A global long-term (1981-2000) land surface temperature product for NOAA AVHRR: Response to Referee 1

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We would like to thank Referee 1 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 is an interesting manuscript described a processed AVHRR LST dataset that is very useful for long-term study of land surface temperature variation. Specifically, the dataset can be referred as a base for the climatological study of surface temperature since 2000: variation analyses between the LSTs derived from recent/current and the AVHRR LSTs can be a solid evidence of the global climate change. The method described in the manuscript can also be applied for producing long-term LST data record from other satellite missions, such as EOS MODIS and JPSS VIIRS.
The manuscript provides details of the LST algorithms being applied, multiple datasets being used, which are all good for readers to use the data, or to process their own long-term record of LST data.

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

Improvements suggested:
How the in-situ LST is estimated? Quality control/noise reduction in the process?

In this study, the *in-situ* LST were collected from SURFRAD sites and NDBC. The NDBC data consisted of water surface temperatures measured directly by buoys: since these are highly accurate and quality controlled by NDBC (https://www.ndbc.noaa.gov/qc.shtml), we used the water temperatures as they were distributed.

The SURFRAD *in-situ* LST were calculated from measured broadband hemispherical upwelling radiance (L_u) and atmospheric downwelling radiance (L_d) using Stefan-Boltzmann's law:

$$T_s = \sqrt[4]{\frac{L_u - (1-\varepsilon)L_d}{\varepsilon\sigma}}$$

where broadband emissivity ε is obtained from AVHRR LSE in channels 4 and 5 via the empirical relationship ε=0.2489+0.2386ε_4+0.4998ε_5 (Liang, 2005) and σ (=5.67×10-8 W/(m^{2}K^4)) is the Stefan-Boltzmann constant.

Quality control is an integral part of the design and operation of the SURFRAD network, which results in datasets of high quality and well-defined measurement uncertainties (https://www.esrl.noaa.gov/gmd/grad/surfrad/). SURFRAD data have been directly used in satellite retrieved LST validation (Liu et al., 2019; Martin et al., 2019; Wang and Liang, 2009); therefore, we did not perform additional quality control or noise reduction. However, the *in-situ* LST and the satellite retrieved LST may still contain outliers, e.g. samples contaminated by undetected clouds. Therefore, three-sigma (3σ) filtering was employed to remove such possible outliers from the match-ups. Please see section 3.5 for the corresponding description (Göttsche et al., 2016; Pearson, 2002).

Reference:

Göttsche, F.-M., Olesen, F.-S., Trigo, I., Bork-Unkelbach, A. and Martin, M.: Long Term Validation of Land Surface Temperature Retrieved from MSG/SEVIRI with Continuous in-Situ Measurements in Africa, Remote Sens., 8(5), 410, doi:10.3390/rs8050410, 2016.

Liang, S.: Estimation of Surface Radiation Budget: I. Broadband Albedo, in Quantitative Remote Sensing of Land Surfaces, pp. 310–344, John Wiley & Sons, Inc., Hoboken, NJ, USA., 2005.

Liu, X., Tang, B. H., Yan, G., Li, Z. L. and Liang, S.: Retrieval of global orbit drift corrected land surface temperature from long-term AVHRR data, Remote Sens., 11(23), 2843, doi:10.3390/rs11232843, 2019a.

Martin, M., Ghent, D., Pires, A., Göttsche, F.-M., Cermak, J. and Remedios, J.: Comprehensive In Situ Validation of Five Satellite Land Surface Temperature Data Sets over Multiple Stations and Years, Remote Sens., 11(5), 479, doi:10.3390/rs11050479, 2019.

Pearson, R. K.: Outliers in process modeling and identification, IEEE Trans. Control Syst. Technol., 10(1), 55–63, doi:10.1109/87.974338, 2002.

Wang, K. and Liang, S.: Evaluation of ASTER and MODIS land surface temperature and emissivity products using long-term surface longwave radiation observations at SURFRAD sites, Remote Sens. Environ., 113(7), 1556–1565, doi:10.1016/j.rse.2009.03.009, 2009.

Cloud pixel exclusion (how cloud information was provided in the original data?) process?

Thanks for your comment. In this study, we used the LTDR AVHRR dataset as the source data to produce the LST products. The dataset provides quality control (QC) flags for each pixel and contains information on clouds as well as other conditions, e.g. cloud shadow, water, etc. When generating the LST products, we used the QC flags to identify pixel containing cloud and cloud shadow and excluded them from the processing. This information has been added in the revised manuscript.

The final 0.05 deg resolution data – Is this the resolution from the original AVHRR dataset? If not how about the compositing/aggregation process applied?

In this study, the LTDR AVHRR dataset served as the source data of the LST product. The spatial resolution of the LTDR AVHRR dataset is 0.05°×0.05° (already processed from AVHRR's native resolution; please see Table 1). In order to clarify this, we added the following sentence to the revised manuscript:

"In this study, the AVHRR datasets from Long-Term Datasets Records (Pedelty et al., 2007) (LTDR, https://ltdr.modaps.eosdis.nasa.gov/) are used, including AVH02C1 and AVH13C1, for which spatial resolution has been processed to 0.05°×0.05° (Table 1)."

Reference:

Pedelty, J., Devadiga, S., Masuoka, E., Brown, M., Pinzon, J., Tucker, C., Vermote, E., Prince, S., Nagol, J., Justice, C., Roy, D., Ju, J., Schaaf, C., Liu, J., Privette, J. and Pinheiro, A.: Generating a long-term land data record from the AVHRR and MODIS instruments, Int. Geosci. Remote Sens. Symp., (May), 1021–1024, doi:10.1109/IGARSS.2007.4422974, 2007.

How the monthly average data set is generated? Details about the compositing/aggregation process?

The monthly average data are obtained from daily orbital drift corrected LST as follows: 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. We added some text explaining this and other LST processing steps in a new section of the revised manuscript:

"3.5 Generation of LST products

The product generation executable (PGE) code includes four Modules. Module I is for generating the multi-LST with the selected SWAs. Three different types of input data enter this module: (i) the satellite data: BTs from AVH02C1, NDVI from AVH13C1, bare soil emissivity (see section 3.3), and AVHRR LCTs from UMD; (ii) look-up tables: coefficients of the SWAs (see section 3.1), emissivities of vegetation, water, and built-up areas (see Table 7); and (iii) ancillary data: NSAT and CWVC from MERRA and land-sea mask. The QC flags in AVHR02C1 are also used to identify cloudy pixel. If a pixel contains cloud or cloud shadow, its LST is not calculated. Therefore, the output of Module I is multi-LST under clear sky conditions.

Module II is for integrating the multi-LST with the trained RF ensemble model. The inputs include the multi-LST from Module I and the RF ensemble model; the output is the ensemble LST, which is termed RF-SWA LST. Module III is for normalizing the LST affected by orbital drift to 14:30 solar time. In this Module, the input datasets include the RF-SWA LST and NDVI; the latter is used for calculating the fraction of vegetation. The output of Module III is orbital drift corrected LST, which is termed OCD LST. Module IV is for generating monthly average LST: the module first groups ODC LST by month, sums the valid LST in each month up, and divides them by the respective number of valid LST. The output from this Module is monthly averaged ODC LST. All LST data are stored in standard HDF-EOS format. Table 8 shows the variables provided in the three types of LST data files."