NOAA20 AND S-NPP VIIRS LAND SURFACE TEMPERATURE PRODUCT VALIDATION AND INTER-COMPARISON

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ABSTRACT

The enterprise Land Surface Temperature (LST) algorithm has been operationally implemented for Visible Infrared Imager Radiometer Suite (VIIRS) onboard both NOAA 20 (N20) and Suomi National Polar-orbiting Partnership (S-NPP) satellite since September, 2019. This study presents the validation of the two LST products. The ground based measurements from Baseline Surface Radiation Network (BSRN) and Surface Radiation Budget Network (SURFRAD) were used to estimate the quantitative uncertainty of the LST product. The validation results present a similarly close agreement between ground observations and satellite estimations from both N20 and S-NPP VIIRS LST products. The accuracy is about -0.4 K for N20 and -0.3 K for S-NPP and the precision is about 1.9 K for both LST products over SURFRAD sites. Similar performance is achieved over BSRN sites. In addition, the global inter-comparison of the two LST products were presented and analyzed.

Index Terms— VIIRS, LST Validation, BSRN, SURFRAD, Enterprise Algorithm, S-NPP, NOAA 20

1. INTRODUCTION

Land surface temperature (LST), a critical parameter controlling surface heat and water exchange with the atmosphere, has been listed as one of the essential variables (ECV) in Global Climate Observing System (GCOS) [1]. Satellite land surface temperatures (LSTs) have been routinely produced for decades from a variety of polar-orbiting and geostationary satellites, which makes it possible to generate LST climate data globally. However, consistency of the satellite LSTs from different satellite missions is a concern for such purpose; an enterprise satellite LST algorithm is desired for the LST production through different satellite missions [2].

The regression algorithm based on the split window (SW) technique has been the most widely used strategy for producing the operational LST products [3-7] due to its simplicity, effectiveness and robustness. Therefore the SW approach is adopted in the development of the enterprise LST algorithm. VIIRS onboard S-NPP, N20 and future JPSS series, has 22 spectral bands covering wavelengths from 0.4 to 12.5 µm, providing data for the production of more than 20 Environmental Data Records (EDRs) including LST EDR. The M bands on VIIRS sensor include two split window channels i.e. M15 and M16 used for the LST retrieval. The enterprise LST algorithm uses emissivity explicitly which allows easy incorporation of the new and improved global emissivity products. NOAA Land Surface Emissivity (LSE) product, a newly developed daily global emissivity product, provides VIIRS two split window narrow bands and one broadband emissivity at 1 km spatial resolution [8].

The details of the enterprise LST algorithm has been described in Liu et al., (2019), in which a comprehensive quality assessment of the enterprise N20 LST product was presented including the theoretical evaluation based on the simulation data, ground evaluation using SURFRAD and BSRN observations and cross satellite evaluation against MODIS LST product. In this study, the focus is given to the validation of both S-NPP and N20 VIIRS LST products and global inter-comparisons between them. The temporal coverage is also extended in the validation practice compared to that in the previous study.

2. DATA

Multiple data sets were used in this study: both NOAA 20 and S-NPP VIIRS LST data, which are to be assessed; ground observations from BSRN and SURFRAD used in temperature based validation.

In this study, the six sites of SURFRAD network over continental U.S. were selected for VIIRS LST validation. The site in Goodwin Creek was excluded due to the site heterogeneity, which has been reported in [2, 4, 9]. Note that though there are 58 stations as of mid-2013 in BSRN, only two stations are selected for LST validation. There are several reasons: firstly there are only 8 sites with long wave upwelling observations, which are required in the ground LST calculation. Secondly, some sites have retired so that no temporal overlap with VIIRS measurements. Thirdly some sites do not satisfy the thermal homogeneity requirements for LST validation particularly some sites are close to the water body. The selected two sites are located at Gobabeb, Namibia (GOB) and Cabauw, The Netherlands (CAB).

The N20 satellite, launched in November, 2017, provides the LST data since January 5, 2018 while the S-NPP satellite, launched in 2011, provides the LST data back to Feb. 2012. Therefore the most available data was used in the ground based validation. The SURFRAD data from Jan. 2018 to Oct. 2019 and Feb. 2012 to Oct. 2019 was used in the validation of N20 and S-NPP VIIRS LST, respectively. The same time period of BSRN data was used for N20 VIIRS LST validation and the data from Jan. 2015 to Oct. 2019 was used for S-NPP VIIRS LST validation. Besides, the gridded global S-NPP and N20 VIIRS LST is collected for inter-comparison.

3. LST ASSESSMENT METHODOLOGY

Three approaches are widely used for LST products validation: T-based method, radiance based (R-based) method and the cross-satellite comparison method [4]. Obtaining reference (or "truth") LST value is the key. In this study, we mainly used the T-based method to assess the VIIRS LST quality.

The T-based method is a direct comparison analysis of the ground LST measurements and the corresponding satellite estimates. It is based on the assumption that the ground LST measurements would represent fairly well the satellite LSTs. Obviously such assumption may be problematic in some ground sites where thermal homogeneity is a serious issue. The ground observations of surface leaving longwave radiation are used to estimate in situ LSTs. The T-based method is limited by the spatial variability of LSTs, especially during daytime [10].

3.1. Ground LST estimation

The in situ surface skin temperature, Ts, is estimated using the following equation

$$T_S = ((R^{\uparrow} - (1-\varepsilon)R^{\downarrow}) / \sigma\varepsilon)^{1/4} \qquad (1)$$

Where $R^{\uparrow}$ and $R^{\downarrow}$ are upwelling and downwelling long wave fluxes respectively, ε is the surface broadband emissivity, and σ is Stefan-Boltzmann constant i.e., 5.67051×10^{-8} $W \cdot m^{-2} \cdot K^{-4}$. ε, the broadband emissivity, is obtained from NOAA LSE product [8]. Both ground data and satellite data are quality controlled using the same procedure described in [4].

3.2. Inter-comparison between S-NPP and N20 VIIRS LST

The N20 satellite is the follow-on mission to the S-NPP satellite in the JPSS series. Both satellites are in the afternoon orbit and N20 leads S-NPP by a half orbit or about 50 minutes. For this reason, when comparing the S-NPP and N20 LST, the temporal and viewing geometry differences have to be taken into account. Note that the VIIRS LST is derived based on the satellite thermal infrared observations and LST is not retrieved under cloudy conditions. Therefore the daily global LST product has many gaps mostly due to the cloud coverage. To account for the impact of viewing geometry and temporal difference, the global mean LST difference over 32-day repeating cycle is used to assess the consistency of the two LST products. The 32-day cycle was chosen to meet the needs with regards to the data availability. In this study, the S-NPP and N20 LST for the time period of May 11, 2019 to June 10, 2019 were collected for the comparison.

4. GROUND VALIDATION RESULTS

As shown in Figure 1, the overall close agreement is observed from the ground validation indicating that both S-NPP and N20 VIIRS LST has a good quality. In detail, the accuracy is -0.39 K and -0.29K, and the precision is 1.89 K and 1.86 K for N20 VIIRS LST comparison with SURFRAD and BSRN over all sites, respectively. The accuracy is -0.29 K and -0.23 K and

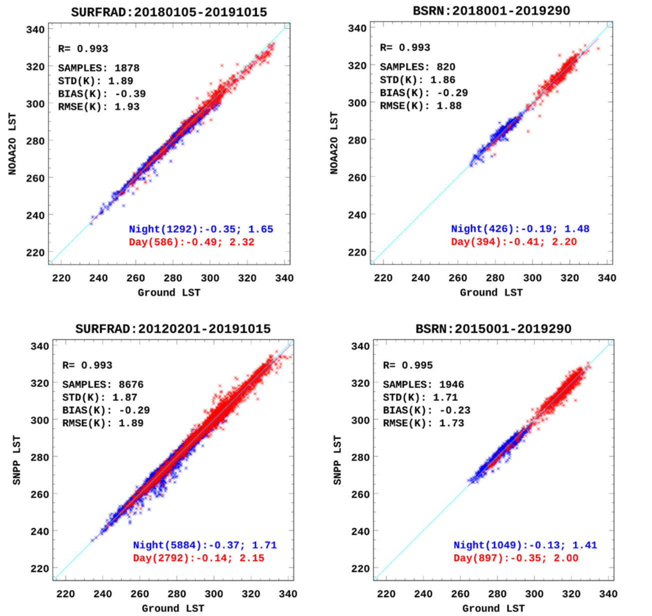

Figure 1. Overall VIIRS LST validation against SURFRAD (left) and BSRN (right) for N20 (top) and S-NPP (bottom)

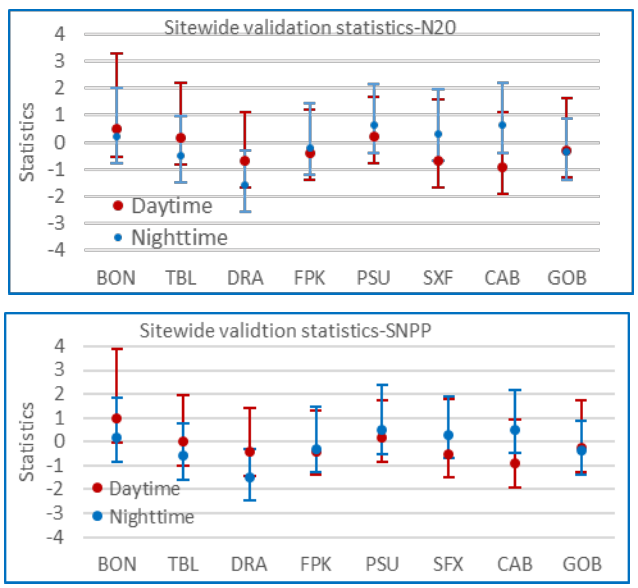

Figure 2. Site wide VIIRS LST validation for N20 (top) and S-NPP (bottom)

the precision is 1.87 K and 1.71 K for S-NPP VIIRS LST comparison with SURFRAD and BSRN, respectively. The day/night statistics indicate an overall closer agreement at nighttime than daytime for most stations, which is expected due to the relative better thermal homogeneity at nighttime than that at daytime. The nighttime precision is from 1.4 K to 1.7 K while it is 2.0 K to 2.3 K for daytime. The site wide result as shown in Figure 2 suggests a varied performance over different sites. The LST underestimation is observed over DRA site, which is related to the site characterization and representativeness. The relatively high precision over BON site is attributed to the observation difference between in-situ radiometer and satellite during the crop growing and harvest seasons [2, 4].

5. INTER-COMPARISON RESULTS OF N20 AND S-NPP VIIRS LST

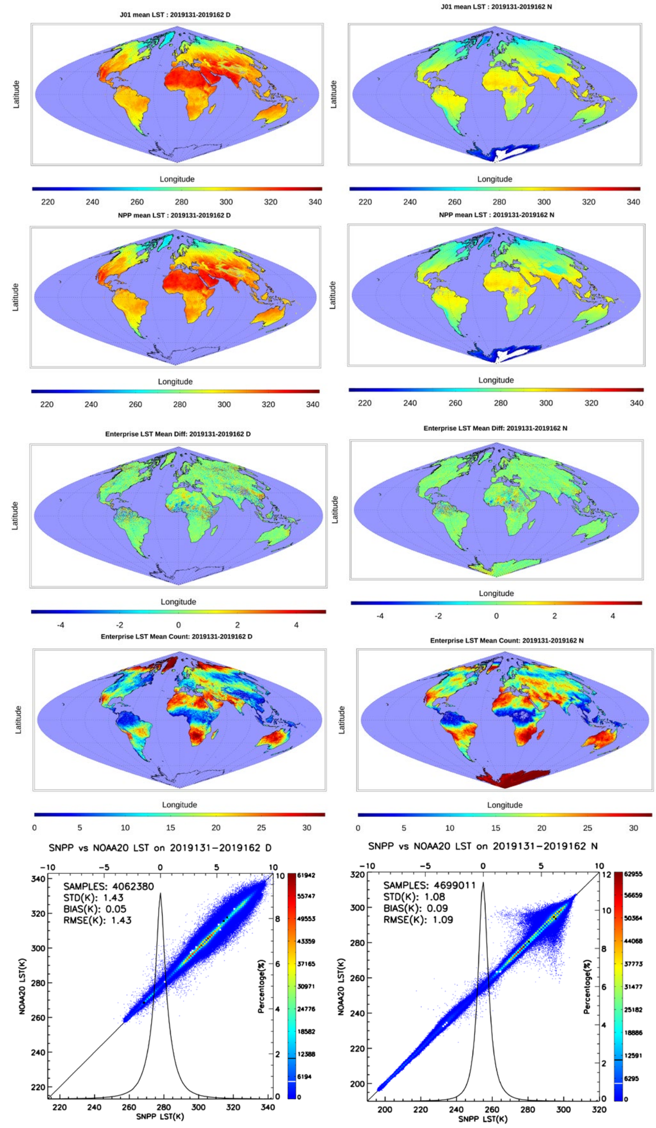

Figure 3. Inter-comparison between N20 and S-NPP VIIRS LST, daytime (left) and nighttime (right). For daytime, from top to bottom, Mean LST of N20 VIIRS; Mean LST of S-NPP VIIRS; LST difference between N20 and S-NPP ; data availability within the

32-day cycle; and overall LST difference statistics. The corresponding plot on the right is for nighttime.

As mentioned in section 3.2, the 32-day mean difference between N20 and S-NPP VIIRS LST was calculated globally with daytime and nighttime separated. Only cloud clear data is involved in the calculation. The difference as shown in Figure 3 has a zonal feature and more differences exist in low latitude zone, where less data pairs were included in the comparison due to cloud coverage and regional climate variation situations. The less data availability within a repeating cycle causes the insufficiency to account for the impacts of the viewing angle and temporal difference. The difference statistics suggests that the S-NPP and N20 VIIRS LST are consistent to each other. At nighttime, a perfect match is observed for the LST lower than 290 K. The outliers in the warm temperature appear in the low latitude near equator mostly affected by the less data availability. For daytime, the two LSTs stick mostly to the 1:1 line with near zero accuracy and a precision of 1.4 K at global scale. Some scattered measurements under the warm temperature over 300 K show slight differences attributed to the greater impact of the viewing geometry and temporal difference during the daytime.

6. CONCLUSION

The enterprise LST algorithm, based on split window technique, has been operationally implemented on both N20 VIIRS and S-NPP VIIRS sensor. The two LST products are publically available on NOAA CLASS, ready for user applications. In this study, the ground observations from SURFRAD and BSRN network were used for the quality assessment of the two LST products. The validation results indicate that both LST products yield a good agreement with ground observations with an accuracy of -0.4 K (N20) and -0.3 K (S-NPP) and precision of about 1.9 K for comparisons with SURFRAD data using up-to-date data. Similar accuracy and precision is achieved for the comparison with BSRN data. This result represents the most recent validation efforts. The cloud contamination and surface heterogeneity are found to have a great impact on the validation results.

The inter-comparison between N20 and S-NPP VIIRS LST was carried out based on 32-day cycle data considering the viewing geometry and temporal difference between each other. The results suggest they are overall consistent with nearly no bias between them. The LST difference has a zonal feature with more difference at low latitude zone, which is attributed to the insufficiency of accounting for the temporal and geometry difference due to its less data availability.

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