

Land Surface Temperature (LST) and Heatwave monitoring

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LST images on the news



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MATT REYNOLOS 27.86.2828 86:88 AM

Six facts that show how bad the record-breaking Arctic heatwave is

Record high temperatures in the Arctic Circle are only one way the region is being kicked out of kilter by humaninduced global heating



Europe's wildfire damage seen from SPACE: Satellite images show smoke and burn scars across France and

• The European Space Agency has revealed satellite images taken by Copernicus Sentinel-3 · The satellite orbits 506 miles above Earth to measure our planet's oceans, land, ice, and atmosphere

• ESA hopes the satellite images will prove to be 'key for mitigation strategies and policymaking'

reaching a whopping 55°C

By SHIVALI BEST FOR MAILONLINE Y

Spain - with land surface temperatures in some regions

• One image shows how land surface areas in parts of Spain and northern Africa hit 55C (131F) on July 17

In one image, the temperature of the land surface in southern France. Spain and northern A 17 July. In the land-surface temperature image, areas shown in dark red have a land surface

Air temperature is the measurement used for our daily Why are will weather forecast, and is a measure of how hot the air is above the ground in a heatwa



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Aug 20, 2020 NASA's ECOSTRESS Monitors California's Record-

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Breaking Heat Wave





Rick Spinrad said in a statement. "This new record adds to the disturbing and disruptive path that climate change has set for the









But sometimes, fact checking is required...

⊘ Fact Check

Did Land Surface Temperatures Reach 140 Degrees F in India, Pakistan?

To answer the question, we must first understand the difference between land and air temperatures, and the impacts of wet built temperature.

By Madison Dapcevich	Published May 3, 2022
Claim:	
As a heatwave struck parts of Southeast Asia in late April 2022, land s temperatures reached upwards of 140 degrees Fahrenheit.	surface
Rating:	
True About this rating C	60°C?!
Context	
For clarification, land surface temperature is an entirely different measurement th temperature.	nan air

Fact Check

As parts of Pakistan and India saw life-threatening temperatures that broke recent records in spring 2022, a map depicting what appeared to be record-setting land surface temperatures was hot on social media.



ADAM Platform



Figure from Göttsche et al 2016





How do we measure LST from space?

- Land Surface Temperature (LST) is the radiative *skin* temperature of the land surface
 - Corresponds to thermal emission from the top thin layer of a few micrometers on the surface (up to 50 μm).
- Satellite sensors can measure this skin temperature by measuring the infrared radiance emitted by the surface



LST at the Land Surface Analysis SAF (LSA-SAF)



EUMeTrain Event Week on Heatwaves & Droughts



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All-Sky LST – now a CDR!

Clear sky LST

IR retrievals for clear sky (Generalized Split-Windows Algorithm, standard L2 LST for SEVIRI)

Cloudy Sky LST

Skin temperature from a surface energy balance model, forced by LSA-SAF products and ECMWF meteorological data

Inputs:

- LSA SAF: L_{\downarrow} , S_{\downarrow} , Albedo, LAI
- ECMWF: T_{air} q_{air} u, v
- soil moisture (H-SAF)

Outputs:

• *H*, *LE* (and evapotranspiration) and *SKT*



- Maximizes use of remote sensing data (mostly LSA-SAF)
- Scheme based on the H-TESSEL surface model (ECMWF)
- Runs every 30 min
- Available from 2004-onwards



All-Sky LST - validation











Overall stats for the 33 stations	6 (BSRN + EFDC + KIT)
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	MLSTS – in situ			ERA5-Land – in situ			MLSTS – ERA5-Land		
	All	Clear	Cloudy	All	Clear	Cloudy	All	Clear	Cloudy
μ (K)	0.0	-0.2	0.2	0.2	0.1	0.3	-0.2	-0.2	-0.2
σ (Κ)	1.5	1.4	1.5	1.6	2.1	1.3	1.7	2.1	1.2
RMSD (K)	2.9	2.8	2.8	2.9	3.3	2.6	3.1	3.5	2.4

- Compares very well with in situ estimates •
- Statistics for cloudy sky estimates are similar to clear sky •
- Compares well to ERA5-Land
- Some problems in the representation of the diurnal cycle (phase shift, amplitude) •





slido



Consider two nearby pixels, with same physiographic features (i.e., same land cover type, same elevation, etc.). One is clear-sky, the other is cloudy.

They are observed at the same time.

Which one is warmer?

(i) Start presenting to display the poll results on this slide.

Why satellite All-Sky LST and not reanalysis?





LSA-SAF All-sky LST



ERA5: Less clouds, warmer temperatures

Clouds are *observed*. Surface energy balance scheme diagnoses lower temperatures

Clouds are masked, no direct LST observation Summer day 3pm Local Time



$(1-\alpha)R_S^{\downarrow} + R_l^{\downarrow} - \epsilon\sigma T_S^4 = H + \lambda E + G + Imb$

LST is a result of **Surface Energy Budget**



Why satellite All-Sky LST and not reanalysis?



Why satellite All-Sky LST and not reanalysis?



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Satellite retrievals: a more realistic representation of clouds

20

More realistic representation of surface energy balance by Allsky LST





figure: IPCC AR6 Report

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🗲 LSA SAF

How exceptional was 2022?

Anomalies JJA All Sky LST Daily Max (ref period: 2004-2021)

- Daily max of LST All-Sky, LST_{max}, ref period 2004-2022
- LST_{max} Monthly means/JJA
- "Climate Normal" Median of monthly means /JJA means for 2004-2021
- Magnitude and spatial extent of 2022 heatwave was unprecedented



How exceptional was 2022?

Monthly anomalies LST-All Sky Daily Max (ref: 2004-2021)



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summer



Can we use LST to study heatwaves?

- Differences between All-sky LST and ERA5 SKT increase throughout the summer;
- 2 m temperature (T2m) traditionally used to study heatwaves. Longer data records. Observations have less spatial coverage.





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What could cause increased differences between LST and T2m anomalies?

(i) Start presenting to display the poll results on this slide.

Connection to drought

Monthly anomalies (ref: 2004-2021)

- **FVC** fraction of vegetation cover (0-1); LSA-SAF data
- SWI Soil Wetness Index (0=wilting point; 1= field capacity); H-SAF data
- Independent data showing that largest LST-T2m differences may be associated to more severe drought



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The role of soil moisture

In case there is increased net surface radiation (e.g., sequence of clear-sky days)...



Soil moisture does not limit evapotranspiration

Plants control their temperature -> Excess energy is used mainly for evapotranspiration





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The role of soil moisture

In case there is increased net surface radiation (e.g., sequence of clear-sky days)...







Heat Wave Magnitude Index (HWMI)

- Heatwave: 3+ days LST_{Max} above T_{p90} ;
- Daily heatwave magnitude, *M_d* (e.g., Russo et al., 2015):

$$M_{d} = \begin{cases} \frac{LST_{Max} - p_{25}}{p_{75} - p_{25}}, & LST_{Max} > p_{25} \\ 0, & LST_{Max} \le p_{25} \end{cases}$$

- Heat Wave Magnitude Index (HWMI):
 - Sum of heatwave days, in terms of a fraction of the IQ range of the LST_{Max} distribution
 - Sum performed over any period of interest (e.g.: one heatwave, <u>one summer</u> or a whole year)









Greatest JJA LST anomaly







Greatest average area under extreme temperature conditions





2004

0

19

8

12

Hot Days

16

4

Greatest JJA LST anomaly



20

Greatest average area under extreme temperature conditions

Greatest number of hot days (T>p90)





Greatest JJA LST anomaly



Greatest number of hot days (T>p90)

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Take home messages

- LST and 2 m temperatures may tell different stories about extreme heat events. Both are useful.
- The new All-Sky LST CDR (2004-present) allows monitoring of extreme heat events (even for cloudy scenes), providing information on magnitude as well as on spatial and temporal scales.
- Satellite observations provide more realistic view of surface energy balance quantities, due to better representation of clouds when compared to models and reanalysis
- LST responds directly to the surface energy balance. With drought conditions, LST anomalies are increased and are greater than T2m anomalies.
- Summer 2022 was exceptional in terms of:
 - Mean LST anomaly
 - Area under extreme temperature conditions
 - Number of hot days
 - HWMI magnitude



Questions?

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Summer hot days in 2018





2018 Monthly anomalies



LST at the Land Surface Analysis SAF (LSA-SAF)



Main LST product at LSA SAF:

- LSA SAF LST is generated on an operational basis with 15 min frequency from 2004 onwards (almost 20 years!), with 3 km spatial resolution at nadir
- Based on SEVIRI observations (onboard Meteosat Second Generation)
- Climate Data Record 2004-2015, compatible with NRT

Retrieved for **clear-sky** conditions only (Infrared sensors are not able to see through clouds) most LST products are limited to clear sky pixels)

