A global long-term (1981-2000) land surface temperature product for NOAA AVHRR: Response to Referee 2

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We would like to thank Referee 2 for her/his careful review of the manuscript and her/his constructive criticism and valuable comments. Comments by the referee are colored in black, our replies or comments are colored in blue.

This manuscript reports a global land surface temperature dataset derived from the historical NOAA AVHRR data. According to my understanding, the most important contribution is that this global dataset was built over a long period of time from 1981 to 2000, and is needed by the scientific community in the field of geoscience. The second contribution is that the authors also conducted orbit-drift correction for the land surface temperature. With this dataset, I believe that the scientific community in the field of geoscience can better address the issues associated with climate change, hydrology, environment, etc. Therefore, this manuscript is definitely within the scope of ESSD. Additionally, this manuscript is well organized and written.

Nevertheless, I suggest that the authors consider the following comments and then improve the manuscript.

Thank you for the positive evaluation and for stressing the usefulness of the data record.

1. Line 38: the authors claim that the coarse resolution and high penetration depth are two main problems, which affect the accuracy of surface temperature from passive microwave remote sensing. However, the authors should keep in mind that the surface emissivity, as well as other physical mechanisms beyond our understanding, are also the main reasons. The authors need to clearly mention these points here.

The uncertainty associated with land surface emissivity is indeed a problem in the LST retrieval from passive microwave data. We also agree that some physical mechanisms related to retrieving LST from passive microwaves are still beyond our understanding. However, uncertainty in thermal sampling depth is one of the largest sources of uncertainty in LST retrieval from passive microwaves. In fact, the physical definitions of land surface temperature (i.e. TIR LST) and the so-called retrieved temperature from passive microwave differ (Zhou et al., 2017). In the revised manuscript, we now additional mention possible uncertainties due to emissivity by writing ": compared to TIR remote sensing, it is limited by factors such as coarser spatial resolution, higher thermal sampling depth, and higher uncertainty in emissivity, which results in a lower retrieval accuracy (Zhou et al., 2017).".

Reference:

Zhou, J., Zhang, X., Zhan, W., Göttsche, F.M., Liu, S., Olesen, F.S., Hu, W., Dai, F., 2017. A Thermal Sampling Depth Correction Method for Land Surface Temperature Estimation From Satellite Passive Microwave Observation Over Barren Land. IEEE Trans. Geosci. Remote Sens. 55, 4743–4756. https://doi.org/10.1109/TGRS.2017.2698828

2. Line 43-44: according to my experience, I also think that the algorithm selection depends on the availability of the required input parameters. I suggest revising here.

We agree with you. We now state in the revised manuscript that “Selecting a suitable algorithm for retrieving LST depends on the sensor’s number of TIR channels and their spectral specifications, as well as the available auxiliary input data.”.

3. Line 46: There are many satellite sensors with both the 11 and 12 microns. I suggest mentioning the NOAA AVHRR and ENVISAT AATSR before SLSTR.

Thanks for your suggestion. We have changed the text in the revised manuscript to “The SWA is a good choice for retrieving LST from sensors with two or more TIR channels centred at 11 μm and 12 μm, e.g. Terra/Aqua MODIS, NOAA AVHRR, ENVISAT AATSR, and Sentinel-3 SLSTR.”.

4. Line 57: The authors state ‘no single SWA performs the best under all conditions’. How can you obtain such a conclusion? Please explain here and add supporting references here.

Thanks for your suggestion. The conclusion is based on previous research, e.g. Yu et al. (2009), Zhou et al. (2019), Yang et al. (2020). The SWA is the simplification of the radiative transfer model, which always depends on the available input parameters. Yu et al. (2009) and Zhou et al. (2019) compared seventeen SWAs developed by the scientific community in recent decades. The results show that some SWAs achieve lower training accuracies and some are more sensitive to the input parameters. In other words, an SWA’s performance depends on the application conditions, e.g. atmosphere conditions. Therefore, we concluded that no single SWA performs the best under all conditions.

Reference:

Yang, J., Zhou, J., Göttsche, F.-M., Long, Z., Ma, J. and Luo, R.: Investigation and validation of algorithms for estimating land surface temperature from Sentinel-3 SLSTR data, Int J Appl Earth Obs Geoinf., 91(April), 102136, doi:10.1016/j.jag.2020.102136, 2020.

Yu, Y., Tarpley, D., Privette, J. L., Goldberg, M. D., Rama Varma Raja, M. K., Vinnikov, K. Y. and Hui Xu: Developing Algorithm for Operational GOES-R Land Surface Temperature Product, IEEE Trans. Geosci. Remote Sens., 47(3), 936–951, doi:10.1109/TGRS.2008.2006180, 2009.

Zhou, J., Liang, S., Cheng, J., Wang, Y. and Ma, J.: The GLASS Land Surface Temperature Product, IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., 12(2), 493–507, doi:10.1109/JSTARS.2018.2870130, 2019b.

5. Line 58-59: The products cannot be retrieved. Also, cite the following references for the MODIS LST products: Wan, 2002, RSE; Wan, 2008, RSE.

Thanks for your comments. We changed the expression and added the suggested references for MODIS LST and now write “Currently, several LST products derived from satellite TIR remote sensing are available. Global LST products for Terra/Aqua MODIS are available since 2000, e.g. MOD11/MYD11 (Wan, 2008, 2014; Wan et al., 2002) and MOD21/MYD21 (Hulley and Hook, 2011).”.

Reference:

Hulley, G. C. and Hook, S. J.: Generating consistent land surface temperature and emissivity products between ASTER and MODIS data for earth science research, IEEE Trans. Geosci. Remote Sens., 49(4), 1304–1315, doi:10.1109/TGRS.2010.2063034, 2011.

Wan, Z.: New refinements and validation of the MODIS Land-Surface Temperature/Emissivity products, Remote Sens. Environ., 112(1), 59–74, doi:10.1016/j.rse.2006.06.026, 2008.

Wan, Z.: New refinements and validation of the collection-6 MODIS land-surface temperature/emissivity product, Remote Sens. Environ., 140, 36–45, doi:10.1016/j.rse.2013.08.027, 2014.
Wan, Z., Zhang, Y., Zhang, Q. and Li, Z-L: Validation of the land-surface temperature products retrieved from terra moderate resolution imaging spectroradiometer data, Remote Sens. Environ., 83(1–2), 163–180, doi:10.1016/S0034-4257(02)00093-7, 2002.

6. Line 65: check the status of Sentinel-3C and make any necessary revision.

Sentinel-3C is still unavailable, i.e. a revision is currently not required.

7. Line 82: I'm confused by 'cover progressively smaller areas'.

With this sentence, we wanted to express that most glaciers on the Tibetan Plateau are in retreat and the areas covered by them are getting smaller and smaller. We changed the sentence to "…, e.g. most glaciers on the Tibetan Plateau are in retreat and the areas covered by them are getting smaller and smaller (Yao et al., 2012)."

Reference:

Yao, T., Thompson, L., Yang, W., Yu, W., Gao, Y., Guo, X., Yang, X., Duan, K., Zhao, H., Xu, B., Pu, J., Lu, A., Xiang, Y., Kattel, D. B. and Joswiak, D.: Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings, Nat. Clim. Chang., 2(9), 663–667, doi:10.1038/nclimate1580, 2012.

8. Line 97: I would suggest deleting the last sentence. It may appear in the wrong place. It should be in the methodology section instead of the introduction.

The respective sentence has been deleted.

9. Line 117: Add references for the SST.

Thanks for your suggestion: we added a reference for SST in the revised manuscript.

10. Line 139: How did you obtain these 48 land surface emissivities? Please explain. Such information is important for the authors.

In this study, channel-effective emissivity was obtained from the Johns Hopkins University (JHU) spectral emissivity library by convolving emissivity spectra with the spectral response functions of NOAA-07/09/11/14 AVHRR, please see lines 141-143.

11. Line 165: many studies use the SURFRAD data to validate the surface temperature derived from satellite data. I would suggest adding more references.

Thanks for your suggestion; we added more references in the revised manuscript.

12. Line 180: you used the random forest to integrate multiple algorithms. Please explain why you selected this method?

Thanks for your question. In line 180 we only mention the general method for integrating multiple algorithms, i.e. the random forest (RF) method, to inform the reader about the basic concepts used in this study. The RF method is then briefly discussed in section 3.2. It has several advantages, including the ability to process large databases with high efficiency, unbiased estimation, and especially minimizing the risk of overfitting in explaining complicated nonlinear relationships when compared with detailed analytic expressions (Hutengs and Vohland, 2016), and it has been used in many studies, e.g land cover classification (Rodriguez-Galiano et al., 2012), land surface parameter downscaling (Zhao et al., 2018), and estimating vegetation cover parameters (Mutanga et al., 2012). Please see lines 211-216.

Reference:

Hutengs, C. and Vohland, M.: Downscaling land surface temperatures at regional scales with random forest regression, Remote Sens. Environ., 178, 127–141, doi:10.1016/j.rse.2016.03.006, 2016.

Mutanga, O., Adam, E. and Cho, M. A.: High density biomass estimation for wetland vegetation using worldview-2 imagery and random forest regression algorithm, Int. J. Appl. Earth Obs. Geoinf., 18(1), 399–406, doi:10.1016/j.jag.2012.03.012, 2012.

Rodriguez-Galiano, V. F., Ghimire, B., Rogan, J., Chica-Olmo, M. and Rigol-Sanchez, J. P.: An assessment of the effectiveness of a random forest classifier for land-cover classification, ISPRS J. Photogramm. Remote Sens., 67(1), 93–104, doi:10.1016/j.isprsjprs.2011.11.002, 2012.

Zhao, W., Sánchez, N., Lu, H. and Li, A.: A spatial downscaling approach for the SMAP passive surface soil moisture product using random forest regression, J. Hydrol., 563(June), 1009–1024, doi:10.1016/j.jhydrol.2018.06.081, 2018.

13. Line 185: how do you conduct the monthly averaging?

The monthly data set is simply averaged from the daily orbital drift corrected LST. In detail, the program first searches the date labels of the daily LST data files to identify the data within the month to be processed. Then the sum of all valid LST within this month is calculated and divided by the number of valid LST. This step is now also explained in the revised manuscript.

14. Line 192: please give the reason why you use 0.12 K?

The design goals for the AVHRR thermal infrared channels were a NEΔT of 0.12K (@ 300K). Therefore, we added a Gaussian-distributed noise with a NEΔT of 0.12 K to simulate BTs measured by satellites more realistically.

15. Line 209-210: Please note that here is the method part, so you have not conducted the integration yet. Therefore, from the logical sequence, you don’t know whether this method can get stable and robust results.

Thanks for your comment. We agree with you. In the study, we want to develop a more stable method to generate global LST. We want to integrate multiple single SWAs to reduce the random error in LST retrieval, which is primarily due to uncertainty in the input parameters. The respective sentence in the revised manuscript has been changed accordingly.

16. Line 243: as for the NDVI threshold method, I suggest citing Sobrino et al. (2008).
Please check this reference.

Thanks for your suggestion. The NDVI threshold method in Sobrino et al. (2008) uses the square of normalized NDVI to calculate the fraction of vegetation. However, in this study, we only use the normalized NDVI instead of its square, which refers to method proposed in Carlson and Ripley (1997).

Reference:

Carlson, T. N. and Ripley, D. A.: On the relation between NDVI, fractional vegetation cover, and leaf area index, Remote Sens. Environ., 62(3), 241–252, doi:10.1016/S0034-4257(97)00104-1, 1997

Sobrino, J. A., Jiménez-Muñoz, J. C., Sòria, G., Romaguera, M., Guanter, L., Moreno, J., Plaza, A. and Martínez, P.: Land surface emissivity retrieval from different VNIR and TIR sensors, IEEE Trans. Geosci.

Remote Sens., 46(2), 316–327,doi:10.1109/TGRS.2007.904834, 2008

17. Line 315: please simply give the results for NOAA-7 and NOAA-11 AVHRR here or somewhere.

Thanks for your suggestion. The results for NOAA-7 and NOAA-11 AVHRR are very similar to those obtained for NOAA-9 and NOAA-14. Therefore, we did not provide the respective results for NOAA-7 and NOAA-11. However, in the original manuscript we stated that “Generally, the SWA training results for the four sensors are consistent with each other.”. In the revised manuscript, we also added a sentence explaining that the results for NOAA-14 AVHRR are a good example for the other sensors.

18. Line 335: why the accuracy depends on the land cover type?

There are two main reasons: on the one hand, the SWAs perform differently over different land covers, i.e. they show different training accuracies over the same land cover, even for the same input data. On the other hand, the nine SWAs were selected because they are relatively insensitive to the main input parameters, i.e. LSE and CWVC; however, the nine SWAs still differ in their sensitivity to uncertainty in the input parameters. In the validation with the simulation data, the LSE was set according to the land cover type over which the atmospheric profile was located. Therefore, the accuracy of each SWA depends on land cover type. The findings from the simulation data motivated us to look for a more suitable optimization method, e.g. random forests, in order to reduce dependence on input parameter uncertainty.

19. Line 397: what are the WMO requirements? Please explain.

Thanks for your suggestion. The WMO provides requirements for LST in several related fields, e.g. the uncertainty requirement is 2.0 K for Agricultural Meteorology and 1.0 K for Climate Monitoring. In the revised manuscript we added the sentence “Furthermore, the validation results meet WMO’s requirements for applications of LST/LSWT in different fields, e.g. an uncertainty of 2.0 K for Agricultural Meteorology and of 1.0 K for Climate Monitoring (WMO, 2020).”

Reference:

WMO: Requirements defined for Land surface temperature, [online] Available from: https://www.wmo-sat.info/oscar/variables/view/96 (Accessed 29 July 2020), 2020.