Radiance-based Validation of VIIRS Land Surface Temperature Product

Zhuo Wang[1, 2], Yunyue Yu[2], Wei Guo[1, 2], Yuling Liu[2, 3], Dan Tarpley[4], Ivan Csiszar[2]

[1] I. M. Systems Group, Inc., Maryland; [2] NOAA/NESDIS Center for Satellite Applications and Research, MD; [3] CICS, University of Maryland; [4] Short and Associates, MD

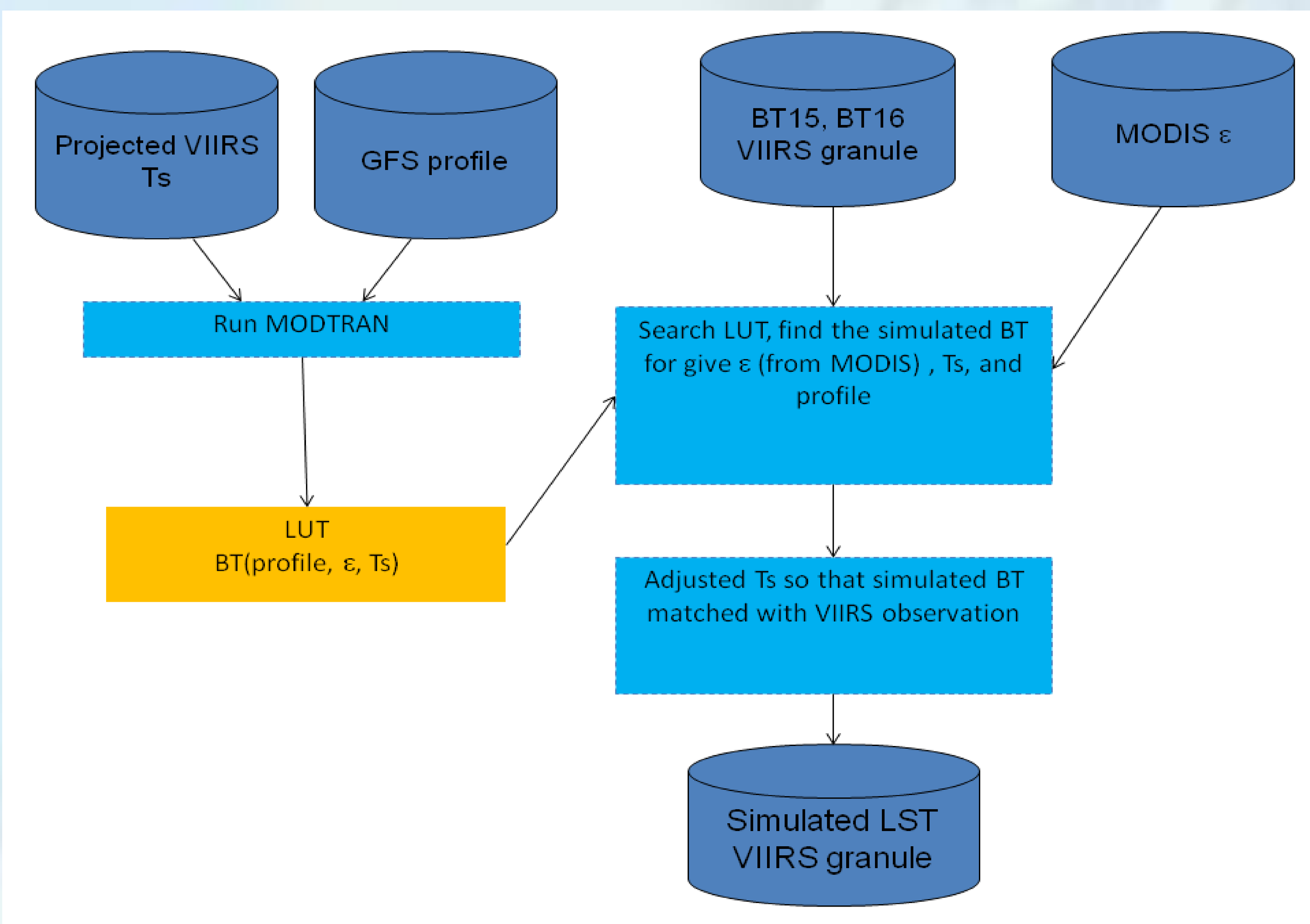
Introduction

Land surface temperature (LST) is an important parameter related to the surface-atmosphere interactions. Currently, satellite measurements over the ocean have been successfully used to improve numerical weather prediction (NWP). However, satellite data over land is much less used because of the difficulty in land surface emissivity and temperature simulations. Improvement in quality of satellite LST product will make it use as efficiently as possible in related weather and climate studies. The traditional method for LST validation is the direct comparison with ground measurements at a field site concurrently with the satellite overpass. The radiance-based validation was an alternative global validation method developed by Wan and Li [2008]. It calculates the ground LST from the top of the atmosphere (TOA) brightness temperature using the emissivity and atmospheric profiles data in radiative transfer model. The radiance-based validation has obvious advantage over the conventional temperature-based validation: it can be applied to much more surface types. Therefore, when there is no enough ground truth for all surface types, it is better to use radiance-based method to get the validation results for the whole region.

Simulation Process and Input Data

In this study, we used the radiative transfer model MODTRAN 5.1 [Berk et al., 2011] to validate the VIIRS LST at the granule level. The model input data includes land surface temperature, brightness temperatures in VIIRS bands M15 and M16, view angle , and satellite path azimuth angles, which can be obtained from VIIRS. Solar zenith angles were computed from the time and location of the profiles. Here we only consider the high-quality and cloud-free pixels. NCEP GFS analysis data are used as the atmosphere profile for model input. To cover a range of environmental conditions, the VIIRS surface temperature (Ts) will be considered as the reference Ts. For a given GFS grid, LUT was generated by running through the possible range of emissivity (0.9 to 1.0) and Ts (reference Ts ± 9K). The simulated brightness temperature for each VIIRS pixel will be obtained from LUT according to its emissivity from MODIS data and atmospheric profiles from GFS. Finally, the brightness temperature difference between satellite measurement and simulation will be minimized, and the corresponding temperature will be considered as the simulated Ts for VIIRS pixel.

Flowchart for VIIRS LST Validation:



Emissivity Determination Process

The emissivity is very important for surface temperature retrieval and validation. MODIS monthly emissivity data and MODIS Land Cover Type data from 2001 to 2012 were analyzed in order to build up the emissivity pairs to represent 17 IGBP surface types. Here we used the MODIS bands 31 and 32 which are spectrally closest to VIIRS bands M15 and M16, respectively. The type-dependent emissivities in MODIS bands 31 and 32 along with their standard deviations for each IGBP were analyzed (E.g., Figure. 1). The standard deviation of type-averaged emissivity in each month are very small, so 12 monthly type-dependent emissivities can be used to represent the emissivity variation within each IGBP type. In order to cover all surface types, we run the model over the emissivity range 0.90 – 1.0.

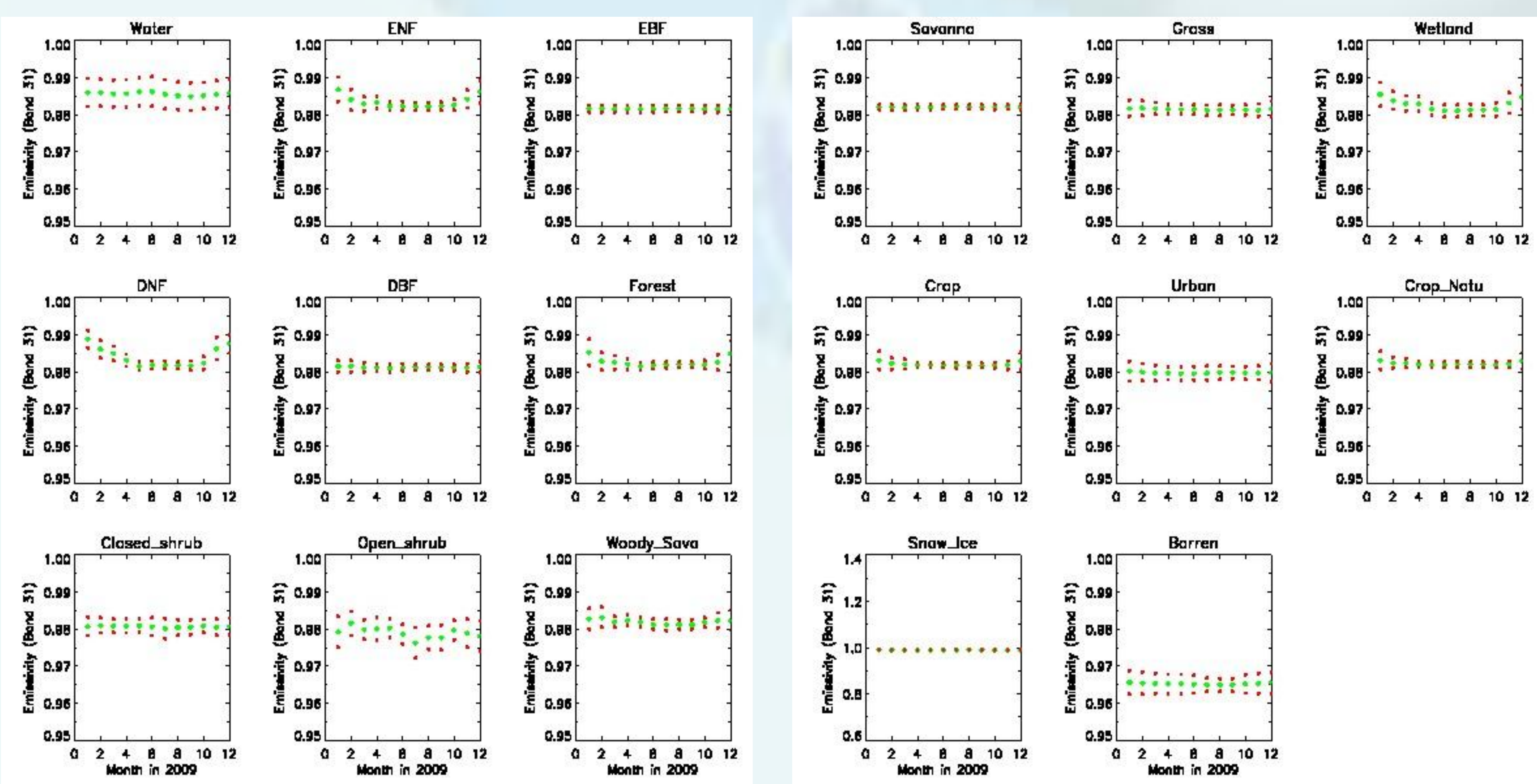


Figure 1. Type-averaged emissivity and their standard deviation for IGBP 0 -16 in band 31. Green: average value; Red: average ± std.

Results for VIIRS LST Validation at granule level

We have performed the validation for 24 granules which cover the sites over SURFRAD station, China, Greenland, Lake Tahoe, and permanent land for daytime and nighttime cases.

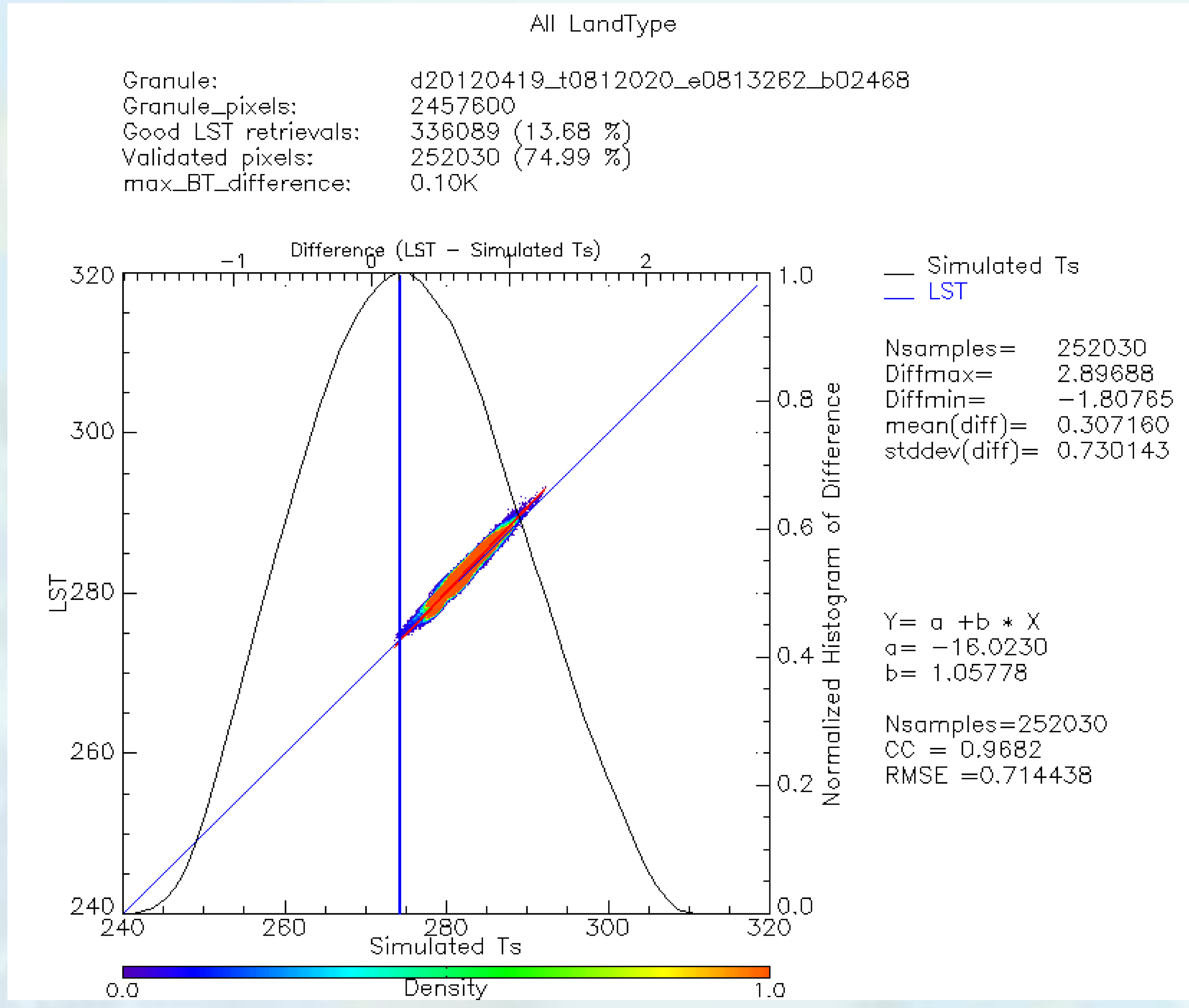


Figure 2. Scatter plot of VIIRS LST vs. simulated LST and the normalized histogram of LST difference using 10-year averaged MODIS monthly emissivity data.

From Figure 2, we can see that there are 336089 pixels with high-quality and cloud-free VIIRS data in granule d20120419_t0812020, and about 74.99% of these good pixels can get the simulated Ts as ground truth from radiance-based validation. The mean value and standard deviation of the land surface temperature difference between VIIRS satellite measurement and simulation are 0.31 and 0.73, respectively.

Since the validation results are affected by the accuracy of atmospheric profiles, we analyzed GFS total cloud cover information, and then used 10% cloud cover as threshold to filter GFS cloudy grid cells.

Accurate emissivity data is required for radiative transfer model input. In this study, we used the emissivity from MODIS 10-year averaged monthly data. Some sensitivity tests have been done in order to see how the validation results are affected by the accuracy of emissivity, We replaced the MODIS 10-year averaged monthly emissivity by MODIS monthly emissivity in 2012. As an example, Figure 3 shows that the statistic values do not change too much when using 2012 MODIS monthly emissivity data instead of 10-year averaged MODIS data.

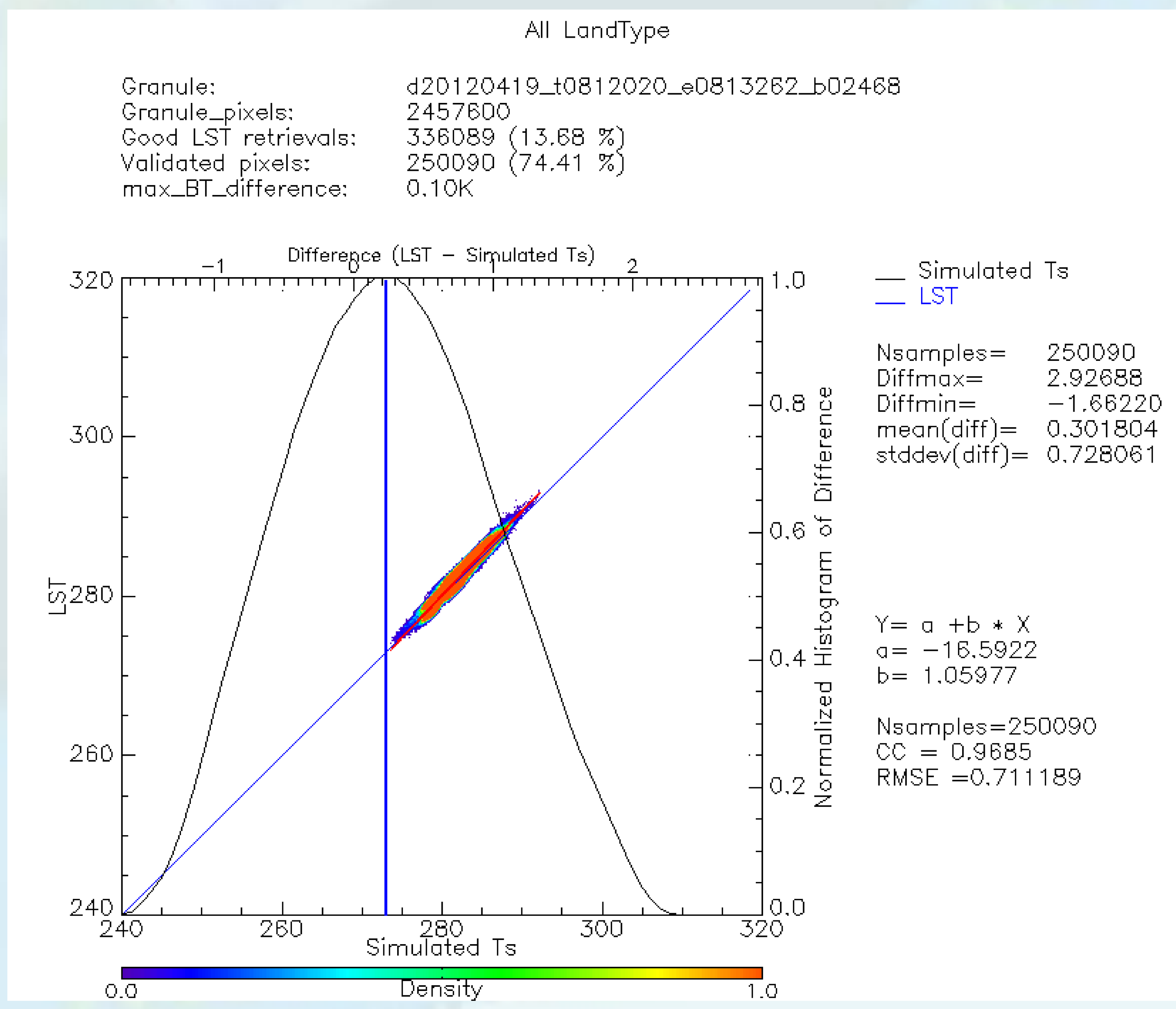


Figure 3. Same as Fig.2 except for using 2012 MODIS monthly emissivity data.

Conclusions

The radiance-based method can validate the satellite products over long time periods both day and night, while the traditional temperature-based method will be limited to more short-term campaign. Besides validating VIIRS LST product, it can also be used to validate other satellite LST product in the near future.