Supplementary Materials

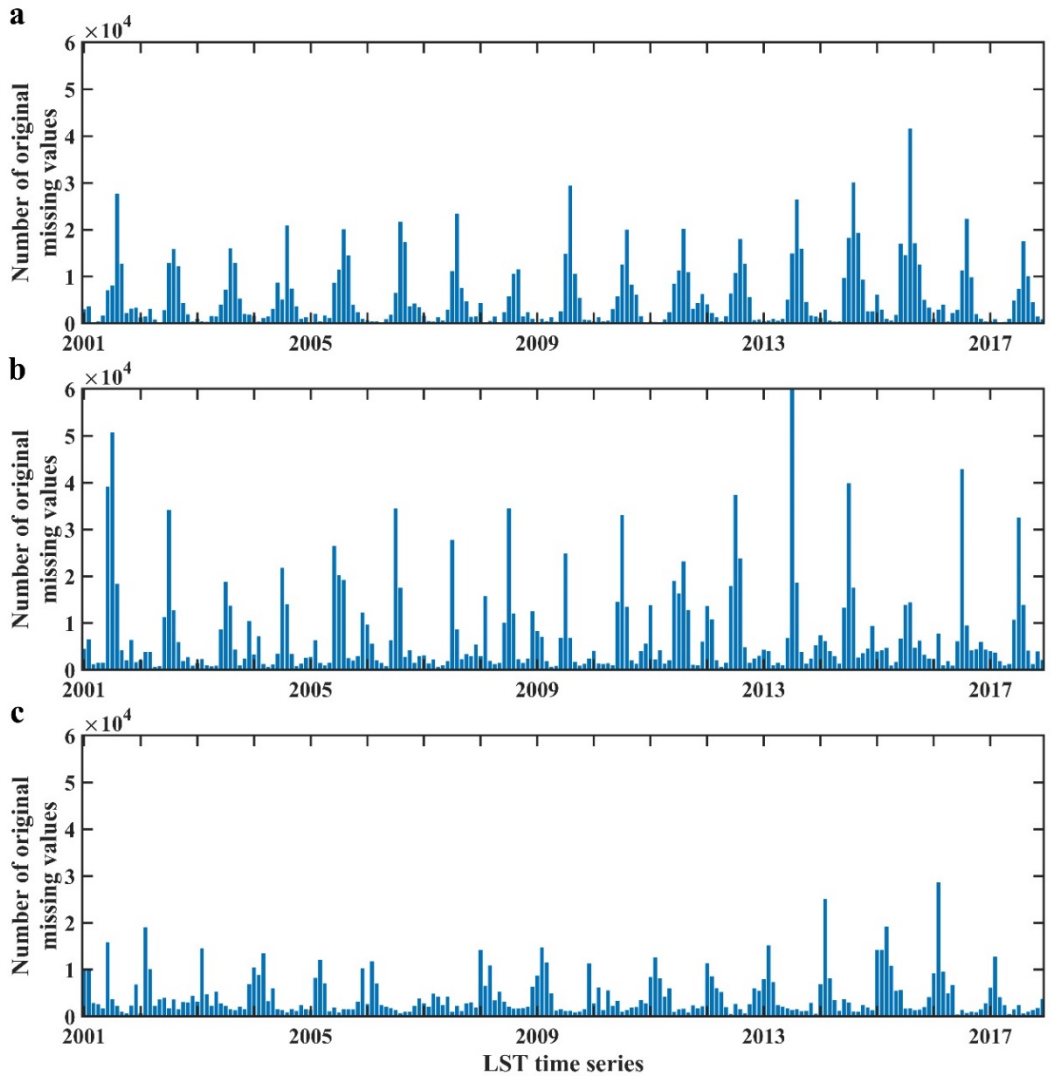

Figure S1. The number of missing values of Africa (**a**), Southeast Asia (**b**) and South America (**c**) in the LST time series (from 2001 January to 2017 December). The gaps of LST on the monthly scale show obvious seasonality. Affected by different background climatic conditions, data gaps exist mainly in warm seasons in Africa and Southeast Asia; and mainly in the cold season in South America. In general, a peculiar month with the significantly largest number of gaps exists in all three regions per year, which suggest the temporal concentration of data gaps in the LST time series.

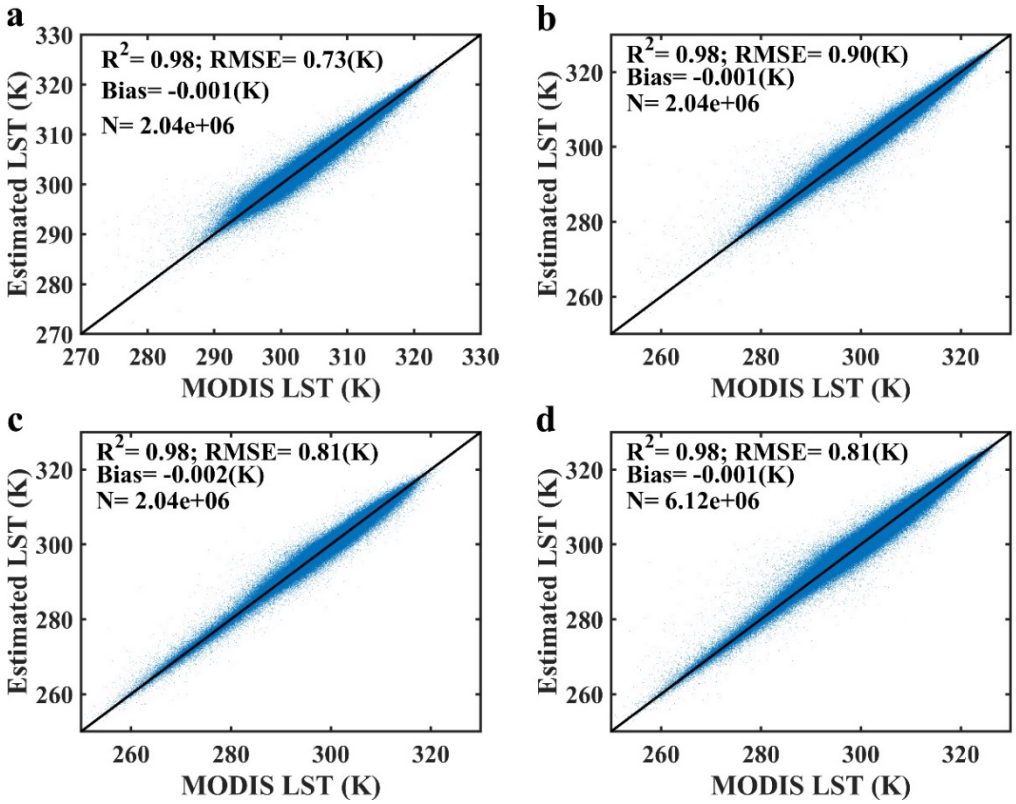

Figure S2. Scatterplot of the estimated LST against original LST of all the blanked gaps over the full time series in Africa (**a**), Southeast Asia (**b**), South America (**c**) and the entire dataset (**d**) respectively. The DCT-PLS generates globally accurate filling results over the full time series for each region with RMSE values of all three regions including the entire dataset are less than 0.9K; R^2 values are larger than 0.98; and bias values are all remain around zero mark.

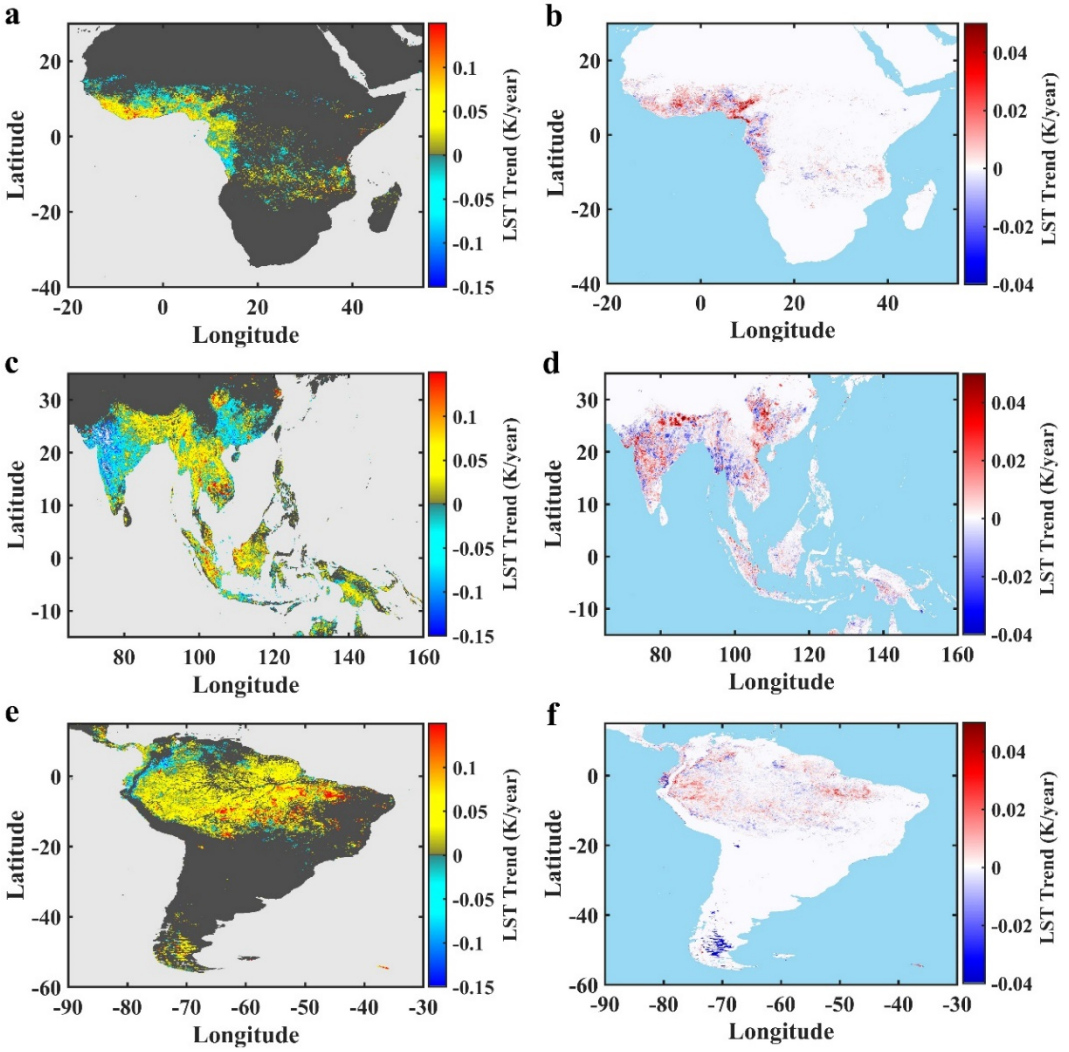

Figure S3. Distribution of actual trends and trend differences between original LST and estimated LST on gap area: actual distribution of LST time series trends in Africa, Southeast Asia and South America, respectively (**a**, **c**, **e**); trend differences of LST time series in three regions (**b**, **d**, **f**). Part of the cooling regions represented by negative area in **a**, **c** and **e** have a positive trend difference in **b**, **d**, and **f**, which indicates a slightly larger cooling tendency of the estimated LST. Similarly, part of the warming regions represented by positive area in **a**, **c** and **e** have a negative trend difference in **b**, **d**, and **f**, which indicates a slightly larger warming tendency of the estimated LST.

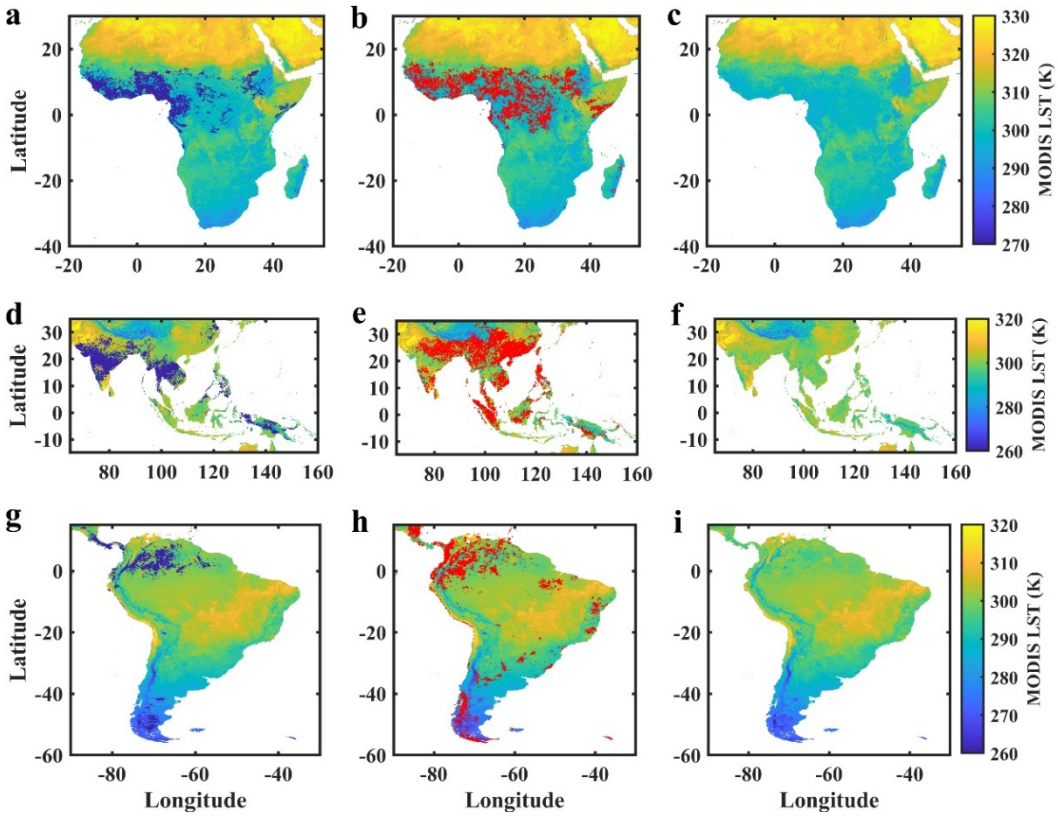

Figure S4. DCT-PLS filling results of MODIS 8-day LST of Africa, Southeast Asia and South America on Aug.5th 2001, respectively: (**a**, **d**, **g**) distribution of original gaps; (**b**, **e**, **h**) distribution of simulated gaps (red pixels) generated by random blanking; (**c**, **f**, **i**) estimated LST filled by DCT-PLS. Although the 8-day LST has larger gap area than monthly LST in all three regions, the filling results also demonstrated a good skill of DCT-PLS for gap filling purposes on 8-day LST dataset.

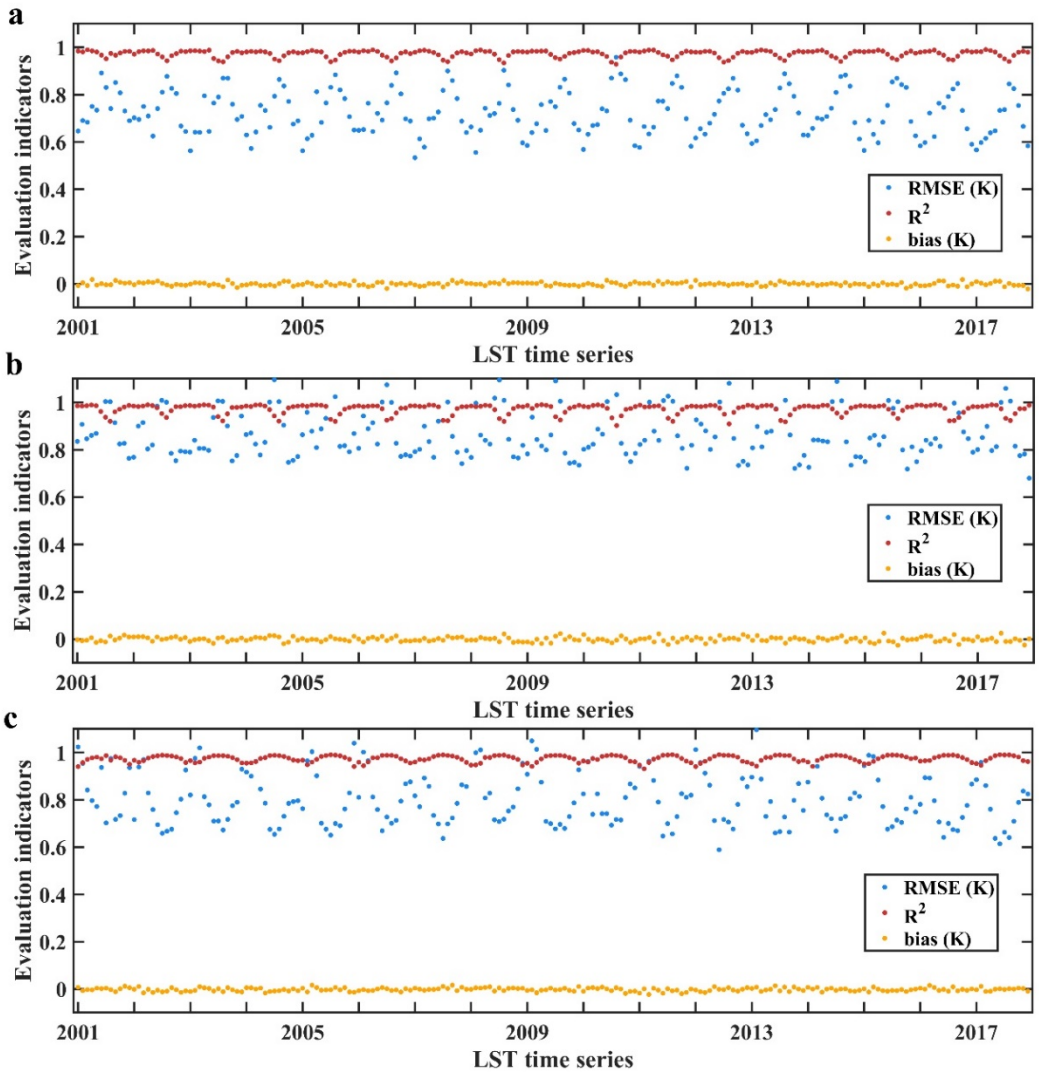

Figure S5. The evaluation indicators value of filling results for the entire MODIS LST dataset with full time series from January 2001 to December 2017 in Africa (**a**), Southeast Asia (**b**) and South America (**c**), respectively. RMSE R^2 and bias show the filling quality on the simulated gaps generated by random blanking over each LST layer for each region. The bias on three regions all remain around zero mark. The RMSE and R^2 present a moderate seasonal variation, and suggest an accurate filling results on the entire dataset with all R^2 values larger than 1 and 100%, 91.2% and 95.6% of RMSE less than 1K for three regions respectively.

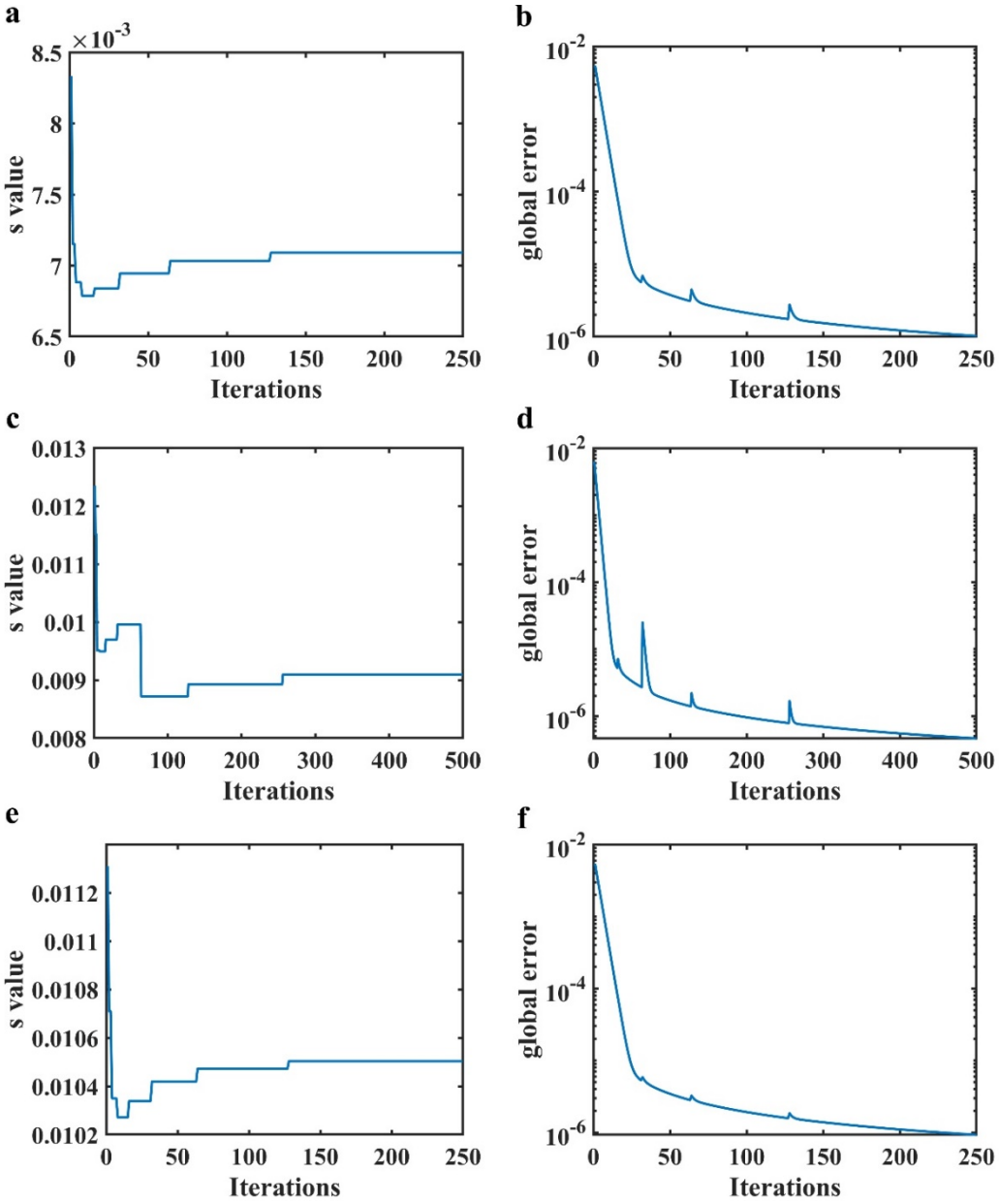

Figure S6. The s values and reconstruction errors averaged over globe for each iteration of DCT-PLS filling process in August 2001 in Africa (**a**, **b**), Southeast Asia (**c**, **d**) and South America (**e**, **f**).

By using the GCV score criterion, choosing of smoothing parameter s is fully automated in the DCT-PLS filling process [1]. For each filling iteration, we evaluate the suitability of DCT-PLS filling method by defining the reconstruction error as the normalized error between original LST y and the estimated LST $\hat{y}$ filled by DCT-PLS method:

$$\frac{\| W \circ (y - \hat{y}) \|}{\| W \circ y \|} \tag{S1}$$

where W is a diagonal matrix *diag(wi)* that contains weights $w_i \in [0,1]$ corresponding to the missing values of y, and $\circ$ stands for the Schur (elementwise) product.

During the iterations of DCT-PLS, the s value decreases rapidly, and then converges to stable values at about 7×10^{-3}, 9×10^{-3} and 1×10^{-2} for three regions respectively (Fig. S6a, S6c and S6e). The global average reconstruction errors show a synchronized decline and all reach small values at 10^{-6} (Fig. S6b, S6d and S6f), which confirms that GCV score criterion is a fast and effective strategy to choose smoothing parameter s in DCT-PLS filling process automatically.

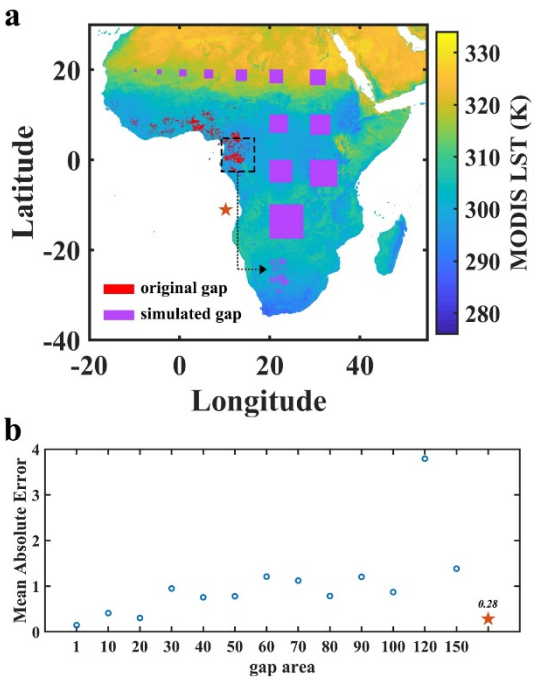

Figure S7. Simulated gaps with varying gap area used to model uncertainty in the gap filling process (**a**) and the mean absolute error (MAE) of filling results (**b**). We simulate a series of data gaps with varying gap area (1 × 1, 10 × 10, 20 × 20, 30 × 30, 40 × 40, 50 × 50, 60 × 60, 70 × 70, 80 × 80, 90 × 90, 100 × 100, 120 × 120, 150 × 150 pixels). Besides, a particular simulated gap with same spatial pattern as the original gap in an 150 × 150 dashed box. The MAE is calculated at all these simulated gaps, and MAE value of the particular simulated gap is show as a star. The MAE value is at about 1 when the gap area is smaller than 100 × 100 pixels. The original gap represented by the particular simulated gap shows a much small MAE (0.28), which is similar with performance of gap area between 1 × 1 and 20 × 20 pixels.

Table S1. The evaluation indicators value of filling results for MODIS 8-day LST dataset with four days in August 2001 (Aug.5th, 13th, 21th and 29th) in Africa, Southeast Asia and South America, respectively. RMSE, R^2 and bias all present a good filling results for each region on each date, totally with RMSE less than 1.2K, R^2 greater than 0.95 and absolute bias less than 0.01K. The Southeast Asia has a relative larger RMSE values, which imply the discrete gaps may have insufficient spatial information to obtain an accurate interpolation. However, it is feasible to utilize DCT-PLS for filling gaps on MODIS 8-day LST dataset.

	Aug.5th 2001	**Aug.13th 2001**	**Aug.21th 2001**	**Aug.29th 2001**
RMSE (Africa)	1.000	1.007	1.023	1.029
RMSE (Southeast Asia)	1.174	1.121	1.176	1.198
RMSE (South America)	1.065	1.068	1.001	1.091
R^2 (Africa)	0.955	0.951	0.950	0.950
R^2 (Southeast Asia)	0.950	0.956	0.950	0.951
R^2 (South America)	0.988	0.984	0.989	0.982
bias (Africa)	-0.005	0.001	0.002	0.003
bias (Southeast Asia)	0.002	-0.004	-0.006	0.008
bias (South America)	0.003	0.002	-0.008	0.002