Response to reviewers

Line numbers mentioned in this reply refer to our clean version of the revised manuscript.

Reviewer #1

Comments:

This work developed a monthly global long-term satellite radar C-band backscatter data set (CScat) by fusion of ERS-1(C-band), QSCAT (Ku-band) and ASCAT(C-band) observations using a new rescaling method. Maybe the CScat data set has useful in analysis and understanding of some global surface parameters (e.g., vegetation and soil moisture). But the temporal resolution is little low. And, there are some main problems of this manuscript:

Response: We thank Referee #1 greatly for the comments. Due to the covid situation in China, this reply is bit late but never careless: we have carefully considered the comments and revised the manuscript accordingly. Please see below a point-by-point response.

Regarding the temporal resolution, we chose monthly time resolution because this is perhaps the most preferred time scale for studies conducted at the global scale. Some data sets are released with a daily time resolution but daily images hardly complete a full global coverage. We have now explained it in the Introduction and Discussion (lines 117-119).

Also, as stated in the previous manuscript, we will soon release a new version of the CScat data set which has a global coverage, a ~4.5 km resolution, and a 4-day temporal resolution, by merging QSCAT and ASCAT images of the BYU version (https://www.scp.byu.edu/data.html). This point, together with the limitations of the current data set, have been made clearer in Abstract, Introduction and Discussion (lines 60, 120, and 475-485).

1) The signals of Ku-band (13.4GHz) and C-band (5.3GHz) microwave is different. Theoretically, comparing the Ku-band, the X-band and C-band have more similar frequency. Authors choose the Ku-band to fill up the six-year gap of the C-band scatterometer, not choose the X-band, L-band. It is no reasonable explanation here. In addition, authors did not choose data of the same C-band satellite radar data for fusion. It is better using same C-band radar data for fusion. For example, ERS-1/2, ASCAT, Sentinel-1 and GF-3 et al. The results of microwave data merging using the same microwave C-band have greater application significance compared with different microwave bands.

Response: We fully agree that Ku-band and C-band signal dynamics are different, but we believe this is exactly why our research is potentially valuable: we successfully developed an approach to adjust the Ku-band signals into C-band signal dynamics.

Regarding the question why X-band or C-band data were not used for filling the six-year (2001-2007) data gap between ERS and ASCAT, there is no such data at the global scale as far as we know. The only X-band sensor covering the entire period of 2001-2007 is TRMM TMI. Unfortunately, TMI is only available for tropical regions. Since we aimed at producing a global dataset, TMI was not used. For C-band Sentinel-1 and GF-3, they are available since 2014 and 2016, respectively, thus cannot be used to bridge the data gap of 2001-2007. L-band data have an even shorter time span, neither can them be used to fill the six-year data gap (2001-2007) between ERS and ASCAT.

To address your concern, we added a table (Table 1, lines 101-105 in Introduction), which lists the most frequently used satellite microwave data sets, and shows that QSCAT is a good candidate for bridging ERS and ASCAT.

2) For the developed new rescaling method, the comparison analysis in Figure 3 is not enough with CDF method in only two sites. And, Is the new rescaling method developed by authors only applicable to Ku-band correction? Can X-band and L-band data also be fused with C-band using this new rescaling method ?

Response: Before replying to this comment, we would like to mention that, thanks to a comment of Referee #3, we now avoid calling our data rescaling method a "new method”, as similar approaches have been used by previous research (Brocca et al. 2010 & 2013). The revised manuscript now focuses on producing a new radar data set, rather than a new data scaling method.

Indeed, we showed only two examples in Fig. 3. This is because these two kinds of pixel are very particular: one has a strong trend and the other has sudden changes in signal. In fact, during our calculation, we visually inspected the rescaling results for every 100 of all the pixels. We found that the three methods performed almost equally well in most pixels (per your suggestion, more examples are shown in Fig. R1). However, linear regression and CDF yielded very unnatural results for pixels with a strong signal trend or sudden changes in signal. It’s out of these reasons we show only these two kinds of pixels in Fig. 3. To address this concern, we have shown Fig. R1 as Fig. S1 in the revised manuscript.

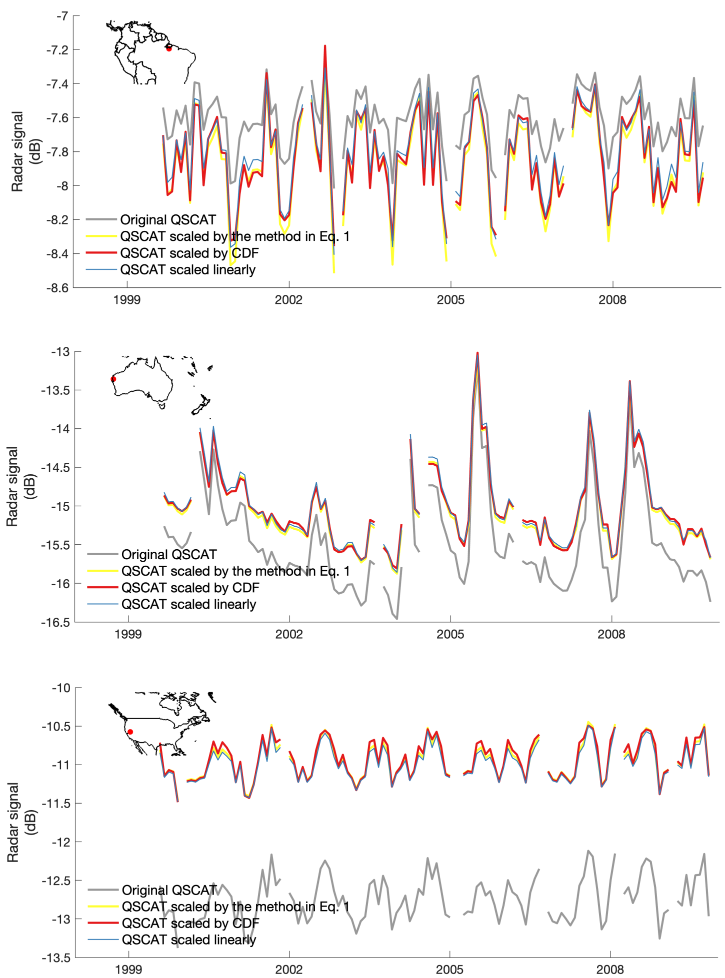

Fig. R1. QSCAT signals rescaled by different methods in different locations of the world.

Regarding the second and the third questions raised here (*And, Is the new rescaling method ….? Can X-band and L-band data also ….?*), we believe there is a misunderstanding between "rescale" and "fuse". Based on our understanding, a rescaling method can scale any time series (irrespective of the radio frequency) into the same scale as long as there are enough overlapping observations. In other words, rescaling only unify the scales of two (or more) time series. Fusing, however, means more than just rescaling: fusing additionally accounts for the signal differences between the scaled signals. In other words, rescale is the first of the two steps of fusing. We sincerely hope this makes sense, and will be glad to exchange more if needed.

3) I think the validation of CScat data set is not sufficient if authors only used ERS-2 data as validation data for CScat. I suggested that the authors consider using the C-band observation data of airborne or other satellite/sensor different ERS-1/2 as comparison data. And, I doubt the reliability of the validation results of CScat data set. Authors used the ERS-1 observation radar signals to correct the Ku-band signals of QSCAT, and used the ERS-2 signals to validate the corrected Ku-band data. Because the satellite parameters and sensor parameters of ERS-1 and ERS-2 are the quite same, the observation radar signals of ERS-1 and ERS-2 are very similar at the same place and time. This may be the reason for the very high correlation coefficient in Figure 9.

Response: We believe there is a misunderstanding here, which is possibly caused by our ambitious use of the word "ERS". In our previous manuscript, we sometimes used "ERS" to refer to "ERS-1", and sometimes to "ERS-2". We apologize and have specified whether it's "ERS-1" or "ERS-2" every time we mention "ERS". Figs. 1 & 2 have been redrawn.

In fact, we did not use ERS-1 to correct the Ku-band signals: ERS-1 scatterometer stopped working in 1996, thus did not overlap with ASCAT. Instead, we used C-band ERS-2 (1996-2001) and ASCAT (2007-2020) to adjust the Ku-band QSCAT (1999-2009) into C-band signal dynamics, based on overlapping observations in the years of 1999-2001 (between ERS-2 and QSCAT) and 2007-2009 (between ASCAT and QSCAT).

To check whether Ku-band QSCAT signals have been well adjusted into C-band dynamics, the best validation data should be a continuous C-band time series extending through our study period—This is exactly what we did with Fig. 9: although ERS-2 stopped working in full mode after 2001, observations are occasionally available for a subset of global pixels until 2011. Comparing our merged radar signal against this long-term but spatially incomplete ERS-2 dataset is the strictest validation we can perform.

Regarding "*the C-band observation data of airborne or other satellite/sensor different ERS-1/2*", we appreciate this suggestion but didn't find such data covering the period of 2001-2007 (during which Ku-band signal was used to bridge the C-band data gap). We would be glad to further test our merged data set if more details can be provided by Referee #1.

4) The English language of manuscript needs to be polished. The abstract of this manuscript is too long. For the introduction of this manuscript, the research background for active microwave fusion or rescaling study is not sufficient. In 110 lines, is there any other studies that show that the Ku-band QSCAT signal can be adjusted to the ERS observations except the author's own research (i.e., Tao et al.,2002b)? I suggest that the abstract and introduction of this manuscript need to be rewritten.

Response: Thank you. As suggested, we have further corrected some grammar errors during this revision. The abstract has also been shortened.

Regarding the Introduction, we very much appreciate the suggestion that more background for fusing active microwave data is needed. Thanks! We have added a new table to specify the sensor details of the most frequently used satellite microwave sensors. From the table (Table 1), it's clear that using QSCAT to fill the 2001-2007 data gap at the global scale is good choice (and perhaps the only choice). For your question "*is there any other studies that show that the Ku-band QSCAT signal can be adjusted to the ERS observations except the author's own research (i.e., Tao et al.,2002b)?*" The answer is yes: recently, Frolking et al. (2022a & b) have been published which merged signals from exactly the same sensors but for global metropolis. Their research therefore confirms that QSCAT is one of the best options for gap-filling the six-year data between the ERS and ASCAT. We have referred to Frolking et al. (2022 a & b) in the revised manuscript (line 104).

Above-mentioned, I am in a difficult position to reject the manuscript for publication

Response: We believe the comments from Referee#1 have largely improved our manuscript, and we hope the revision has address all the raised concerns. Once again, we thank Referee #1 for the helpful comments.

References

Brocca L, Melone F, Moramarco T, et al. Scaling and filtering approaches for the use of satellite soil moisture observations[J]. Remote Sensing of Energy Fluxes and Soil Moisture Content, 2013, 411: 426.

Brocca L, Melone F, Moramarco T, et al. Improving runoff prediction through the assimilation of the ASCAT soil moisture product[J]. Hydrology and Earth System Sciences, 2010, 14(10): 1881-1893.

Frolking, S., Milliman, T., Mahtta, R., Paget, A., Long, D. G., and Seto, K. C.: A global urban microwave backscatter time series data set for 1993–2020 using ERS, QuikSCAT, and ASCAT data. Sci. Data, 9(1), 1-12, 2022a.

Frolking, S., Mahtta, R., Milliman, T., and Seto, K. C. (). Three decades of global trends in urban microwave backscatter, building volume and city GDP. Remote Sens. Environ., 281, 113225, 2022b.

Tao, S., Chave, J., Frison, P.-L., Toan, T. L., Ciais, P., Fang, J., Wigneron, J.-P., Santoro, M., Yang, H., Li, X., Labrière, N., and Saatchi, S.: Increasing and widespread vulnerability of intact tropical rainforests to repeated droughts, Proc. Natl. Acad. Sci. U.S.A.: 119, e2116626119, 2022b.