GROUND STATION SPATIAL REPRESENTATIVENESS IN SATELLITE-RETRIEVED LAND SURFACE TEMPERATURE (LST) VALIDATION

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Abstract

A reliable accuracy is essential for the application of land surface temperature (LST) products. The validation of satellite-retrieved LST is usually performed over homogeneous surfaces, while most of the earth is typically inhomogeneous natural surfaces. Therefore, it is crucial to be able to evaluate LST over inhomogeneous surfaces. Thus, a temporal variation method for evaluating the spatial representativeness of ground stations was proposed for kilometer-scale LST validation. The method introduces the spatial representativeness indicator (*SRI*) defined as the LST difference between the ground radiometer's FOV and the corresponding satellite pixel, and combines the temporal variation of LST and its main influence factors to estimate temporal-continuous *SRI*. Meanwhile, according to its definition, the *SRI* allows to validate satellite LST against *in-situ* LST at the same spatial scale. The method was applied in the validation of MODIS and AATSR LST, associated with Landsat TM/ETM+ LST and CLDAS/GLDAS. Results for MODIS and AATSR LST show that the effect of spatial representativeness on the validation results over the sites is large, with MBE range of -1.95~5.60 K and STD ranges of 0.07~3.72 K. It can be concluded that large systematic deviations and random errors can result from a lack of spatial representativeness of a ground station, which considerably reduces the meaningfulness of the validation. Therefore, it is recommended to always analyze and account for the spatial representativeness of ground stations at the satellite pixel scale.

Background

- Land Surface Temperature (LST) is a key parameter for energy exchange between the ground and the atmosphere.
- *In-situ* LST plays an important role in the development of satellite-derived LST and land surface models.
- A significant scale difference exists between the field of view of ground station sensors and satellite sensors.
- Validation of satellite-retrieved LST is usually performed over homogeneous surfaces.

Objectives & Data

Objectives

- Validating the satellite retrieved LST
- How to consider the spatial representativeness of ground stations in LST validation?
- Quantify the uncertainty in the LST validation

EO and other data (2002-2012)

- Terra MODIS 6.0 level-3 LST Product (MOD11A1)
- ENVISAT AATSR Product (ENVISAT.ATS.LST_2P)
- 16 ground observations in China (Shown in Fig. 1)
- GLASS Broadband Emissivity from BNU
- Meteorological reanalysis data from CLDAS and GLDAS

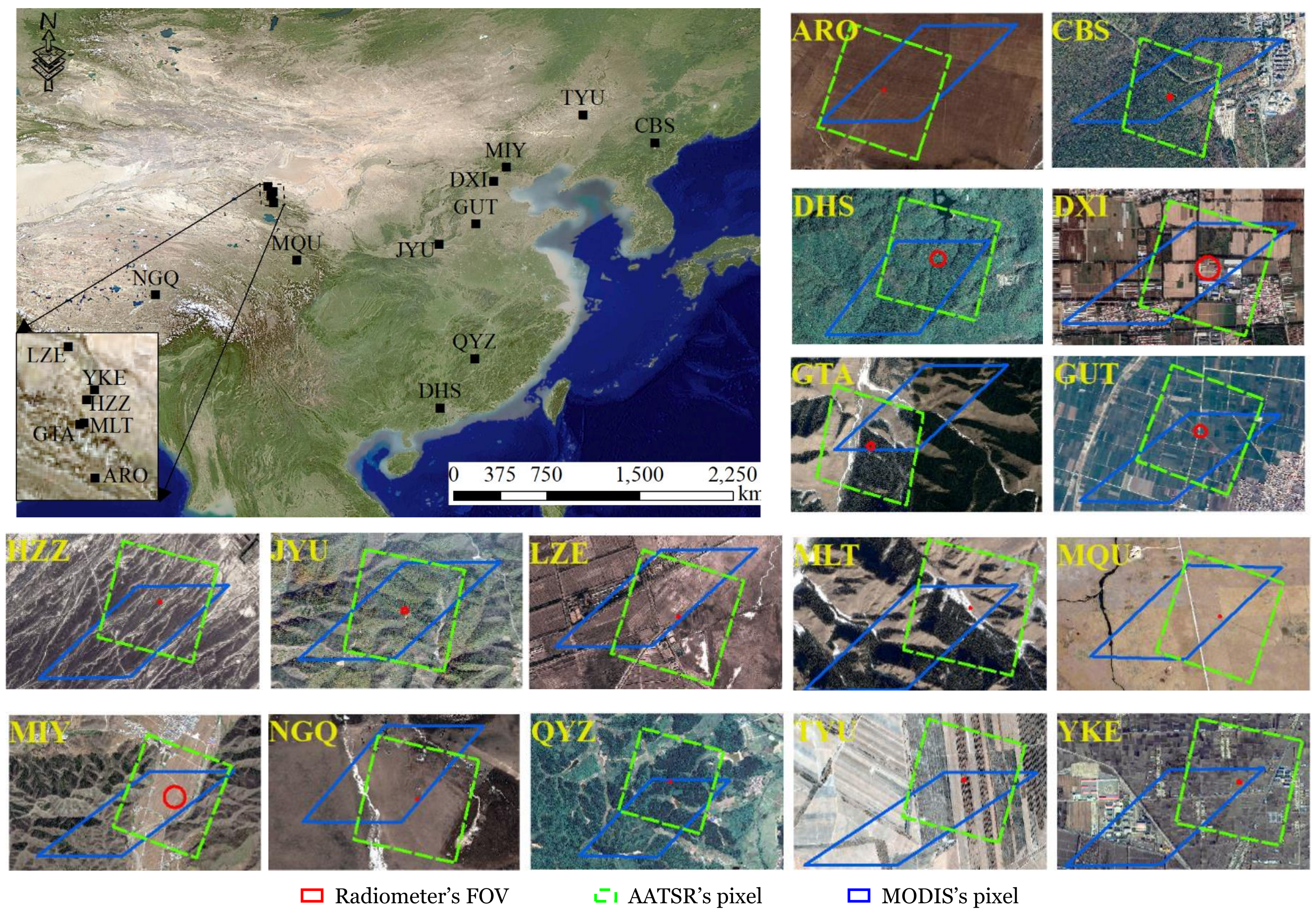

Fig. 1 Geolocations of the selected 16 sites, the overlayed high resolution images is provided by www.tianditu.gov.cn.

Method

Definition of Spatial Representativeness Indicator

$$SRI(t) = T_F(t) - T_P(t)$$

where *SRI* is the indicator for spatial representativeness; T_F and T_P are the true LST within the *in-situ* radiometer's FOV and satellite pixel, respectively, and simulated from Landsat LST.

Temporal Extension for *SRI*

$$\begin{cases} T_F(t) = ATC_F(t) + \Delta DTC_F(t) + USC_F(t) \\ T_P(t) = ATC_P(t) + \Delta DTC_P(t) + USC_P(t) \end{cases}$$

Continuous, indicating the average state of temperature difference between the two scales

Ignorable

Discrete, representing the temperature difference fluctuations of the two scales, affected by environmental factors, need to be continuous

$$SRI(t) = \Delta ATC(t) + \Delta DTC_{F-P}(t) + \Delta USC(t)$$

$$ATC(t) = \Delta \bar{T}_a + A \sin\left(\frac{2\pi t}{365} + \theta_0\right)$$

$$\Delta ATC(t) = ATC_F(t) - ATC_P(t)$$

Weather condition parameters, land surface parameters, etc.

$$\Delta USC(t) = g[x_1(t), x_2(t), \ldots\ldots x_n(t)]$$

Temporal variation model: $SRI_{TPR}(t) = \Delta \bar{T}_a + A \sin\left(\frac{2\pi t}{365} + \theta_0\right) + g[x_1(t), x_2(t), \ldots\ldots x_n(t)]$

Validation

Conversion the *in-situ* LST to pixel scale associated with *SRI* as the bridge:

$$T_{P,in\text{-}situ}(t) = T_{in\text{-}situ}(t) - SRI_{TPR}(t)$$

- **Normal validation**

$$T_{SAT}(t) - T_{in\text{-}situ}(t) = \varepsilon_{\text{total,P-F}} = \varepsilon_{\text{SAT}}(t) + \varepsilon_{in\text{-}situ}(t) + \varepsilon_{\text{REP}}(t) + \varepsilon_{\text{time}}(t)$$

$$STD^2_{\text{total,P-F}} = STD^2_{\text{SAT}} + STD^2_{in\text{-}situ} + STD^2_{\text{REP}} + STD^2_{\text{time}}$$

- **Validation with spatial representativeness considered**

$$T_{SAT}(t) - T_{P,in\text{-}situ}(t) = \varepsilon_{\text{total,P-P}} = \varepsilon_{\text{SAT}}(t) + \varepsilon'_{\text{in-situ}}(t) + \varepsilon_{\text{time}}(t)$$

$$= \varepsilon_{\text{SAT}}(t) + \varepsilon_{in\text{-}situ}(t) + \varepsilon_{\text{SRI}}(t) + \varepsilon_{\text{time}}(t)$$

$$STD^2_{\text{total,P-P}} = STD^2_{\text{SAT}} + STD^2_{in\text{-}situ} + STD^2_{\text{SRI}} + STD^2_{\text{time}}$$

The accuracy of the satellite LST products/datasets

$$\text{MBE}_{SAT} = \frac{1}{N}\sum_{n=1}^{N}\left(\varepsilon_{\text{total,P-P}} - \varepsilon_{in\text{-}situ} - \varepsilon_{\text{SRI}} - \varepsilon_{\text{time}}\right)$$

$$STD^2_{\text{SAT}} = STD^2_{\text{total,P-P}} - STD^2_{in\text{-}situ} - STD^2_{\text{SRI}} - STD^2_{\text{time}}$$

The ground station's spatial representativeness influence in normal validation

$$\text{MBE}_{\text{REP}} = \frac{1}{N}\sum_{n=1}^{N}\left(\varepsilon_{\text{total,P-F}} - \varepsilon_{\text{total,P-P}} + \varepsilon_{\text{SRI}}\right)$$

$$STD^2_{\text{REP}} = STD^2_{\text{total,P-F}} - STD^2_{\text{total,P-P}} + STD^2_{\text{SRI}}$$

Results

Temporal-continuous *SRI*

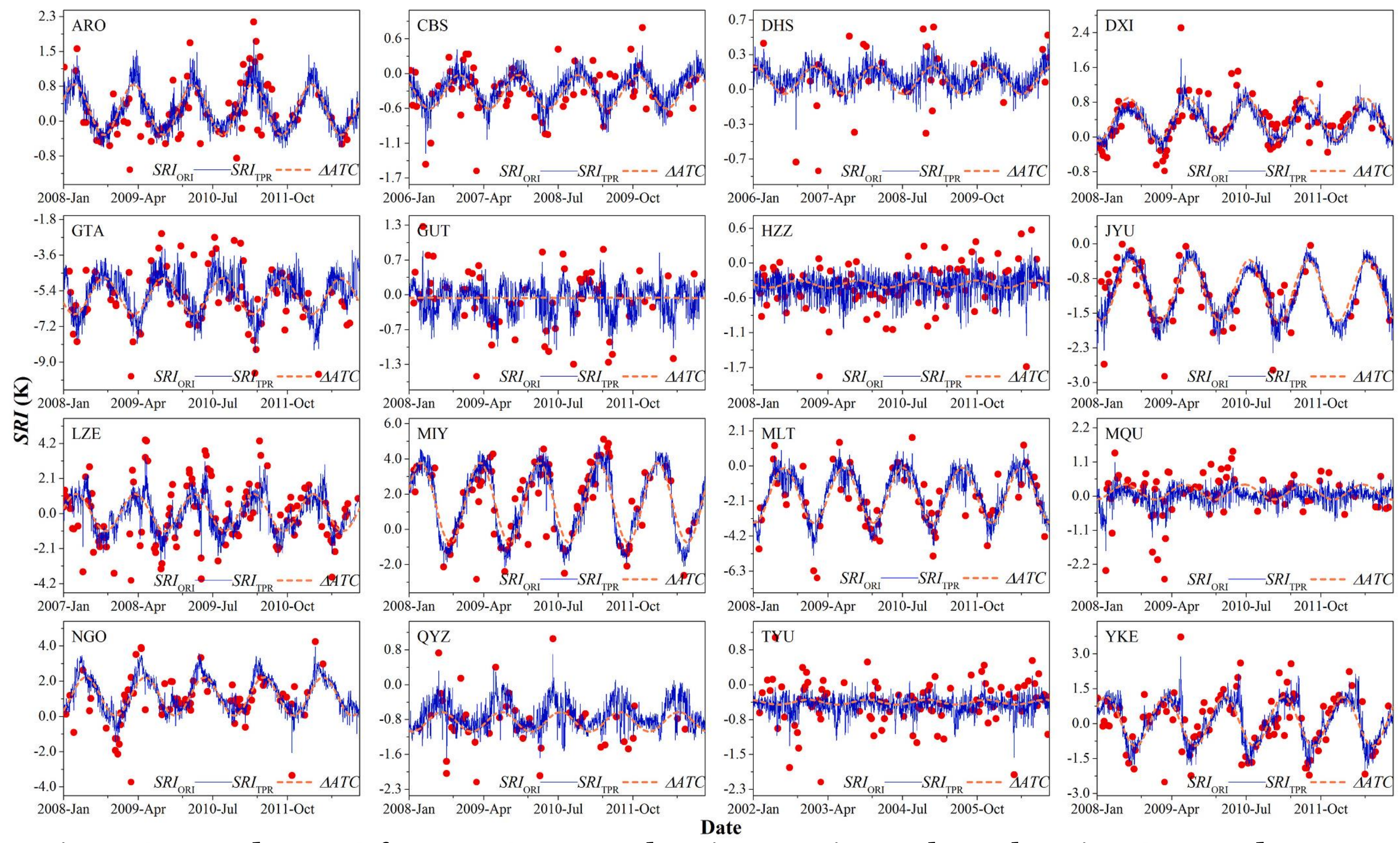

Fig. 2 *SRI* and Δ*ATC* for AATSR over the sixteen sites. The subscript ORI and TPR denote "original" and "temporal", respectively

Table 1. Validation of AATSR LST against T_{ground} and $T_{\text{P,ground}}$

Site		Sample size	$T_{SAT} - T_{ground}$			T_{SAT} - $T_{P,ground}$			Representativeness Error		Product Quality	
			μ_{total} (K)	σ_{total} (K)	R^2	μ_{total}' (K)	σ_{total}' (K)	R^2	e_{REP} (K)	μ_{REP} (K)	e_{SAT} (K)	μ_{SAT} (K)
ARO	D	63	0.62	3.26	0.95	0.99	3.13	0.95	−0.37	0.97	0.99	2.91
	N	89	1.98	1.85	0.97	–	–	–	–	–	–	–
CBS	D	9	1.78	1.71	0.84	1.50	1.64	0.86	0.31	0.84	1.48	1.25
	N	33	−0.58	2.06	0.98	–	–	–	–	–	–	–
DHS	D	7	2.08	1.27	0.96	2.15	1.29	0.96	−0.11	0.42	2.18	0.89
	N	13	0.16	0.45	0.99	–	–	–	–	–	–	–
DXI	D	29	3.00	1.72	0.98	3.59	1.93	0.98	−0.55	0.72	3.56	1.32
	N	108	−1.88	1.11	0.99	–	–	–	–	–	–	–
GTA	D	30	7.28	2.53	0.96	1.72	2.07	0.97	5.60	1.71	1.68	1.66
	N	84	−0.61	1.22	0.98	–	–	–	–	–	–	–
GUT	D	14	2.72	2.62	0.97	2.43	2.41	0.97	0.21	1.51	2.50	1.97
	N	41	−0.25	1.26	0.99	–	–	–	–	–	–	–
HZZ	D	92	2.51	1.79	0.99	2.16	1.82	0.99	0.37	0.07	2.14	1.56
	N	106	1.61	1.10	0.99	–	–	–	–	–	–	–
JYU	D	5	3.26	3.54	0.56	2.34	3.41	0.67	0.87	1.43	2.39	3.14
	N	29	−0.99	2.25	0.95	–	–	–	–	–	–	–
LZE	D	37	1.97	2.70	0.96	1.98	2.66	0.96	0.03	1.02	1.94	2.35
	N	47	2.62	1.67	0.98	–	–	–	–	–	–	–
MIY	D	54	2.42	2.14	0.97	4.40	2.04	0.98	−1.95	1.45	4.36	1.32
	N	84	1.32	1.85	0.99	–	–	–	–	–	–	–
MLT	D	12	−0.03	6.35	0.81	−1.63	5.25	0.82	1.67	3.72	−1.70	5.07
	N	29	4.54	1.57	0.96	–	–	–	–	–	–	–
MQU	D	16	1.93	2.33	0.94	2.07	2.28	0.94	−0.03	0.67	1.96	2.02
	N	11	3.05	1.99	0.96	–	–	–	–	–	–	–
NGQ	D	40	−3.57	2.47	0.94	−2.61	2.39	0.94	−0.94	0.95	−2.63	2.21
	N	64	1.67	1.41	0.98	–	–	–	–	–	–	–
QYZ	D	6	2.52	1.26	0.95	1.96	1.34	0.94	0.54	0.93	1.98	0.28
	N	17	−1.18	1.34	0.98	–	–	–	–	–	–	–
TYU	D	34	2.00	2.78	0.95	1.56	2.78	0.95	0.47	1.02	1.53	1.73
	N	36	−0.20	2.02	0.98	–	–	–	–	–	–	–
YKE	D	79	1.46	2.33	0.97	1.73	2.04	0.97	−0.27	1.27	1.73	1.77
	N	94	0.46	1.62	0.98	–	–	–	–	–	–	–
All	D	527	2.00	2.55	0.87	1.65	2.40	0.88	0.37	1.17	1.63	1.97
	N	885	0.73	1.55	0.98	–	–	–	–	–	–	–

Note: No scale conversion was performed at nighttime when LST is more spatially homogenous; D denotes daytime, N denotes nighttime.

Conclusion

- Defined the ground station's spatial representativeness and Temporal extended based on the temporal variation of LST.
- Quantified the temporal variation of spatial representativeness of 16 ground stations on MODIS and AATSR pixels by incorporating Landsat TM/ETM+ data and meteorological environmental parameters.
- Quantified the uncertainty in LST validation caused by ground station's spatial representativeness, shown that the station's spatial representativeness could cause a mean biases between – 1.95 K and 5.60 K and standard deviations between 0.07 K and 3.72 K on the normal validation results.

Key References

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