in full while others are abbreviated. Please ensure all references adhere strictly to the journal's specific formatting guidelines.

**Response:** Thanks for this careful observation. We have conducted a line-by-line check of the entire reference list to ensure strict adherence to the journal's specific formatting guidelines (Copernicus Publications style). All journal names have been standardized using standard abbreviations, and citation formats (including DOIs) have been unified. The complete, formatted reference list is available in the revised manuscript.

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