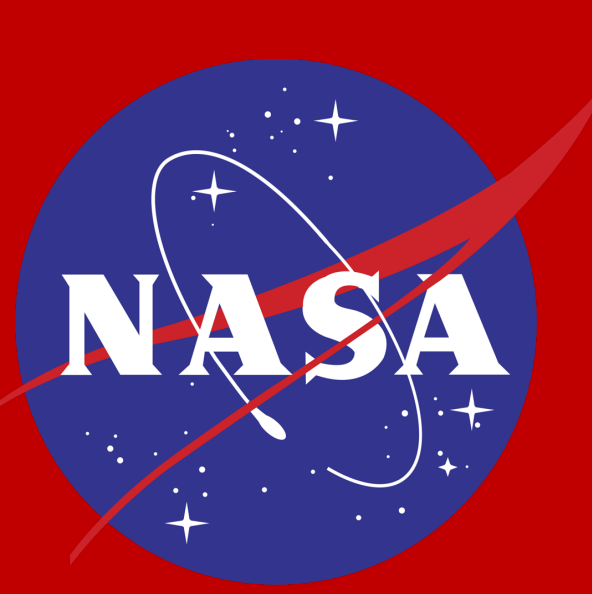




Satellite Thermal Imaging for Solar Infrastructure Assessment

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Introduction



Source: Solar Review

With funding from NASA and QTS, our team at the University of Wisconsin has been working to identify use cases where satellite data can support the information needs of energy assessment. One area of exploration has been how satellite data can inform solar PV operational needs.

PV performance can be affected by many factors, including weather patterns, dust accumulation on the panels, overheating, and material degradation. Traditional methods for gauging PV performance have involved on-the-ground inspections of panels for temperature disruptions, signs of damage, dust accumulation, or hot spots. In-situ networks are also put in place to assess solar farm output, which may be compared with energy system models. However, these ground-level inspections can be quite time-consuming, leading utilities to search for more efficient methods.

Thermal Imaging: Background

Equipped with thermal infrared (TIR) sensors, Unmanned Aerial Vehicles (UAVs) can gauge individual panels' temperatures (Akay et al, 2024), informing PV efficiency, or how much of the incoming sunlight is being converted into usable electricity. Utility companies will often contract with an external UAV company to perform scans 1-2 times a year.

Key to this evaluation is the relationship that, **as the panel temperature increases, the efficiency decreases**. Panel temperatures can be measured using a radiometric thermal camera, which calculates a surface's temperature from TIR imagery. The smaller-scale flyover images are merged into one larger one, an orthomosaic. Each solar panel is then isolated to calculate its efficiency, a process known as solar panel segmentation (SPS), as seen in **Figure 1**.

Satellite data offer the potential for more regular monitoring, potentially at a lower cost. With adequate resolution and accuracy, space-based data could complement, or even replace, UAV scans.

References & Acknowledgements

Akay, S. S., Özcan, O., Özcan, O., & Yetemen, Ö. (2024). Efficiency analysis of solar farms by UAV-based thermal monitoring. *Engineering Science and Technology, an International Journal*, 53, 101688. <https://doi.org/10.1016/j.jestech.2024.101688>

Araji, M. T., Waqas, A., & Ali, R. (2024). Utilizing deep learning towards real-time snow cover detection and energy loss estimation for solar modules. *Applied Energy*, 375, 124201. <https://doi.org/10.1016/j.apenergy.2024.124201>

ASTER. (n.d.). Terra. Retrieved April 6, 2026, from <https://terra.nasa.gov/about/terra-instruments/aster>

Desta, F., Buxton, M., & Jansen, J. (2020). Fusion of mid-wave infrared and long-wave infrared reflectance spectra for quantitative analysis of minerals. *Sensors*, 20(5), 1472. <https://doi.org/10.3390/s20051472>

HotSat-1. (n.d.). Earth Online; ESA. Retrieved September 15, 2025, from <https://earth.esa.int/eogateway/missions/hotsat-1>

Huang, S., Jin, X., Jiang, Q., & Liu, L. (2022). Deep learning for image colorization: Current and future prospects. *Engineering Applications of Artificial Intelligence*, 114, 105006. <https://doi.org/10.1016/j.engappai.2022.105006>

Landsat 8 | Landsat Science. (2021, November 30). <https://landsat.gsfc.nasa.gov/satellites/landsat-8/>

Zhu, P., Li, H., Gao, B., Zhao, X., & Wang, Q. (2025). Photovoltaic dust accumulation index: Monitoring PV dust with Sentinel-2 satellite imagery. *Energy*, 335, 138130. <https://doi.org/10.1016/j.energy.2025.138130>

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Monitoring Solar PV

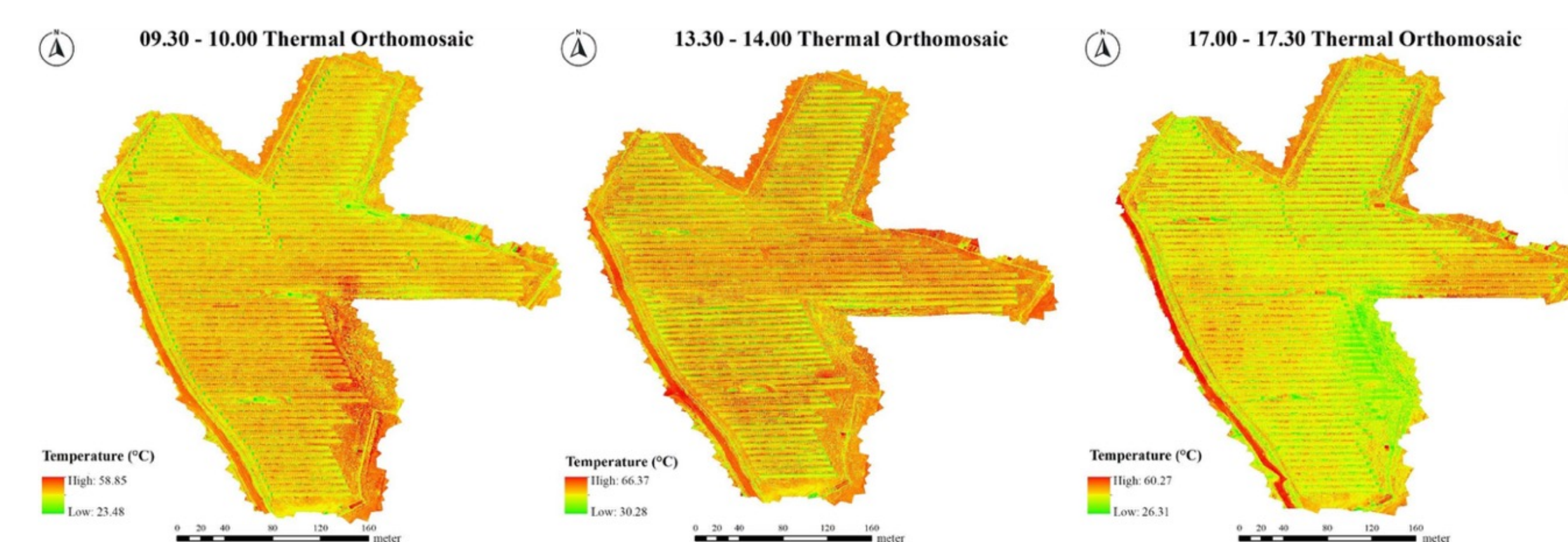


Figure 1: Thermal orthomosaic of a solar farm in Turkey assembled from a series of high-res UAV thermal IR images, in the morning, mid-day, and evening (from left to right). Temperature (°C) was calculated from radiometric imagery and subsequent calibration (Akay et al, 2024).



Figure 4: Color imagery of the O'Brien Solar Farm in Fitchburg, WI, on February 11 (left) and March 8 (right), 2026, as the winter snow melted, from Sentinel-2 MSI. Red striping is an artifact of the imagery.



Figure 5: 2026 Airbus imagery over the O'Brien Solar Farm in Fitchburg, WI, courtesy of Google Maps.

Infrared Satellite Products



Figure 3: An inventory of the various publicly (purple) and commercially (red) available satellite instruments, plotted based on their individual spatial resolutions (m). The instruments are color-coded based on their wavelengths: short- (SWIR, 1.4-2.5 μm , green), medium- (MWIR, 2.5-7 μm , blue), and long-wave (LWIR, 7-15 μm , orange) IR (Desta et al., 2020). The ideal resolution of ≤ 5 m is plotted as a yellow star on the far left. Each instruments' operational information was obtained from the ESA's eoPortal site.

Thermal Infrared Satellite Imagery

The two highest resolution satellite instruments with TIR capabilities are:

1. Landsat 8 satellite's Thermal InfraRed Sensor (TIRS - Resolution: 100 m, resampled to 30 m; Overpass: 10:12 a.m., local time; Revisit time: global coverage every 16 days; can be reduced to 8 days using Landsat 9 TIRS-2 data; Operation: 2013 – present). See **Figure 2**.
2. The Terra satellite's Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER - Resolution: 90 m; Overpass: 10:30 a.m., local time; Revisit time: global coverage every 16 days; Operation: 1999 – present)

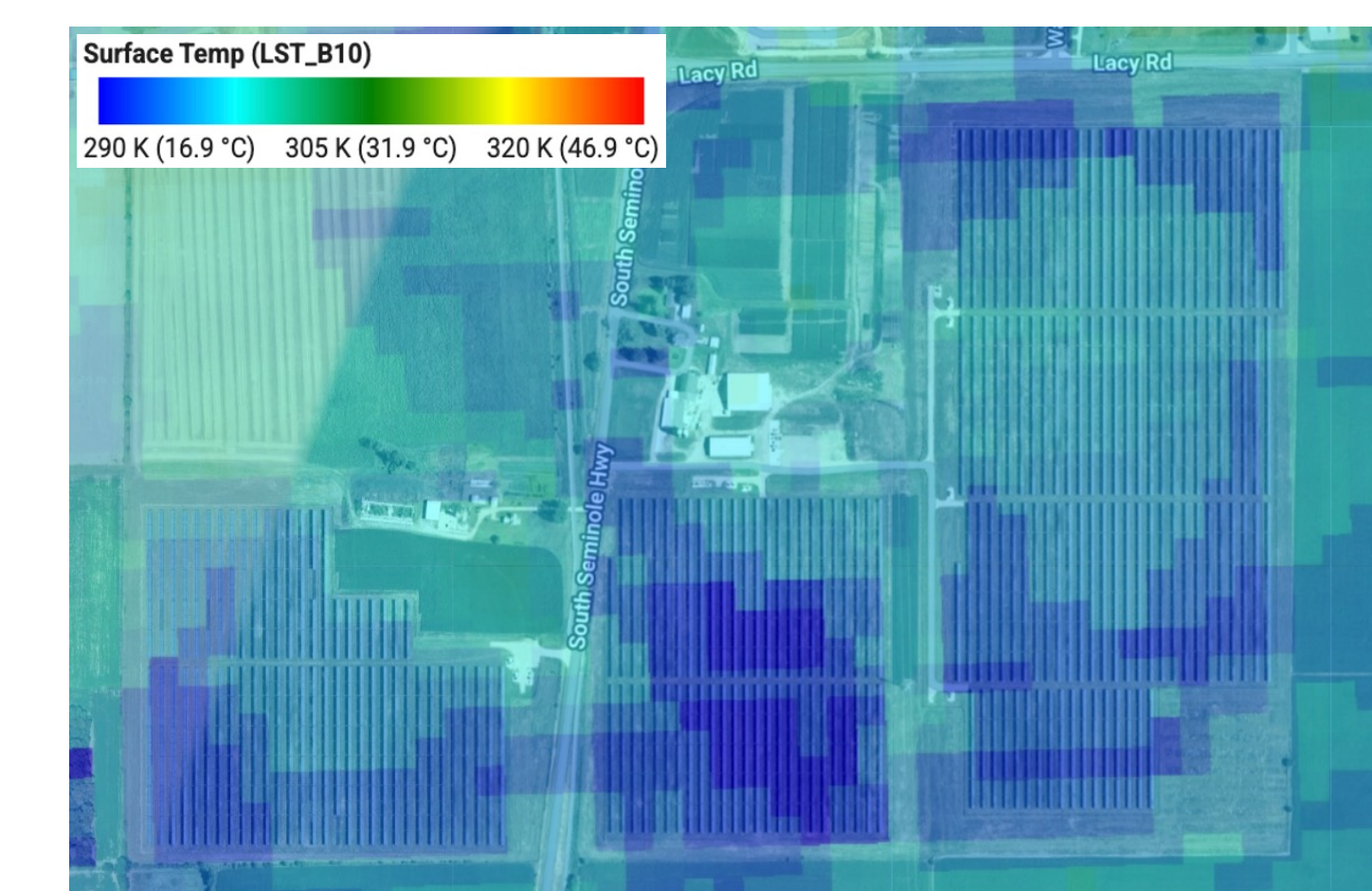


Figure 2: Imagery showing O'Brien Solar Farm in Fitchburg, WI using (a) Google Maps visible satellite imagery and (b) Landsat 8 TIRS imagery in 2025, courtesy of USGS.

- No publicly available satellite has sufficient spatial resolution to analyze each panel individually.
- Of the commercially available TIR satellite instruments, HotSat-1 is the most promising, with a 3.5-meter resolution. There are plans to expand operations, with HotSat-2 having just been launched in April 2026 and HotSat-3 in development.
- Other high-resolution commercial TIR satellite instruments include Constellr's SkyBee-1 & -2 (30 m), OroraTech's OTC-1 (4 m AI-enhanced hotspot detection), and Hydrosat's VanZyl-1 & -2 (70 m).

Alternative Infrared Satellite Data Options

- Short-wave IR (SWIR) can detect snow and dust, which adversely affect solar panel efficiency.
- The accumulation of snow on panels can reduce the performance by up to 54.5%, significantly affecting power output (Araji et al., 2024). Dust accumulation can significantly reduce PV output and instigate hot-spot effects, damaging panels (Zhu et al., 2025).
- As reflected in **Figure 3**, there are several SWIR satellites available (color coded in green) both publicly and commercially, with temporal resolutions ranging from daily to bi-monthly. Recent studies have used public satellite imagery to measure the amount of dust that accumulated on a solar panel (Zhu et al., 2025).
- The highest resolution SWIR data are available from commercial satellites, notably Vantor (formerly Maxar Technology) on their WorldView-3 satellite with a 3.7 m pixel size.

Visible Imagery for Monitoring Solar PV Farms

Visible imagery can provide useful intelligence for utility planning, such as monitoring construction and detecting visible obstructions such as snow accumulation on the panels. Snow detection may be seen even at the coarser resolution of public satellite imagery. The two highest resolution public satellite instruments are:

1. The Sentinel-2 satellite's Multi-Spectral Instrument (MSI - Resolution: 20 m; Overpass: 10:30 a.m., local time; Revisit time: every 5 days; Operation: 2015 – present)
2. The Landsat 8 satellite's Operational Land Imager (OLI - Resolution: 30 m; Overpass: 10:12 a.m., local time; Revisit time: every 16 days, or 8 with Landsat 9 data; Operation: 2013 – present)

Figure 4 shows the O'Brien Solar Farm in Fitchburg, Wisconsin, on February 11 and March 8, 2026, respectively, as the snow on the ground melted, using visual imagery from the Sentinel-2 MSI. Sentinel-2 has a 5-day revisit time, allowing for regular updates.

- Several commercial satellite data providers offer visible wavelength data at higher resolutions:
 1. Airbus's Pleiades Neo constellation (0.30 m). See **Figure 5**.
 2. Vantor's WorldView-3 panchromatic (black and white; 0.31 m) and VNIR (visible and near-infrared; 1.24 m) imagery.
 3. Planet's PlanetScope (3-4 m) and Owl (1 m) constellations.