Estimation and Evaluation of GOES-16 Land Surface Temperature Measurement

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Introduction

Land surface temperature (LST) is defined as the radiative skin temperature of the land. It is one of the baseline products for the GOES-R satellite mission measured from the Advanced Baseline Imager (ABI). LST data is widely used in many aspects of the geosciences, e.g., studies of net radiation budget at the Earth surface, monitoring state of crops and vegetation, as well as an important indicator of both the greenhouse effect and the physics of land-surface processes at local through global scales. It has been listed as an Essential Climate Variable (ECV) in the Global Climate Observation System (GCOS).

Algorithm of the GOES-R LST derivation was developed at NOAA/NESDIS center for SaTellite Applications and Research (STAR), based on a traditional split-window technique. Quality of the LST estimation may vary depending on cloudy fraction, water vapor, and view zenith angle, etc. Such quality information, recorded as quality flags and metadata, is provided with the LST estimates for user reference, product monitoring and evaluation analysis. GOES-R satellite provides LST products with three domains: CONUS, hemisphere, and mesoscale. Evaluation of the GOES-R LST product has been conducted using radiative transfer simulation datasets and proxy ABI data. After the launch of the first GOES-R series satellite, i.e. GOES-16, in November 2016, we have performed the ABI LST evaluation using 5 months of the ABI SDR and LST dataset. Quality flags and metadata of the LST product are tested and compared with local independent computation, LST estimates were compared to some in-situ LST data derived from the SURFRAD station measurements. This presentation shows our evaluation results, as well as the ABI LST derivation details, which are helpful in user's product applications.

The Baseline GOES-R LST Algorithm

- Split-Window Retrieval Algorithm;

$$T_s = C + A_1 T_{11} + A_2 (T_{11} - T_{12}) + A_3 \varepsilon + D(T_{11} - T_{12})(\sec\theta - 1)$$

T_{11} and T_{12} are the brightness temperature at the two split-window bands centered at 11.2 μm and 12.3 μm

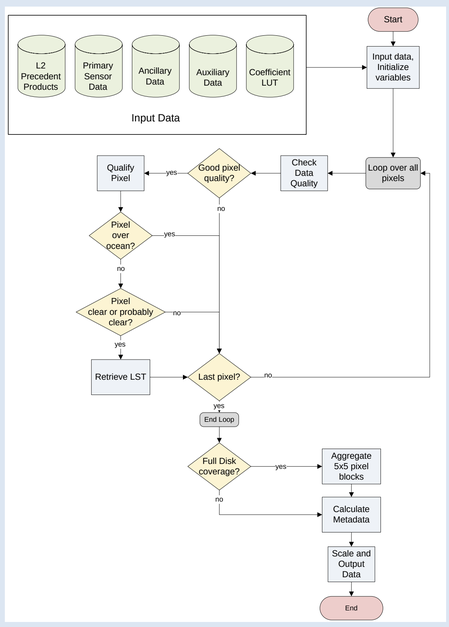
C, A_i, and D are the retrieval coefficients stratified by day/night and atmospheric total column water ranges, [0., 2.] and [2., 5.], T_s is the retrieved LST, and θ is the sensor view zenith angle.

- Algorithm was selected among nine different formula

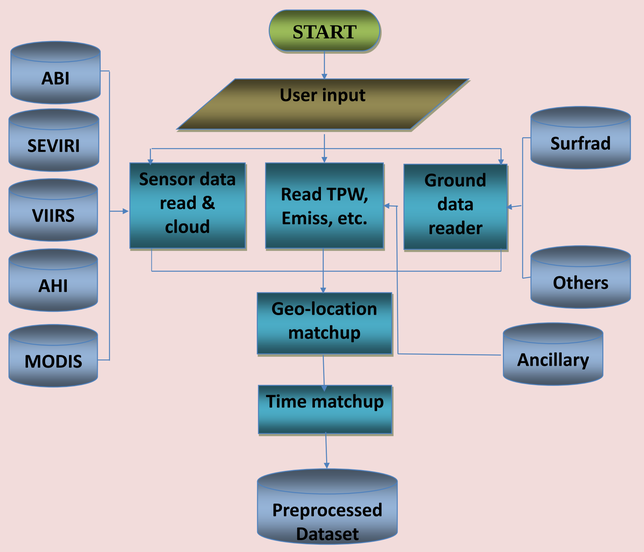
Candidate split window LST algorithms.

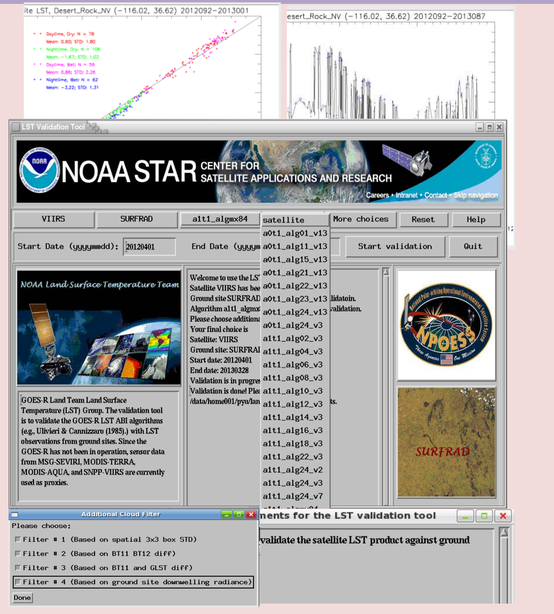
No	Formula#	Reference
1	$T_s = C + (A_1 + A_2\frac{1-\varepsilon}{\varepsilon} + A_3\frac{\Delta\varepsilon}{\varepsilon^2})(T_{11}+T_{12}) + (A_4 + A_5\frac{1-\varepsilon}{\varepsilon} + A_6\frac{\Delta\varepsilon}{\varepsilon^2})(T_{11}-T_{12}) + D(T_{11}-T_{12})(\sec\theta - 1)$	Wan & Dozier (1996); Becker & Li (1990).
2	$T_s = C + A_1\frac{T_{11}+T_{12}}{2} + A_2\frac{T_{11}-T_{12}}{2} + A_3\frac{1-\varepsilon}{\varepsilon} + D(T_{11}-T_{12})(\sec\theta - 1)$	Prata & Platt (1991); modified by Caselles et al. (1997).
3	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3(1-\varepsilon_{11}) + A_4\Delta\varepsilon + D(T_{11}-T_{12})(\sec\theta - 1)$	Coll & Valor (1997).
4	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3\frac{1-\varepsilon}{\varepsilon} + A_4\frac{\Delta\varepsilon}{\varepsilon^2} + D(T_{11}-T_{12})(\sec\theta - 1)$	Vidal (1991).
5	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3(T_{11}-T_{12})\varepsilon_{11} + A_4 T_{12}\Delta\varepsilon + D(T_{11}-T_{12})(\sec\theta - 1)$	Price (1984).
6	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3\varepsilon + D(T_{11}-T_{12})(\sec\theta - 1)$	Ulivieri & Cannizzaro (1985).
7	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3\varepsilon + A_4\frac{\Delta\varepsilon}{\varepsilon} + D(T_{11}-T_{12})(\sec\theta - 1)$	Sobrino et al. (1994).
8	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3(1-\varepsilon) + A_4\Delta\varepsilon + D(T_{11}-T_{12})(\sec\theta - 1)$	Ulivieri et al. (1992).
9	$T_s = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3(T_{11}-T_{12})(T_{11}-T_{12}) + A_4(1-\varepsilon_{11}) + A_5\Delta\varepsilon + D(T_{11}-T_{12})(\sec\theta - 1)$	Sobrino et al. (1993).

Each algorithm is composed of two parts: the base split window algorithm and path length correction (the last term in each algorithm). The base split window algorithms are adapted from those published split window algorithms as referred in the references, while the path length term is particularly added for additional atmospheric correction.



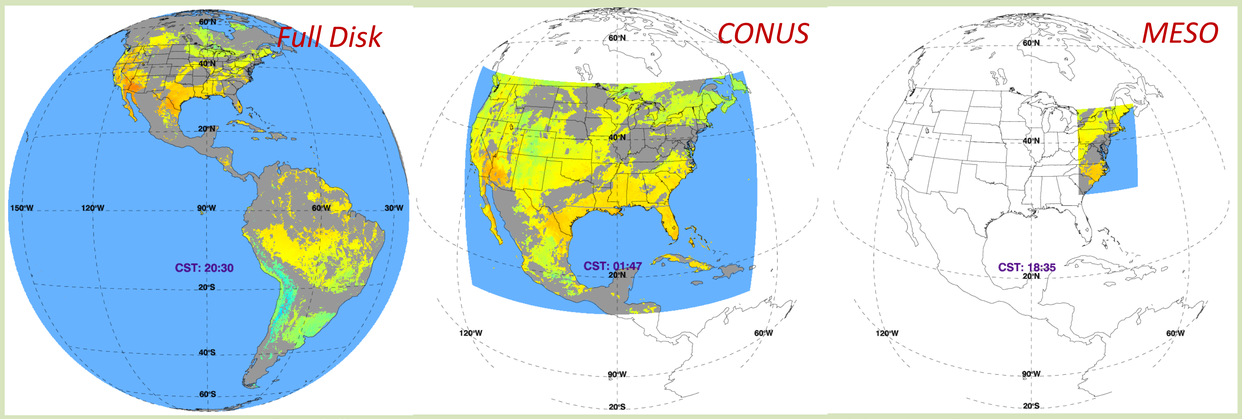
The GOES-R LST Validation/Monitoring System





The GOES-R Baseline Land Surface Temperature Product

Three ABI baseline LST products



Qualifiers

Product	Temporal Coverage	Product Extent	Cloud Cover Conditions	Product Statistics
LST (CONUS)	Day and Night	LZA < 70	Clear Conditions associated with threshold accuracy	Over specified geographic area
LST (Full Disk)	Day and Night	LZA < 70	Clear Conditions associated with threshold accuracy	Over specified geographic area
LST (Mesoscale)	Day and Night	LZA < 70	Clear Conditions associated with threshold accuracy	Over specified geographic area

Mission Requirement

Product	Accuracy	Precision	Range	Refresh Rate	Resolution
LST (CONUS)	2.5 K	2.3 K	213 ~ 330 K	60 min	2 km
LST (Full Disk)	2.5 K	2.3 K	213 ~ 330 K	60 min	*10 km*
LST (Mesoscale)	2.5 K	2.3 K	213 ~ 330 K	60 min	2 km

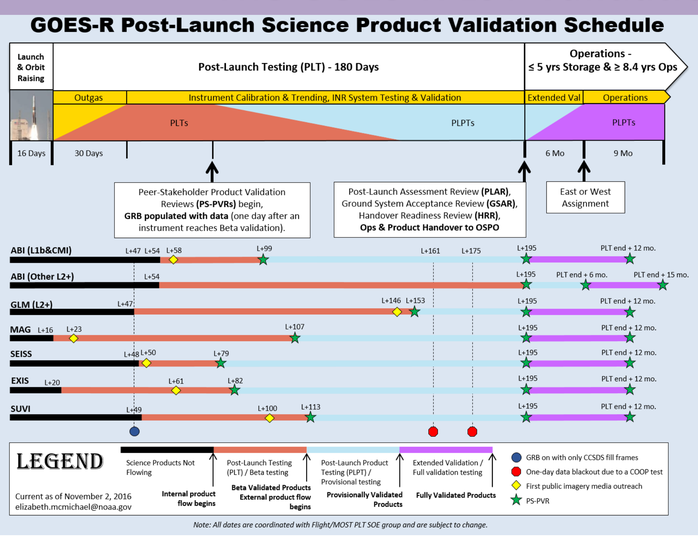
Product Quality Information (PQI)

Byte	Bit	Flag	Source	Effect
1	0	Empty		Reserved for future use
	1			
	2	Availability	SDR	00=normal, 01=out of space, 10=bad data, 11=missing data
	3			
	4	Surface Type*	Land/sea Mask	00=land, 01=snow/ice, 10=in-land water, 11=sea
	5			
	6-7	Cloud Index	Cloud Mask	00=clear, 01=probably clear, 10=probably cloudy, 11=cloudy
2	0	Atmospheric Condition	LST	00=dry atmosphere (wv<=2.0g/cm^2); 01=moist atmosphere(wv>2.0g/cm^2); 10= very moist(wv>5.0/cm^2)
	1			
	2	Day/Night	SDR	0=day (solar zenith <= 85 deg), 1=night
	3	View Angle	LST	0=normal, 1=large view angle (LZA>55 deg)
	4	LST Quality	LST	00=normal, 01=cold surface (<250 K & >=213K), 10= out of range (not in 213-330K)
	5			
	6	Emissivity Quality	LST	0=normal, 1=historical emissivity
	7	Empty		Reserved for future use

Product Control Flags (DQF)

Byte	Bit	Flag	Source	Effect
1	0	Empty		Reserved for future use
	1	Availability	SDR	0=normal, 1=out of space, bad data, missing data
	2	Cloud Index	Cloud Mask	0=clear or probably clear, 1=probably cloudy, or cloudy
	3	View Angle	LST	0=normal, 1=large view angle (LZA>70°)
	4	Surface type	Land/sea mask	0 = land, including inland water, 1= water
	5	LST Quality	LST	0=normal, 1= out of range (not in 213-330K)
	6-7	Empty		Reserved for future use
2	0-7	Empty		Reserved for future use

The GOES-R LST Validation Plan/Schedule



Components of LST Validation

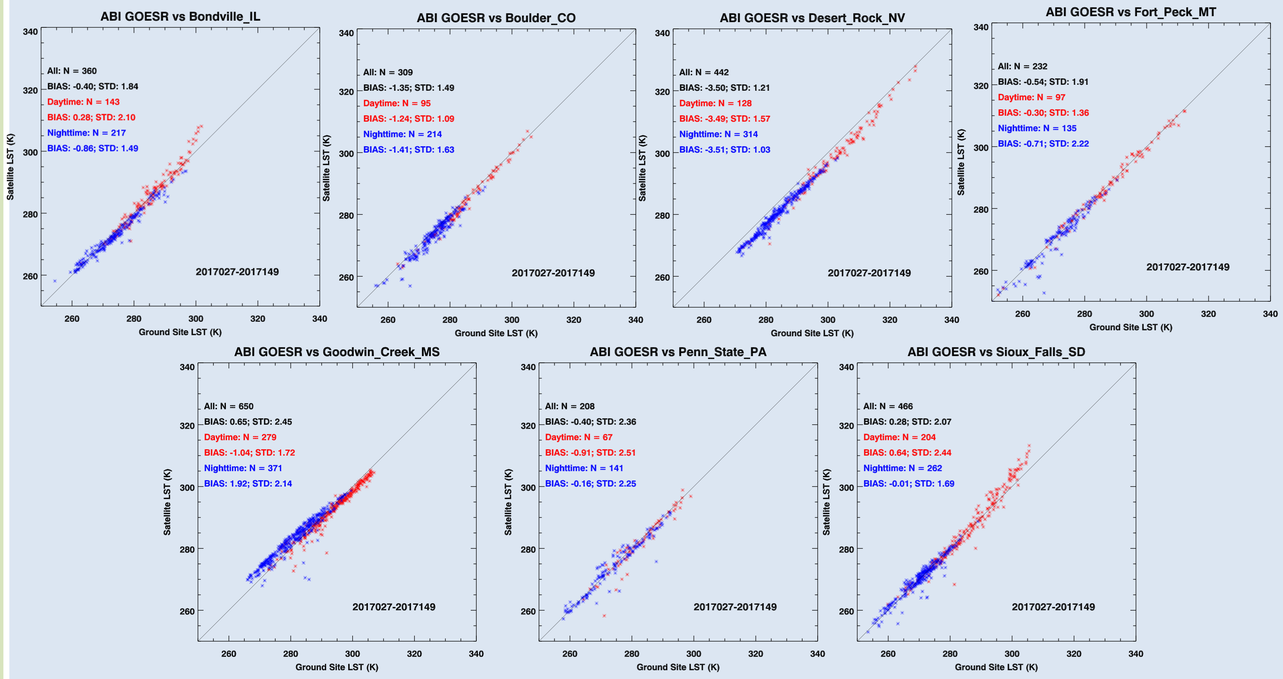
- In-situ measurement comparisons and analyses
- Cross-satellite comparisons and analyses
- Successful applications –users promotion

Strategy of In-situ measurement comparisons and analyses

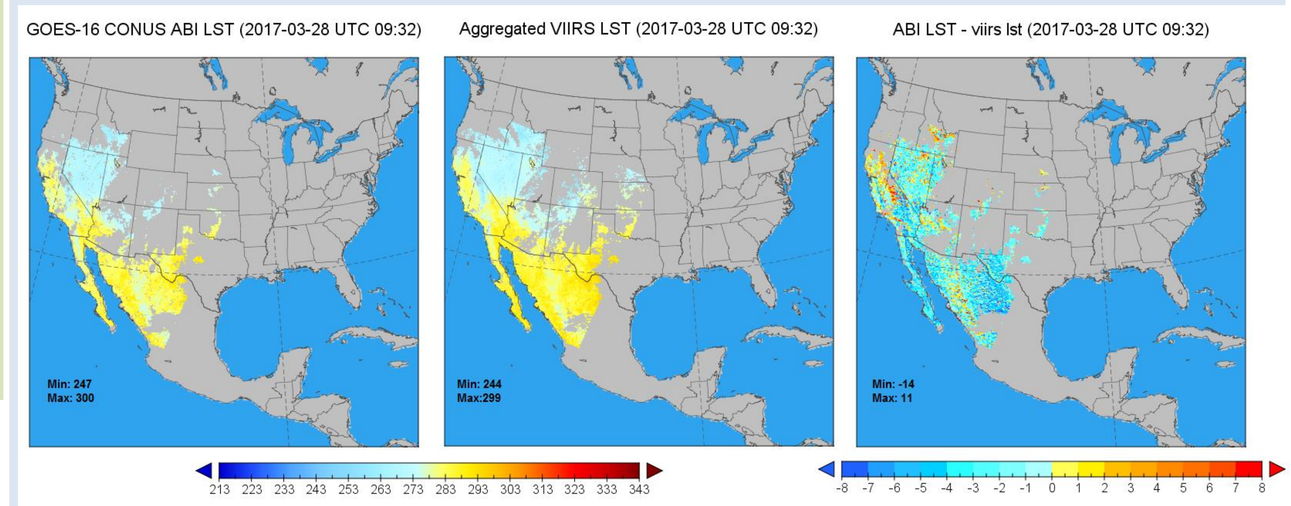
- Existing ground station observations (e.g. SURFRAD Network), as long-term data source
- Field campaign data plays three important roles
  - ❑ High quality observations for direct comparison and analysis
  - ❑ Calibrating co-site ground station observations
  - ❑ Characterizing heterogeneity feature of co-site ground station

Product Validation/Monitoring Results

Validation Results of corrected satellite LST



Comparison with SNPP VIIRS LST



Summary

- GOES-16 ABI LST reached Beta maturity on May 24th, 2017. All PLPT activities required to make Beta have been completed
- Routine visual inspection yields satisfactory results, no major issues were found.
- LST quality was assessed with SURFRAD in-situ observations. Results from most sites meet the mission requirement. However, significant underestimate was found at the Desert Rock site.
- GOES-16 LST was compared with SNPP VIIRS LST, good agreement between the two was found.
- Some minor problems were identified in the product, mostly related to the quality flag . This does not have impact on the product quality.