Assessing the accuracy of LST_cci products and analyzing LST trends in the Iberian Peninsula

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In this study, we first evaluated different versions of the LST_cci products using ground thermal-infrared radiance data acquired at the Valencia Test Site (VTS, rice paddy). EOS-Terra and EOS-Aqua MODIS and Sentinel-3A and Sentinel-3B SLSTR LST_cci products were validated, together with the corresponding operational and alternative LST algorithms. Systematic uncertainties of around 1.2-2 K and random uncertainties up to 1.5 K were shown for v2 to v4.00 of the LST_cci MODIS L3C products, leading to total uncertainties (RMSD or R-RMSD) around 1.5-2 K (far lower than 4 K obtained for the v1 uncertainties). V4.00 slightly reduce systematic uncertainties compared to the previous ones, although it still overestimates ground LSTs at the VTS. Lower systematic uncertainties were shown for the operational products, with total uncertainties from <1 K to 1.5 K. In the case of the SLSTR validation, similar results were obtained for the LST_cci product and the operational product (systematic uncertainties from 1.5 to 1.7 K and RMSDs from 2 K to 2.4 K), but they were much lower for an alternative proposed emissivity-dependent algorithm.

Finally, we analyzed LST trends with the complete LST_cci EOS-Aqua MODIS L3C 0.01° dataset (2002-2021) over the Iberian Peninsula. The analysis showed significant LST trends in the 22% of the area, with a mean value of 0.1 K/year at daytime, while the area with significant trends was 34% with a mean value of 0.07 K/year at nighttime.

Introduction

- **Land Surface Temperature (LST)** is an essential climate variable (ECV) for monitoring the Earth climate system and thus trends associated to climate change.
- The validation of satellite-derived LSTs against independent references is crucial for assessing their accuracy and precision.
- The GCOS recommends an uncertainty threshold for satellite-retrieved LSTs of:
➤ ±1 K for accuracy (i.e., systematic uncertainty) ➤ ±1 K for precision (i.e., random uncertainty)

Product String and version	Sensor type	Resolution	Data availability/ Data used	Local time of descending node
TERRA_MODIS_L2P (v1)	TIR	1 km swath	2000-2021/2016-2018	~10:10-11:50
AQUA_MODIS_L2P (v1)	TIR	1 km swath	2002-2021/2016-2018	~12:40-14:00
TERRA_MODIS_L3C (v1-v4)	TIR	0.01°/0.05°	2000-2021/2014-2019	~10:10-11:50
AQUA_MODIS_L3C (v1-v4)	TIR	0.01°/0.05°	2002-2022/2002-2021	~12:40-14:00
SENTINEL3A_SLSTR_L3C (v1-v4)	TIR	0.01°	2016-2022/2020-2022	~10:15-10:45
SENTINEL3B_SLSTR_L3C (v1-v4)	TIR	0.01°	2018-2022/2020-2022	~10:15-10:45

Table 1. A summary of LST_cci products used.

Aims

➤ LST validation:

- LST_cci TERRA-MODIS and AQUA-MODIS, SENTINEL3A_SLSTR_L3C and SENTINEL3B_SLSTR_L3C products were evaluated against ground data at the VTS to:
1) Assess their accuracy and precision for meteorological and climate studies within the research projects leaded by the Thermal Remote Sensing Group of the University of Valencia.
2) Contribute feedback to the LST_cci project.
- MODIS operational LST products (MOD/MYD11_L2 and MOD/MYD21) using the same VTS ground data as reference data.
- SLSTR operational LST products and an alternative emissivity-dependent, and also viewing-angle dependent, split-window algorithm (E-SWA) [1].

➤ LST trends: Analyze LST trends over the Iberian Peninsula using 20 years of the v4 AQUA_MODIS_L3C product series (2002-2021).

LST validation

Validation site and ground data:

Valencia Test Site (VTS):

- Uniform and thermally-homogeneous 100 km^2 rice paddy area located near Valencia (Spain) with three different land covers across the year (Figure 1).

Ground data for SLSTR products:

- Fixed station data (VTS), 2020-2022.

Ground data for MODIS products:

- Average of the LST measurements acquired by calibrated multiband radiometers (CIMEL Electronique, model CE-312).
- Acquired, at day-time, concurrently to MODIS overpasses in cloud-free days at VTS, 2014-2021.
- Taken along predefined transects to obtain more representative data at the MODIS spatial resolution and to better consider the thermal spatial and temporal variability of the area in the ground data uncertainty [2], [3].

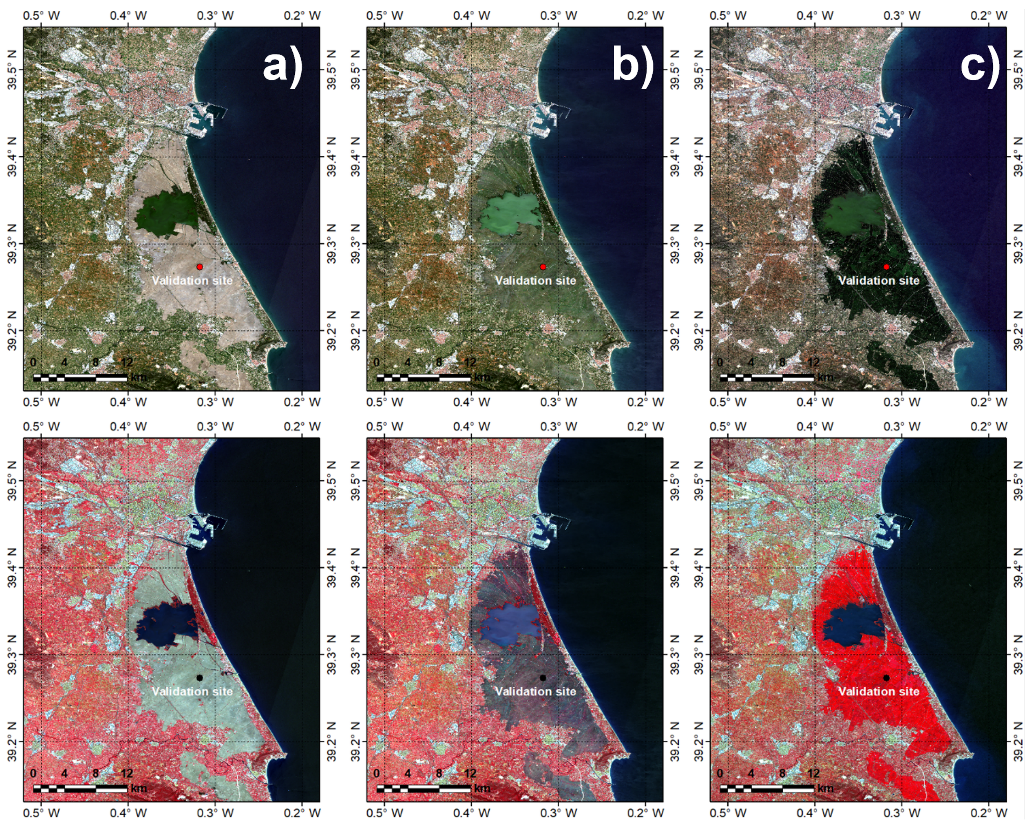
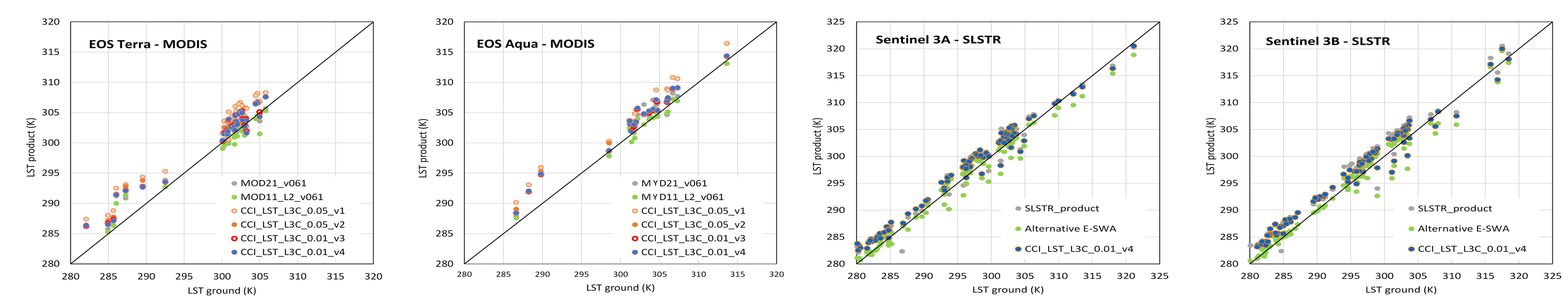


Figure 1. RGB true color compositions (R-G-B 4-3-2; top) and false color compositions (R-G-B 8-4-3; bottom) for Sentinel-2 Multispectral Instrument (MSI) scenes in: a) April (bare soil), b) May (flooded soil), c) August (full vegetation).

- Emissivities for the different land covers and spectral bands were measured at the site using the TES method [4] and the Box Method [5] with the CE-312 radiometers.

Results:



	Terra Aqua			Terra Modis		
Product	LST_CCI v4.00	MYD11 v061	MYD21 v061	LST_CCI v4.00	MOD11 v061	MOD21 v061
Bias	1.5	0.0	1.0	1.2	-0.3	0.7
SD	1.3	0.8	1.1	1.7	1.6	1.4
RMSD	2.0	0.8	1.5	2.0	1.6	1.6
Median	1.3	0.0	0.8	1.0	-0.6	0.5
RSD	1.0	0.9	0.8	1.5	1.4	1.2
R-RMSD	1.6	0.9	1.1	1.9	1.5	1.3
N-events	26	20	20	42	33	33

Table 2. Results of the evaluation of the day-time LST_TERRA[AQUA]_MODIS_L3C v4.00 and v061 products (MOD11 and MOD21) for EOS Terra [Aqua] - MODIS. (2014-2021) [(2014-2019)].

	Sentinel A			Sentinel B		
Product	LST_CCI v4.00	LST operational	LST E-SWA	LST_CCI v4.00	LST operational	LST E-SWA
Bias	1.6	1.6	0.0	1.6	1.8	0.1
SD	1.1	1.1	1.2	1.3	1.4	1.5
RMSD	2.0	2.0	1.2	2.1	2.3	1.5
Median	1.7	1.8	0.1	1.9	2.3	0.3
RSD	0.9	1.1	1.2	0.7	0.9	0.9
R-RMSD	1.9	2.1	1.2	2.0	2.5	1.0
N-events	81	81	81	79	79	79

Table 3. Results of the evaluation of the SENTINEL3A/B_SLSTR_L3C LST_cci (v4.00) product, operational one together and the alternative E-SWA for the SLSTR data in Sentinel-3A/B. (2021-2022).

LST trends over the IP

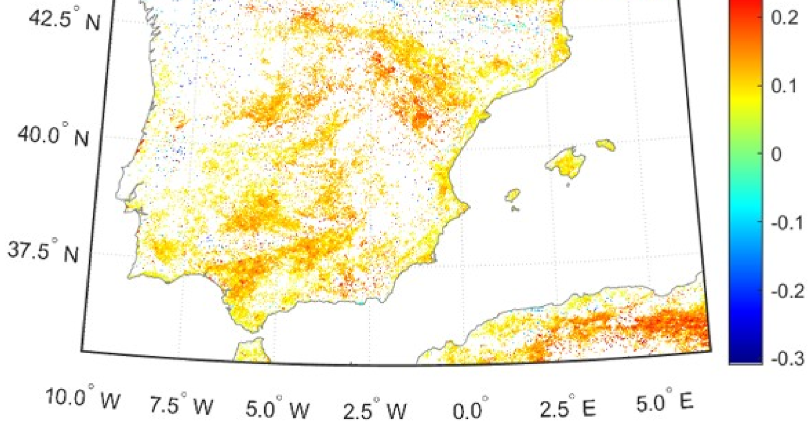
Product: MODIS/Aqua LST_cci data (v4) 2002-2021.

Methodology: Seasonal Mann-Kendall test and Theil-Sen estimator [6].

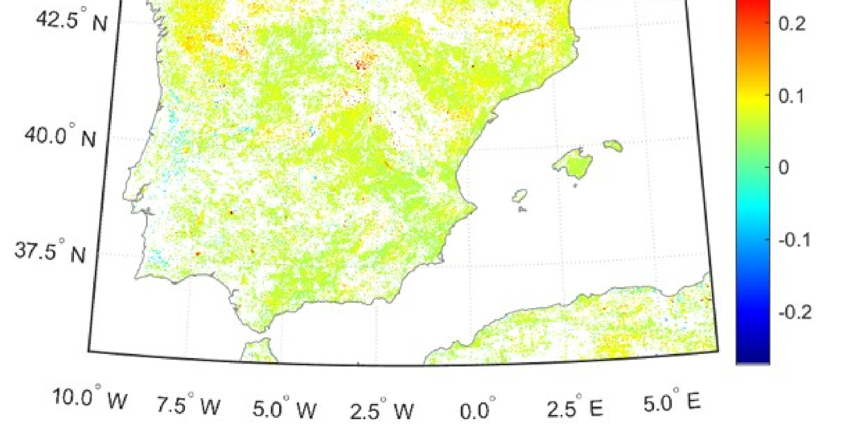
Results:

		Area with trends (%)	Mean trend (K/year)
Mean	Day	22	0.10
	Night	34	0.07
Max	Day	23	0.14
	Night	39	0.10
Min	Day	5	0.04
	Night	7	0.03

Daytime trends



Nighttime trends



Conclusions

- **MODIS:** V4.00 slightly reduce systematic uncertainties. It still overestimates ground LSTs both for EOS-Aqua and EOS-Terra at the VTS (1-1.5K), but the results for v2-v4.00 are much better than those for v1 products (with 4 K uncertainties).
The remaining overestimation is due to differences between emissivities used in the product for the site and ground-measured emissivities. The product emissivities are underestimated at the site, still in v4.00.
- **SLSTR:** Similar results were obtained for the LST_cci product and the operational product. Negligible biases were obtained for the alternative E-SWA.
In the case of the LST_cci product, emissivities included do not reproduce the site emissivity changes and LST_cci emissivities included do not reproduce the site emissivity changes and they are also underestimated for the site.
- **LST trends** (LST_cci AQUA MODIS L3C 0.01° v4) over the Iberian Peninsula:
Significant in the 22% of the area with a mean value of 0.1 K/year at daytime and in the 34% with a mean value of 0.07 K/year at nighttime. Similar trend values were found for the region in [7] and over Europe in [8].

Complete results can be found at the Climate Assessment Report v3 (LST-CCI-D5.1-CAR, 25/05/2024).

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