Estimation of All-Weather 1 km MODIS Land Surface Temperature for Humid Summer Days

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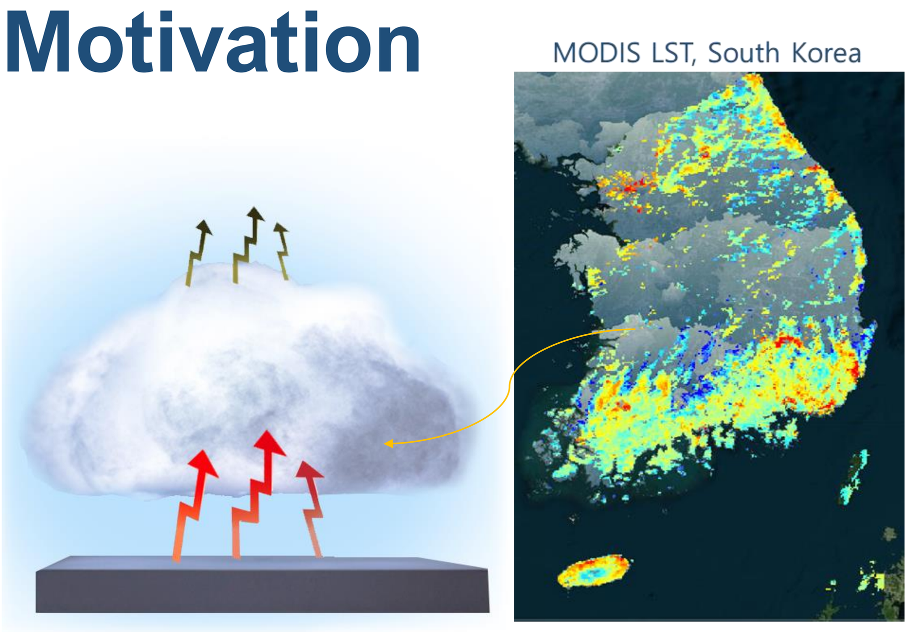
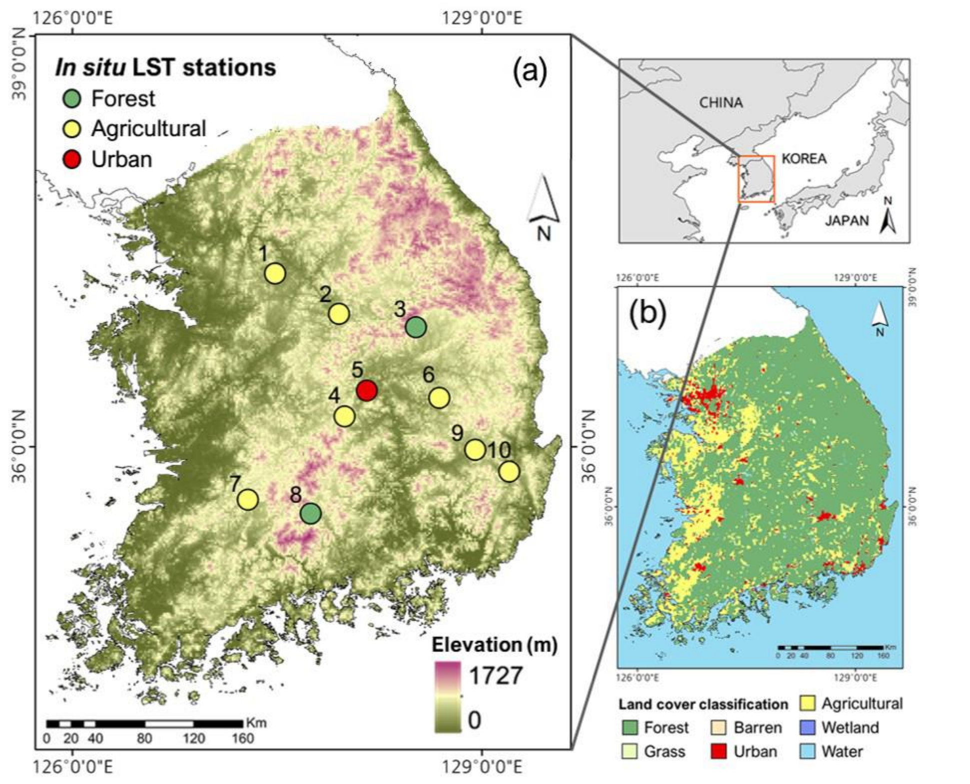
Motivation



Land surface temperature (LST) is used as a critical indicator for various environmental issues because it links land surface fluxes with the surface atmosphere. Moderate-resolution imaging spectroradiometers (MODIS) 1 km LSTs have been widely utilized but have the serious limitation of not being provided under cloudy weather conditions. In this study, we propose two schemes to estimate all-weather 1 km Aqua MODIS daytime (1:30 p.m.) and nighttime (1:30 a.m.)

Study area



The study area is the mainland of South Korea. In South Korea, **summers can often be scorching, causing a variety of disasters.** A total of 10 automated surface observing systems (ASOSs) were selected for in situ reference LST data locations.

- Study periods: July-August, 2013-2018

Data and Input Variables

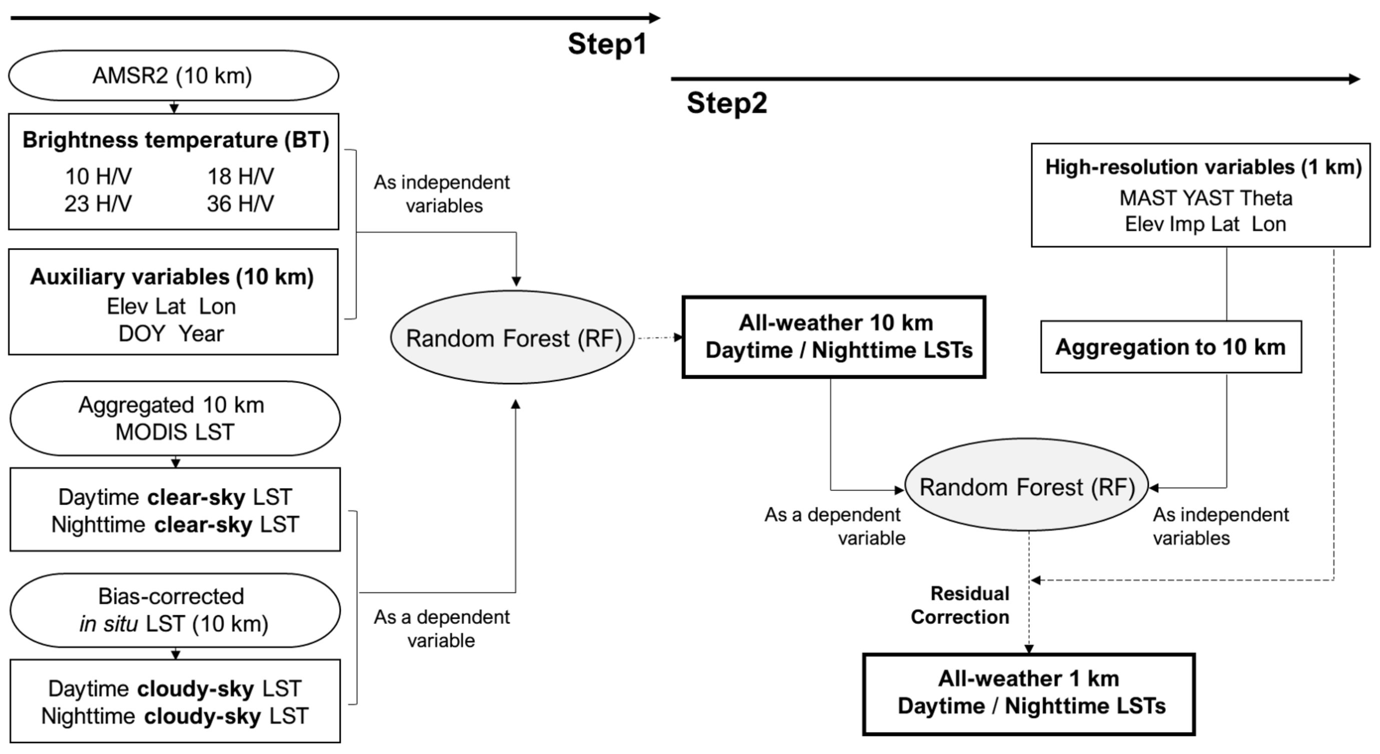
We used eight AMSR2 BTs, three ACPs (i.e., MAST, Yast, and theta), and six auxiliary variables for the LST estimations. The MYD11A1 LST data, which have 1 km spatial resolution, from 2013–2018 were downloaded.

Type	Variables	Acronym
AMSR2 BT	36.5 GHz horizontal polarization	36H
	36.5 GHz vertical polarization	36V
	23.8 GHz horizontal polarization	23H
	23.8 GHz vertical polarization	23V
	18.7 GHz horizontal polarization	18H
	18.7 GHz vertical polarization	18V
	10.7 GHz horizontal polarization	10H
	10.7 GHz vertical polarization	10V
Annual cycle parameters	Mean annual LST (K)	MAST
	Mean annual amplitude of LST (K)	YAST
	Phase shift relative to spring equinox on the Northern hemisphere	theta
Auxiliary variables	Elevation (m)	Elev
	Impervious surface fraction (%)	Imp
	Latitude (°)	Lat
	Longitude (°)	Lon
	Converted day of year	DOY
	Year as a discrete value	Year

LST Processing

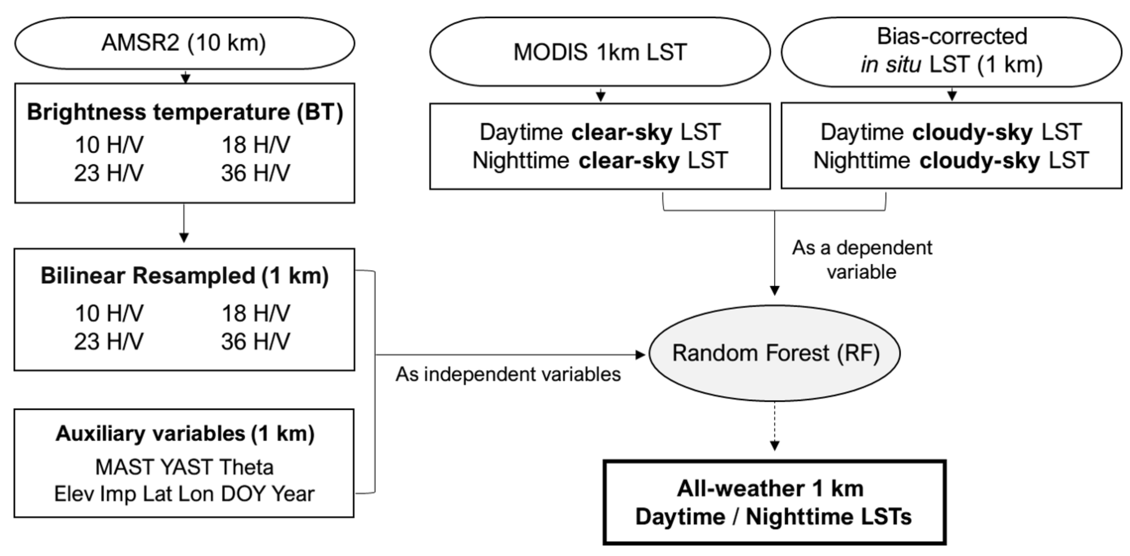
- The 1 km MODIS LSTs with quality control (QC) flags of 'cloud' were considered to be pixels under cloudy sky conditions.
- We fitted in situ LST and MODIS LST under clear sky conditions using polynomial regression by station to bias-correct in situ LSTs for both daytime and nighttime.
- Clear sky 1 km MODIS LSTs were aggregated to 10 km based on the 10 km AMSR2 grid area.
- We also fitted the in situ LSTs and the 10 km MODIS LSTs under clear sky conditions using polynomial regression

Methods: Scheme1 (S1)



Scheme 1 (S1) is a two-step approach that first estimates 10 km LSTs and then conducts the downscaling of LSTs from 10 km to 1 km based on random forest.

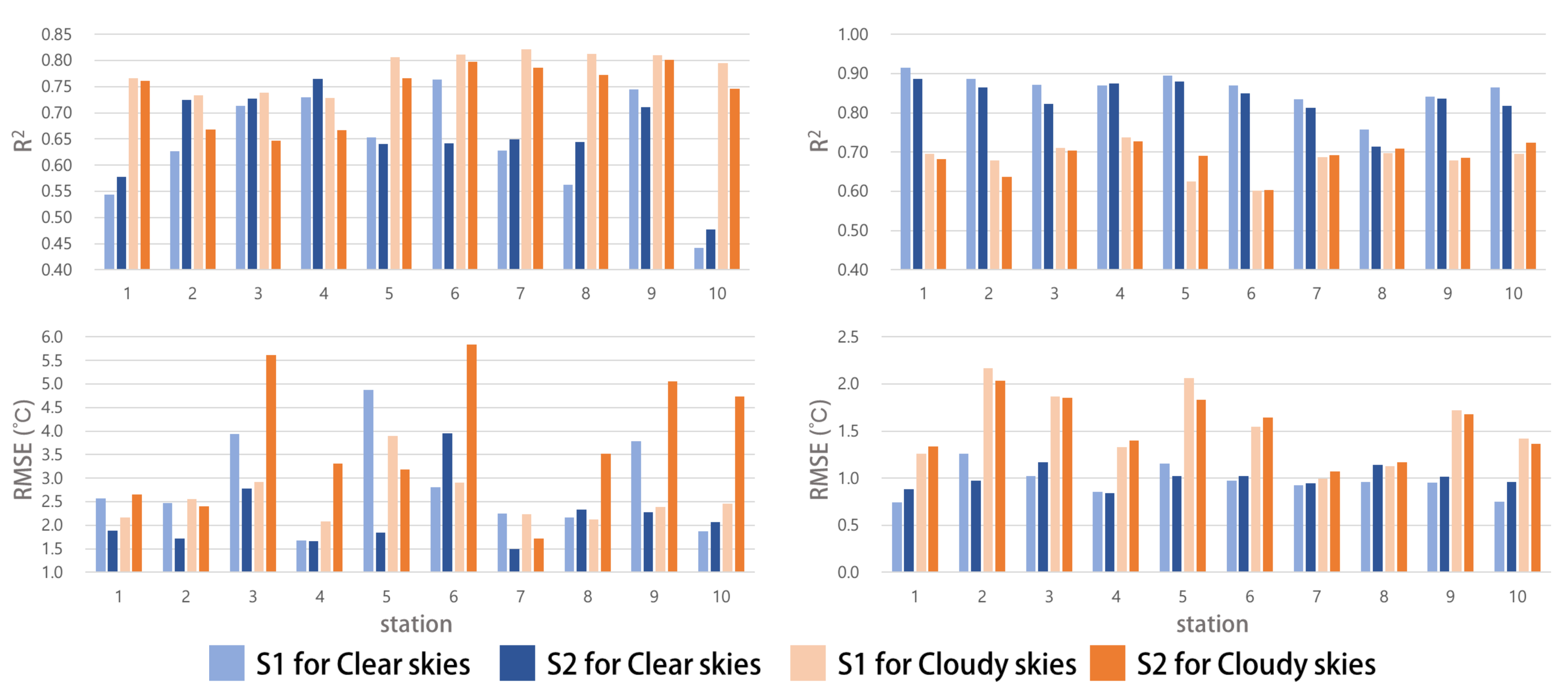
Methods: Scheme2 (S2)



Scheme 2 (S2), a one-step algorithm, directly estimates the 1 km all-weather LSTs. For S1 and S2, **both clear sky MODIS LSTs and the bias-corrected in situ LSTs under cloud sky conditions were used as a dependent variable** to provide the models with the LST characteristics for clear and cloudy skies.

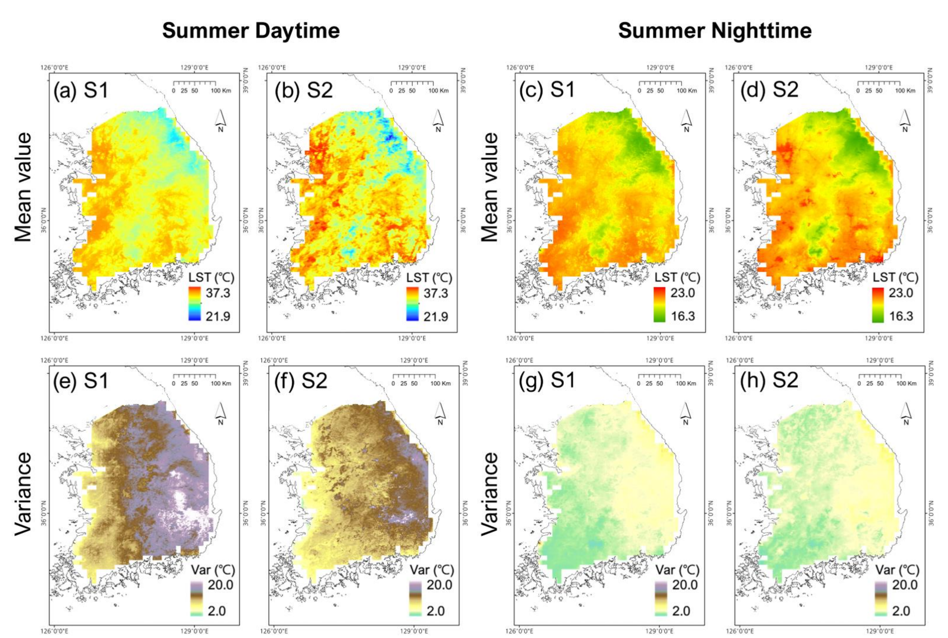
Results: Two-scheme (S1 and S2) Comparisons

Daytime LOOCV validation / Nighttime LOOCV validation



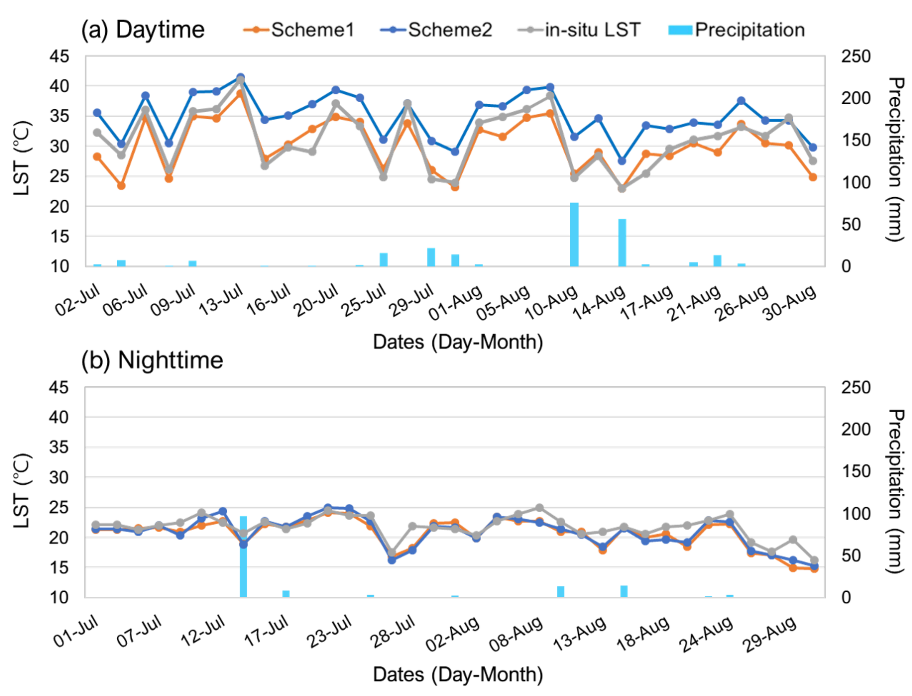
The leave one-station out cross-validation (LOOCV) results show that the performance of S2 was better than S1 in clear-sky daytime. However, **in cloudy sky daytime, S1 simulated low LSTs better than S2, with an average root mean squared error (RMSE) of 2.6℃ compared to an average RMSE of 3.8 ℃ over 10 stations.** At nighttime, S1 and S2 demonstrated no significant difference in performance both under clear and cloudy sky conditions.

Spatial distribution of all-sky LSTs



In the daytime, S2 generally simulated LSTs higher in urban and agricultural areas than S1. At nighttime, the S1 and S2 showed similar LST distributions, except urban areas. **The variance of S1 LSTs is quite a lot higher than S2 in most areas in the daytime.** S1 could simulate the temporal pattern of daily LSTs accurately.

Time-series of the estimated LSTs and 1 km bias-corrected in situ LSTs with precipitation at station9



In the daytime, extremely high LSTs were well predicted by S2, as opposed to S1; however, relatively low LSTs were better predicted by S1. **S1 also simulated the rapid temperature changes (i.e. rainy days) better than S2.**

Two Scheme Combinations (SC)

- We further examined the combination of the two schemes (S1 and S2). In daytime, **the LSTs developed from S2 were used for days with relatively high LSTs, whereas S1 was used for days with lower temperatures.** For nighttime, the average of S1 and S2 LSTs was used.
- When the two schemes were combined (SC) , **the proposed all-weather LSTs resulted in an average R^2 of 0.82 and 0.74 and with RMSE of 2.5 ℃ and 1.4 ℃ for daytime and nighttime**, respectively, compared to the in situ data.

LOOCV validation results for S1, S2 and SC

Station	Daytime (All-weather)						Nighttime (All-weather)					
	R^2			RMSE (°C)			R^2			RMSE (°C)		
	S1	S2	SC	S1	S2	SC	S1	S2	SC	S1	S2	SC
1	0.78	0.77	0.82	2.2	2.5	1.9	0.76	0.73	0.75	1.1	1.2	1.2
2	0.75	0.72	0.79	2.5	2.3	2.3	0.73	0.68	0.72	2.0	1.8	1.9
3	0.80	0.73	0.82	3.2	5.0	2.6	0.73	0.71	0.73	1.7	1.7	1.7
4	0.78	0.74	0.79	2.0	3.0	2.1	0.76	0.76	0.77	1.2	1.3	1.2
5	0.83	0.79	0.81	4.1	3.0	3.3	0.70	0.73	0.73	1.9	1.7	1.7
6	0.83	0.80	0.85	2.9	5.5	3.0	0.66	0.67	0.68	1.4	1.5	1.4
7	0.83	0.81	0.82	2.2	1.7	2.1	0.74	0.74	0.75	1.0	1.0	1.0
8	0.82	0.81	0.83	2.1	3.2	2.2	0.71	0.71	0.73	1.1	1.2	1.1
9	0.84	0.83	0.82	2.8	4.5	2.5	0.73	0.73	0.74	1.5	1.5	1.5
10	0.82	0.76	0.80	2.3	4.3	2.6	0.74	0.76	0.76	1.3	1.3	1.2

Conclusion

This paper demonstrates the ability of the **two different schemes to produce all-weather dynamic LSTs.** The strategy proposed in this study can improve the applicability of LSTs in a variety of research and practical fields, particularly for areas that are very frequently covered with clouds.