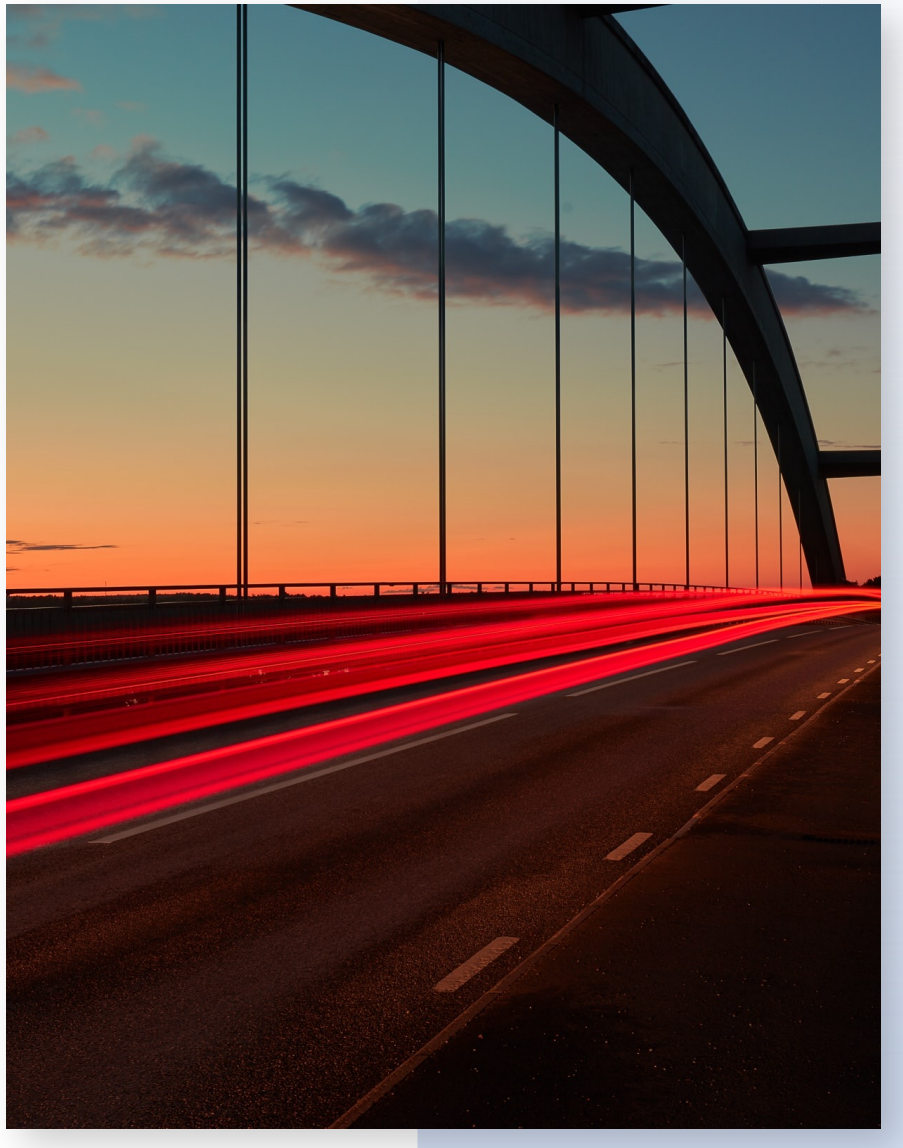
# Technical Challenges for Time-Series Remote Thermography of Highway Bridge Decks



Dr Bandon Decker

ASPRS Mid-South 2023

# DECKER
# Using Time-Series Thermography to Find Bridge Defects

## PROBLEM:

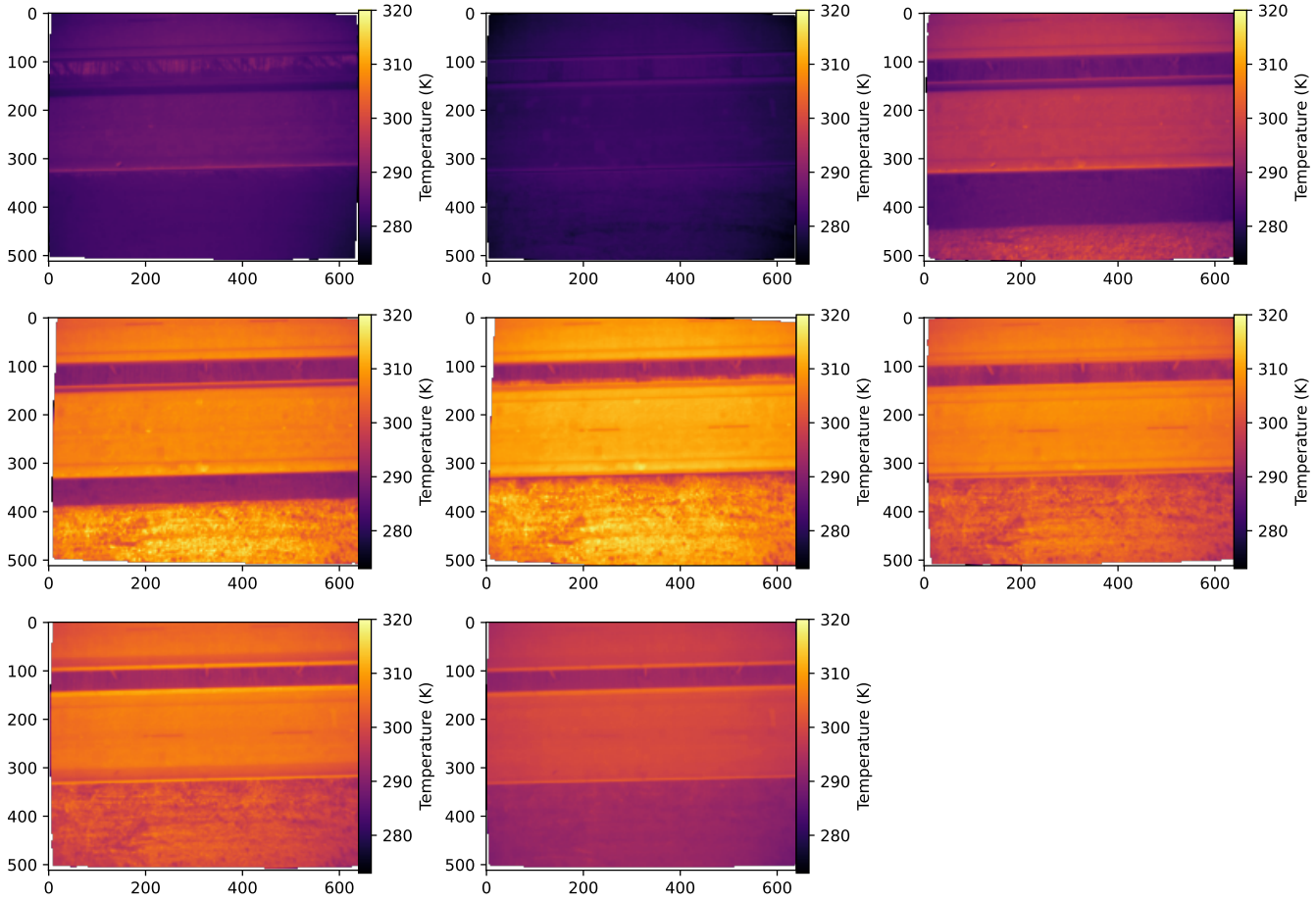
- Reinforced concrete in highway bridge decks becomes delaminated over time, weakening the structure
- Difficult to detect from the surface, but can show up as thermal anomalies owing to areas of delamination having a higher specific heat than healthy concrete

## OUR SOLUTION:

- Fly a UAV with a thermal camera over the bridge deck at regular intervals
- Different rates of passive heating will be visible in the time series, pinpointing delamination

# Thermal Anomalies in Time-Series Data

KTA 125220 SB

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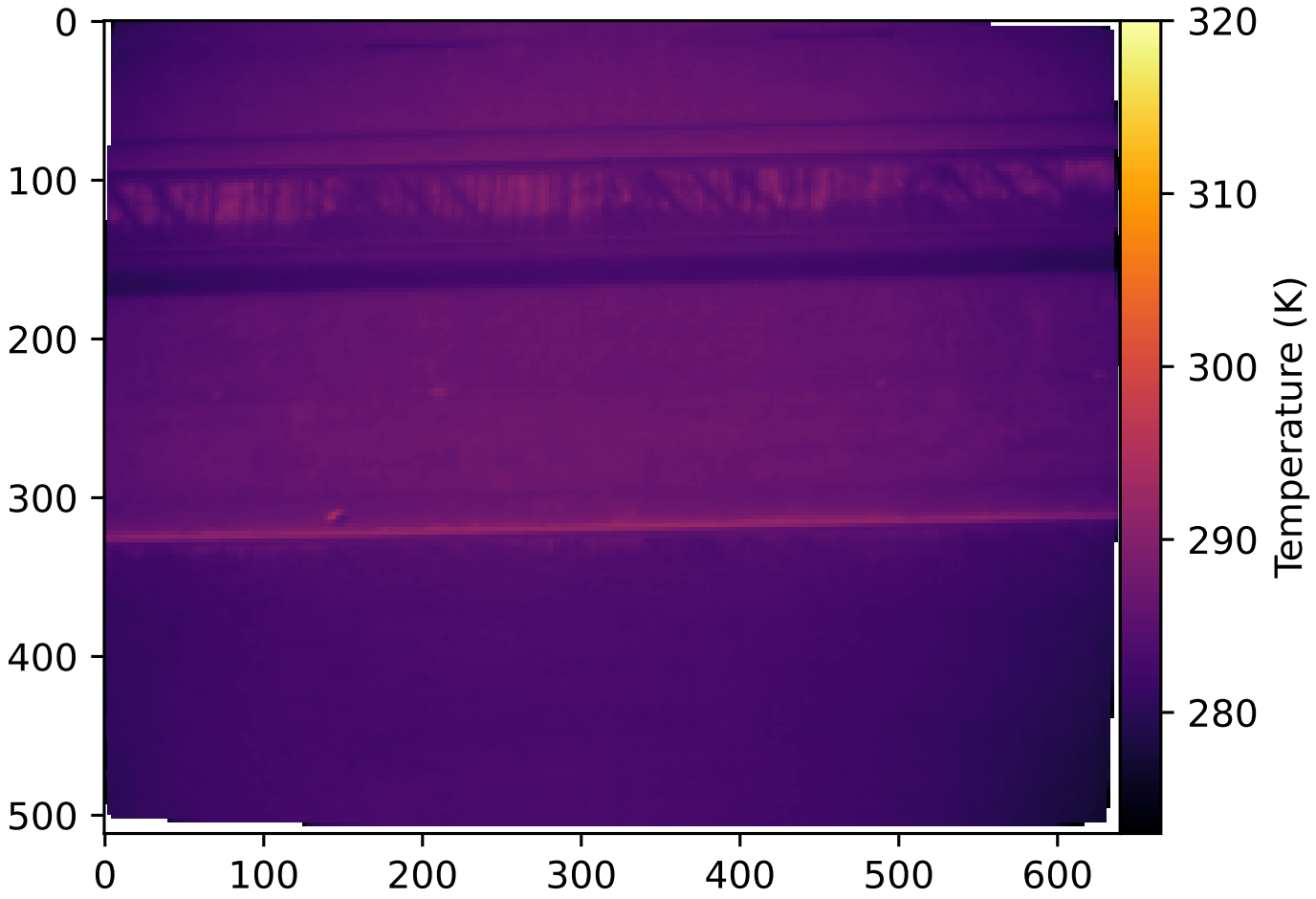


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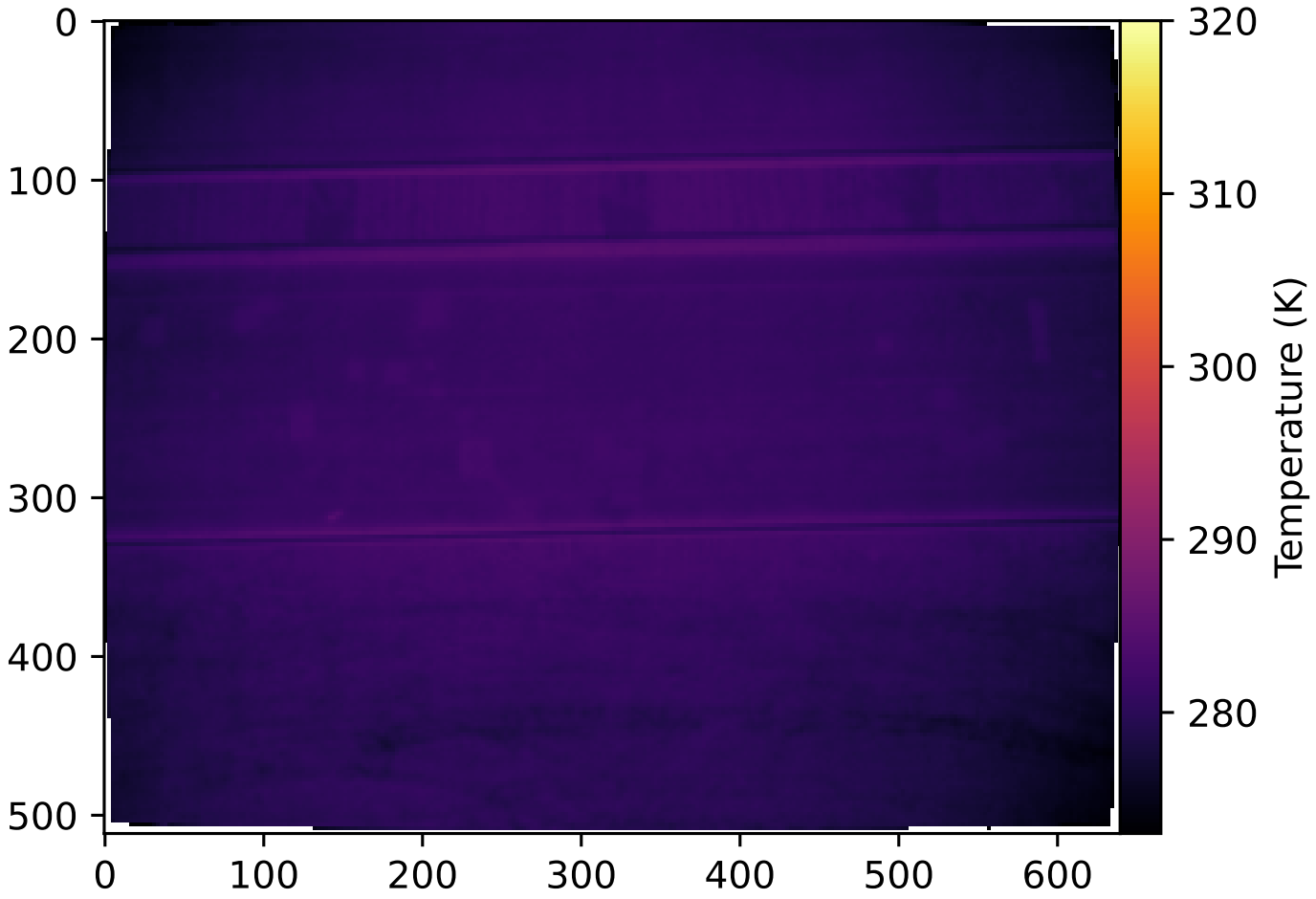


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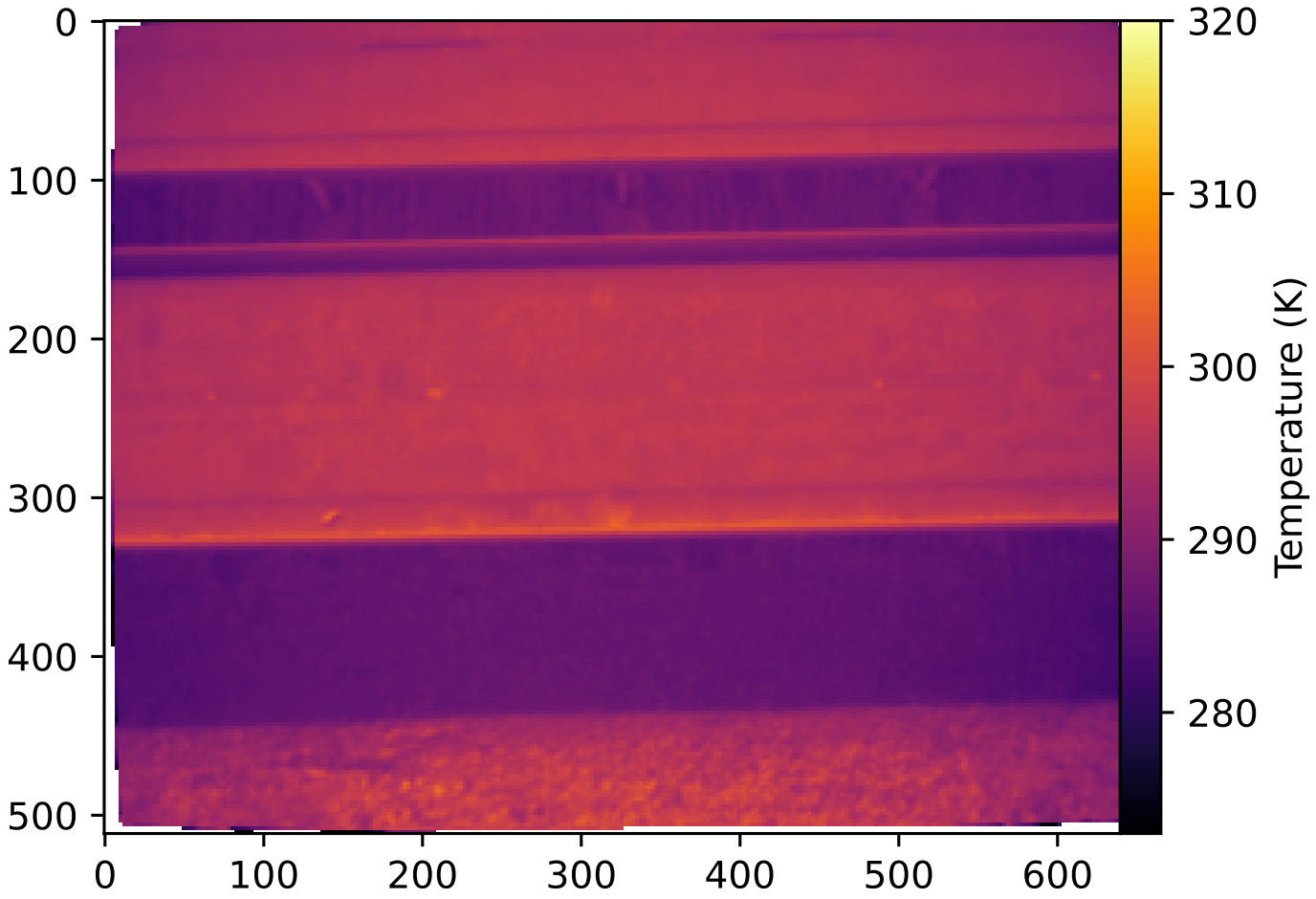


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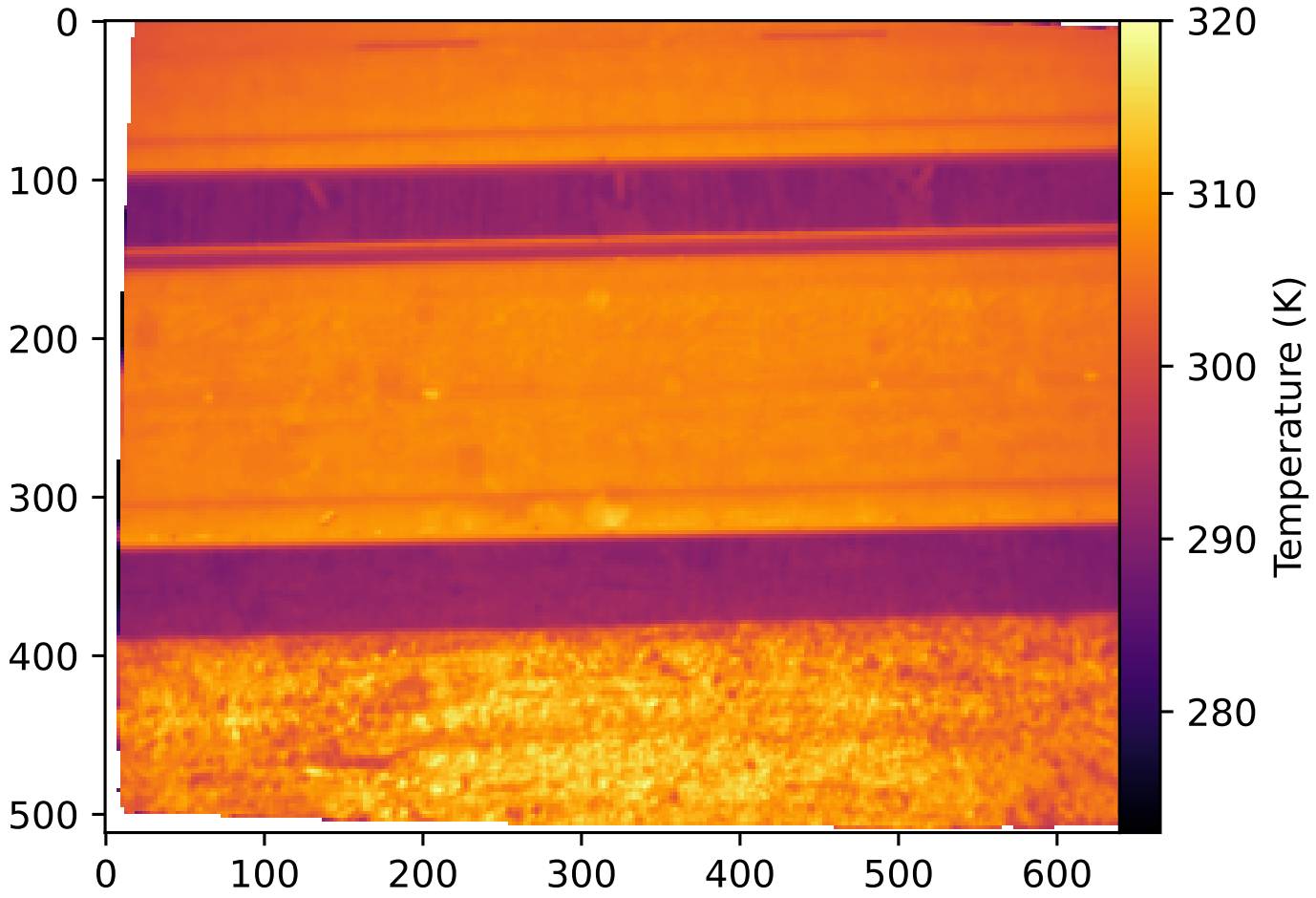


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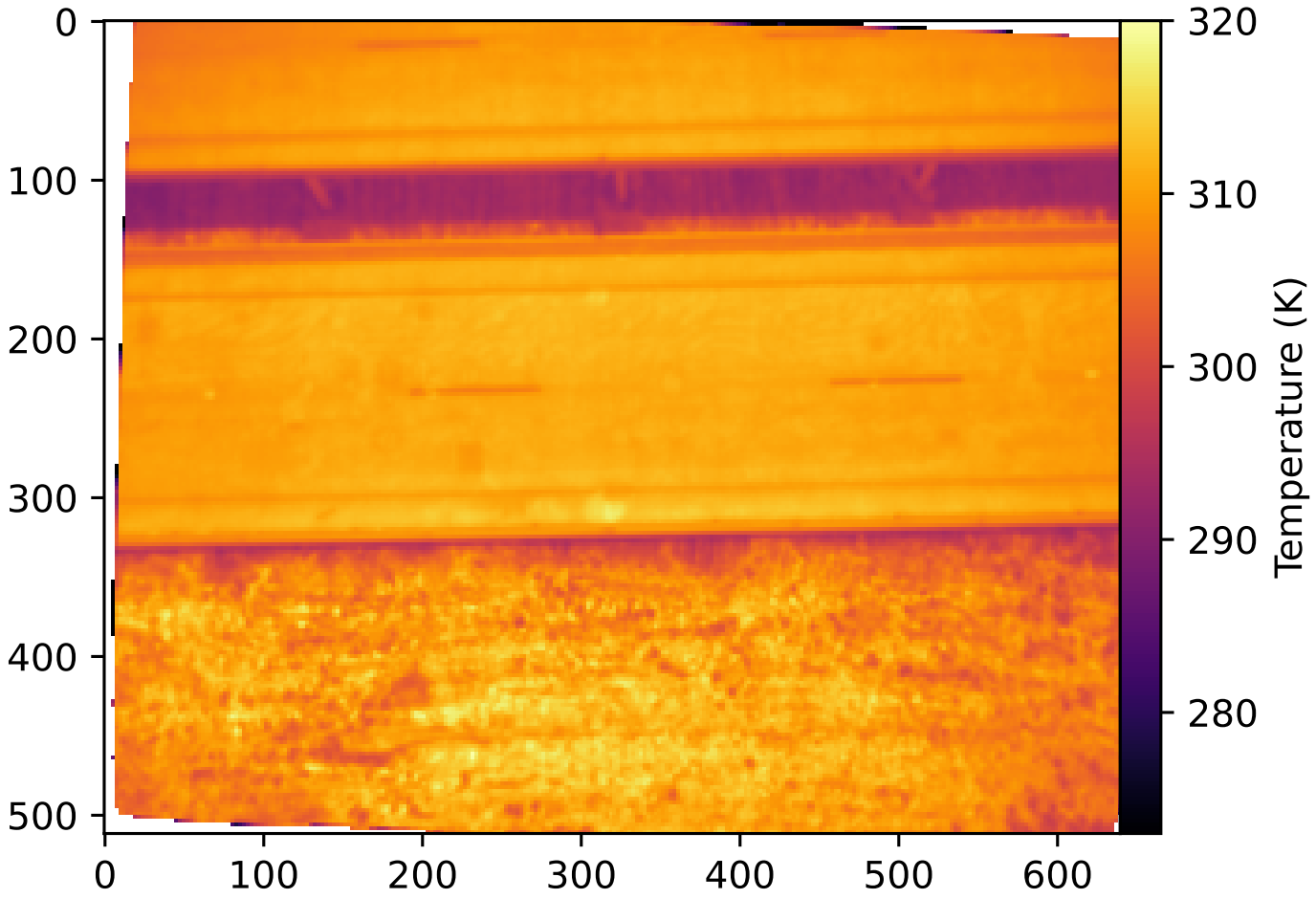


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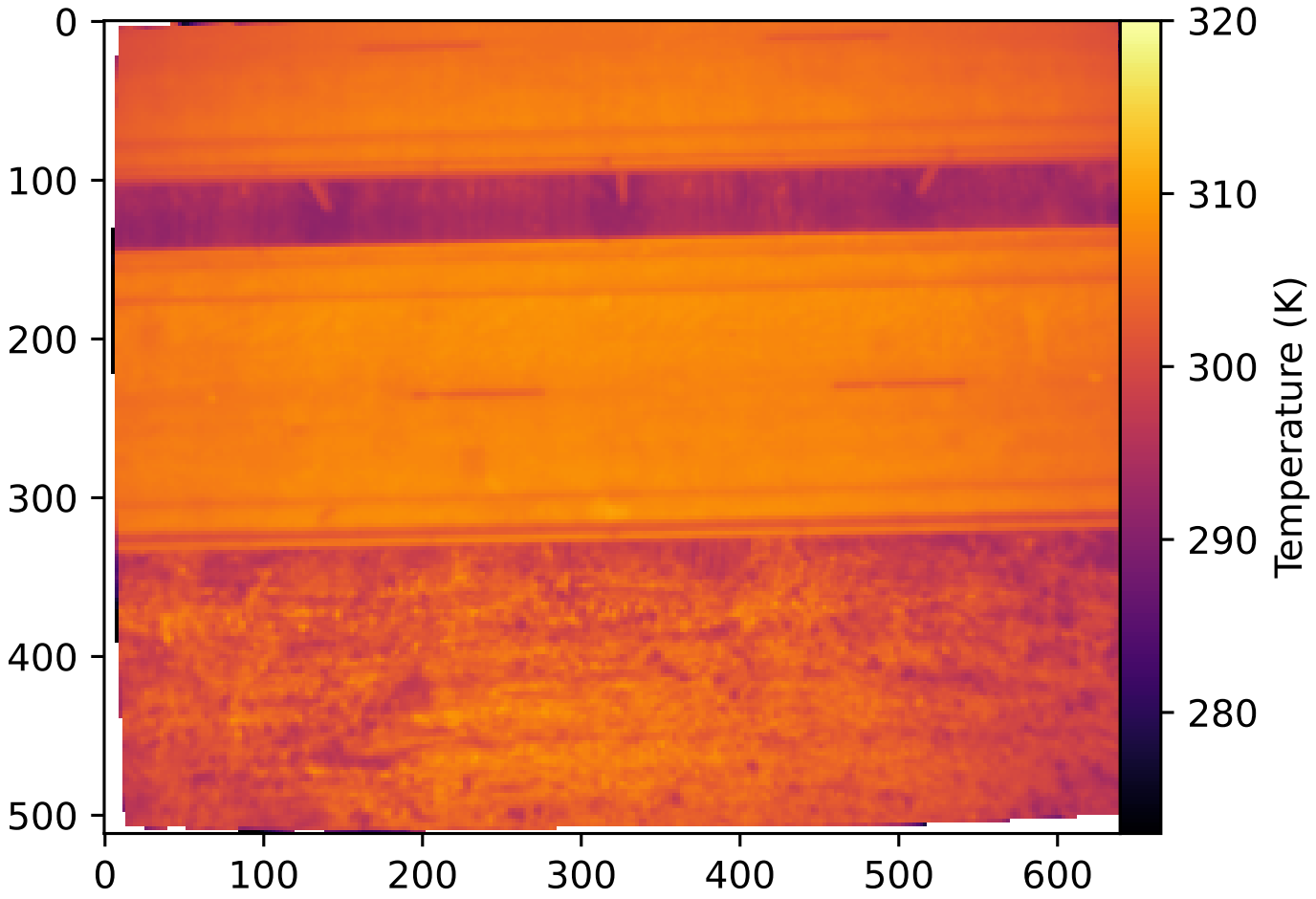


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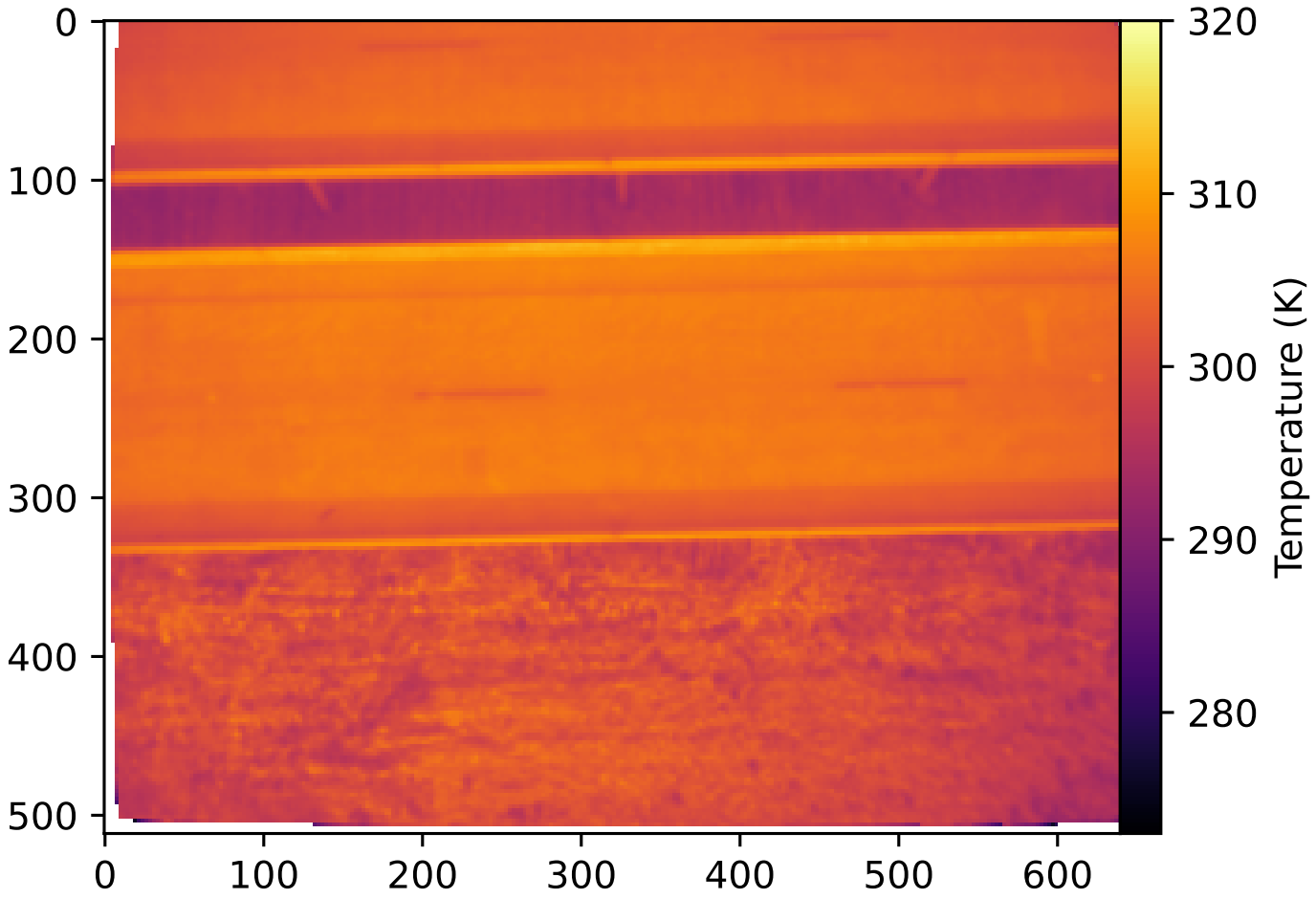


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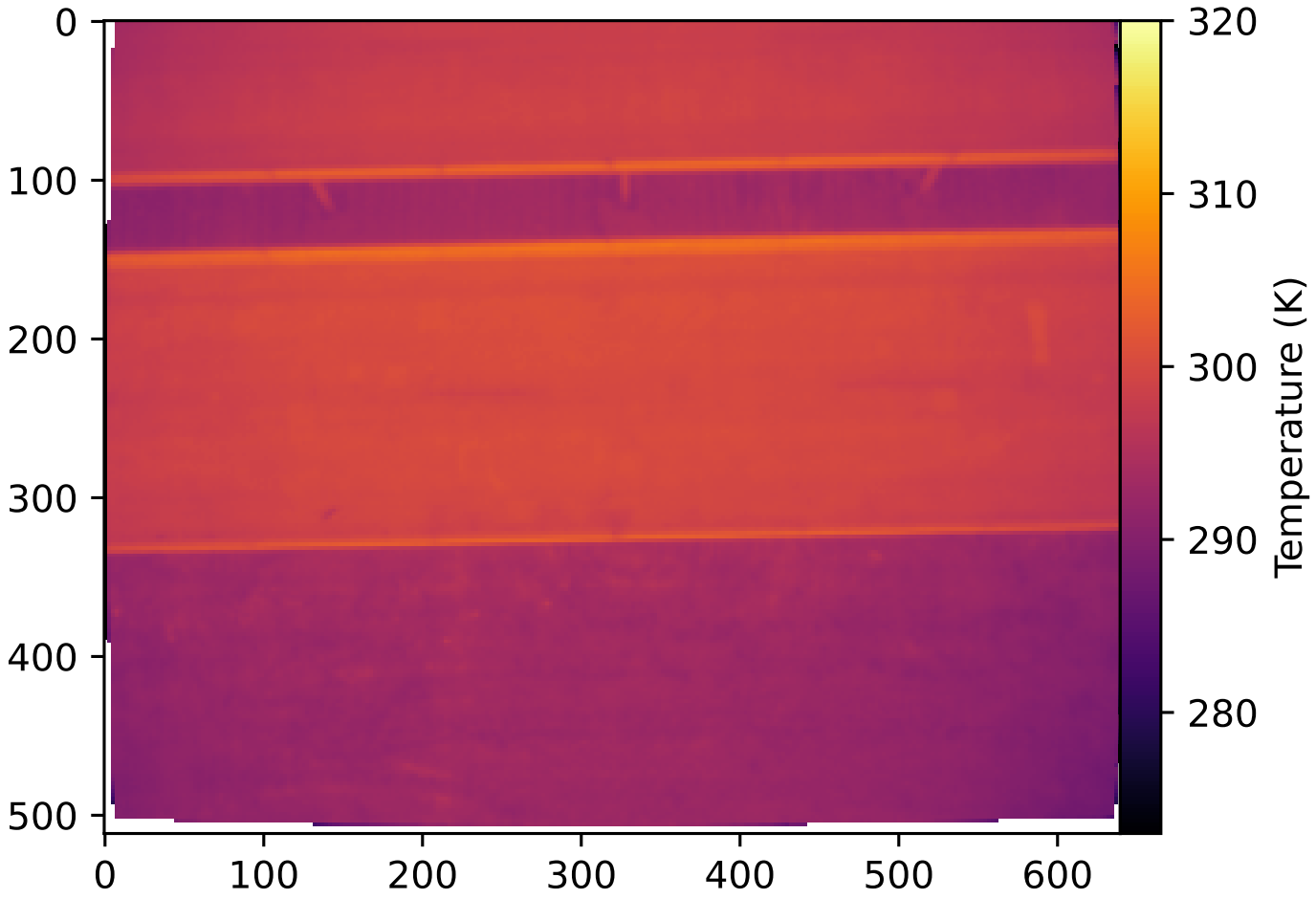



# Poor Image-to-Image Registration

## CAUSES:

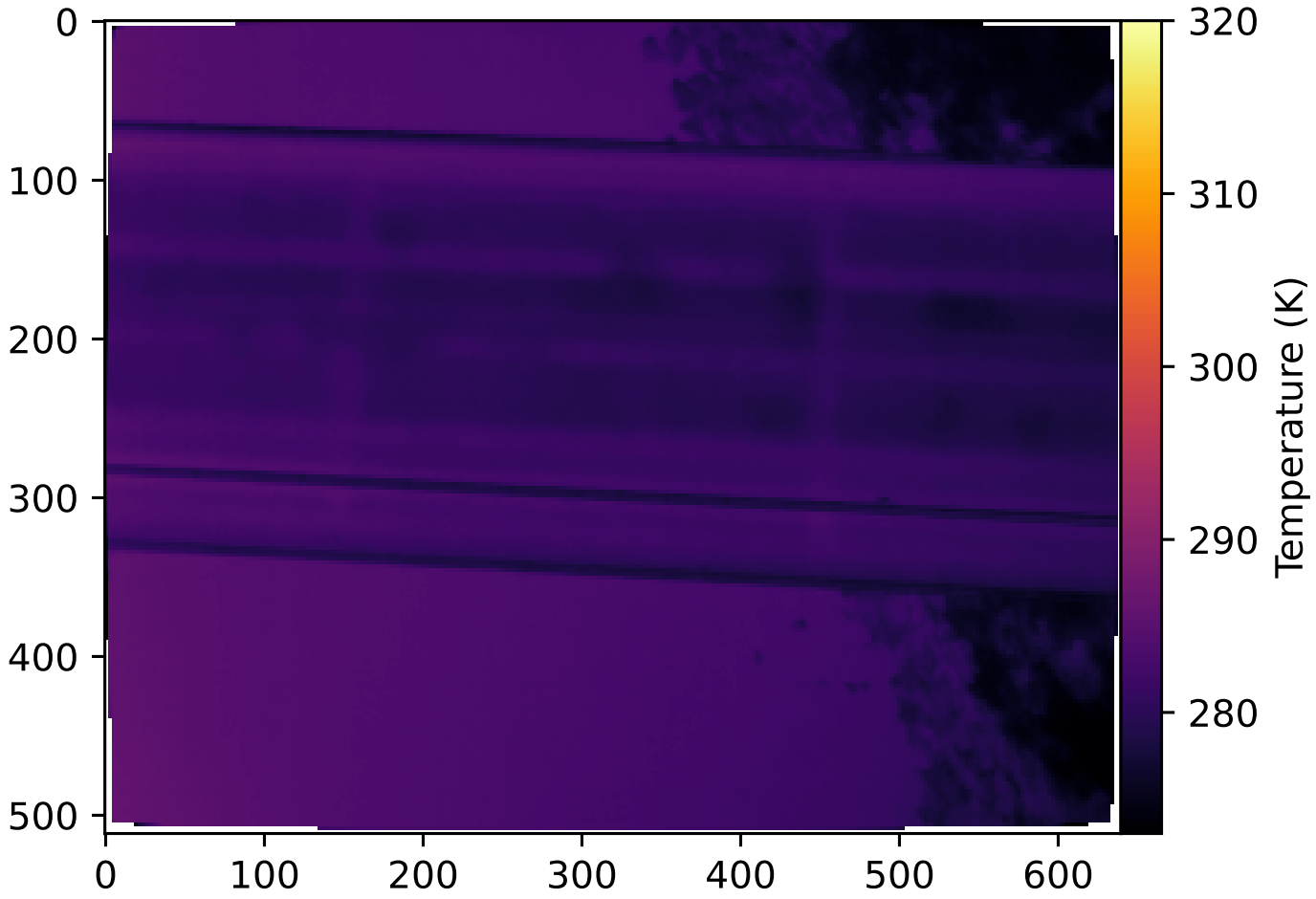
- Weather
    - Drone can steady itself against the wind, but not perfectly
- Precision of Telemetry
    - Inherent uncertainty of GPS produces a significant uncertainty in the resulting footprint

## EFFECTS:

- Anomaly signal gets `smeared out', and sometimes becomes undetectable
- Bridge edges become harder to detect
    - Impacts both anomaly detection and vignette correction

# Poor Image-to-Image Registration

CRAB NINE MILE BRIDGE

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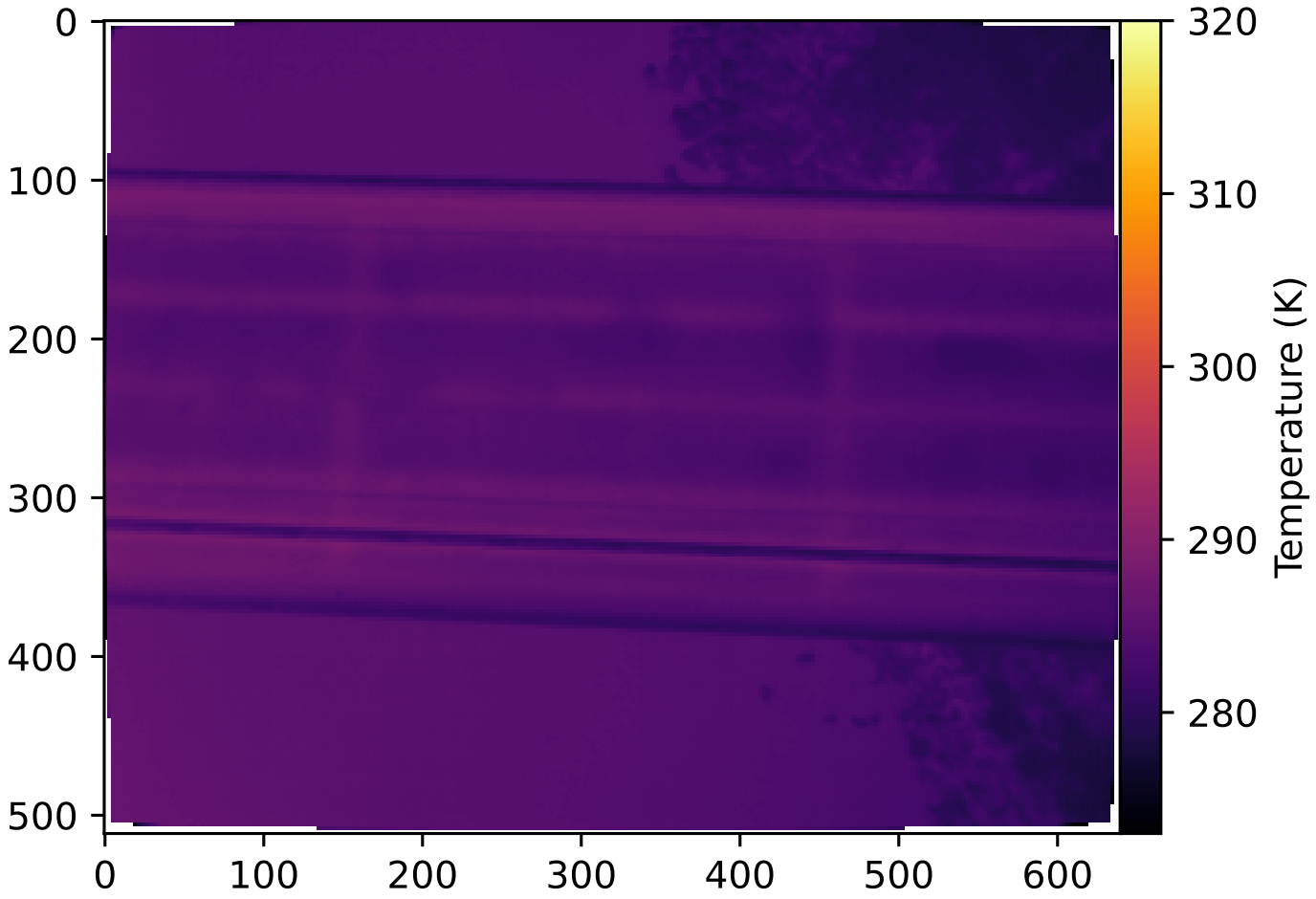


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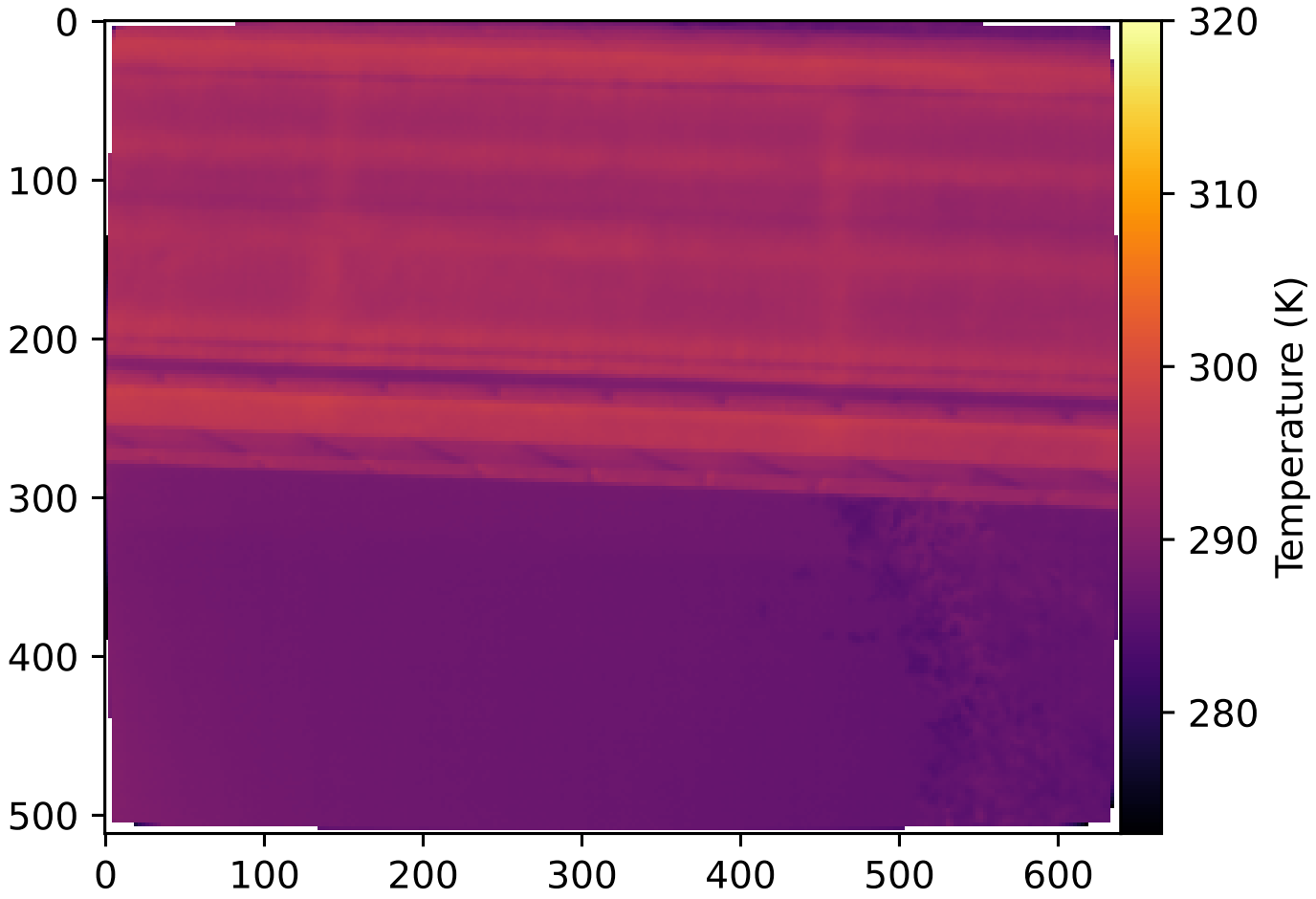


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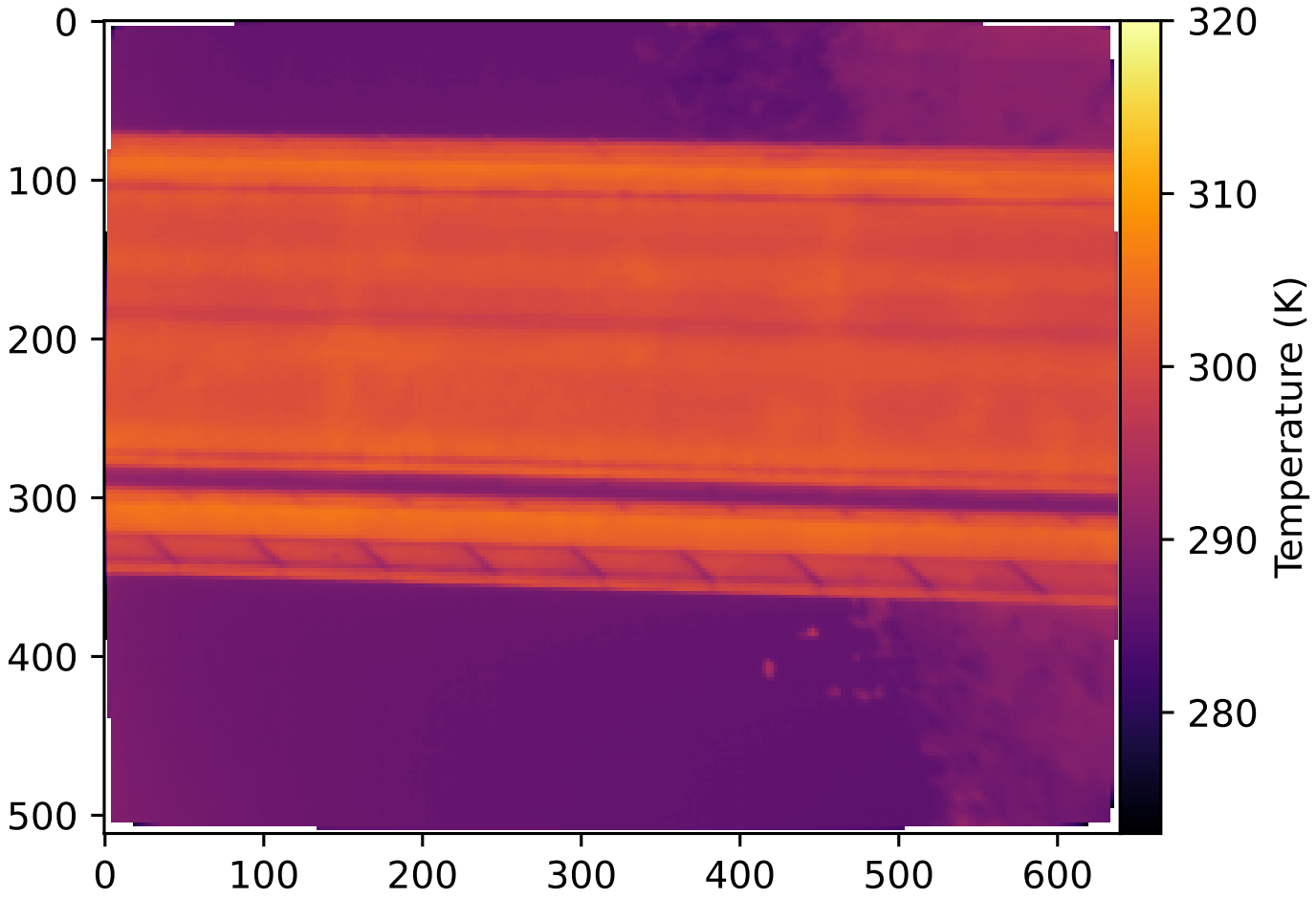


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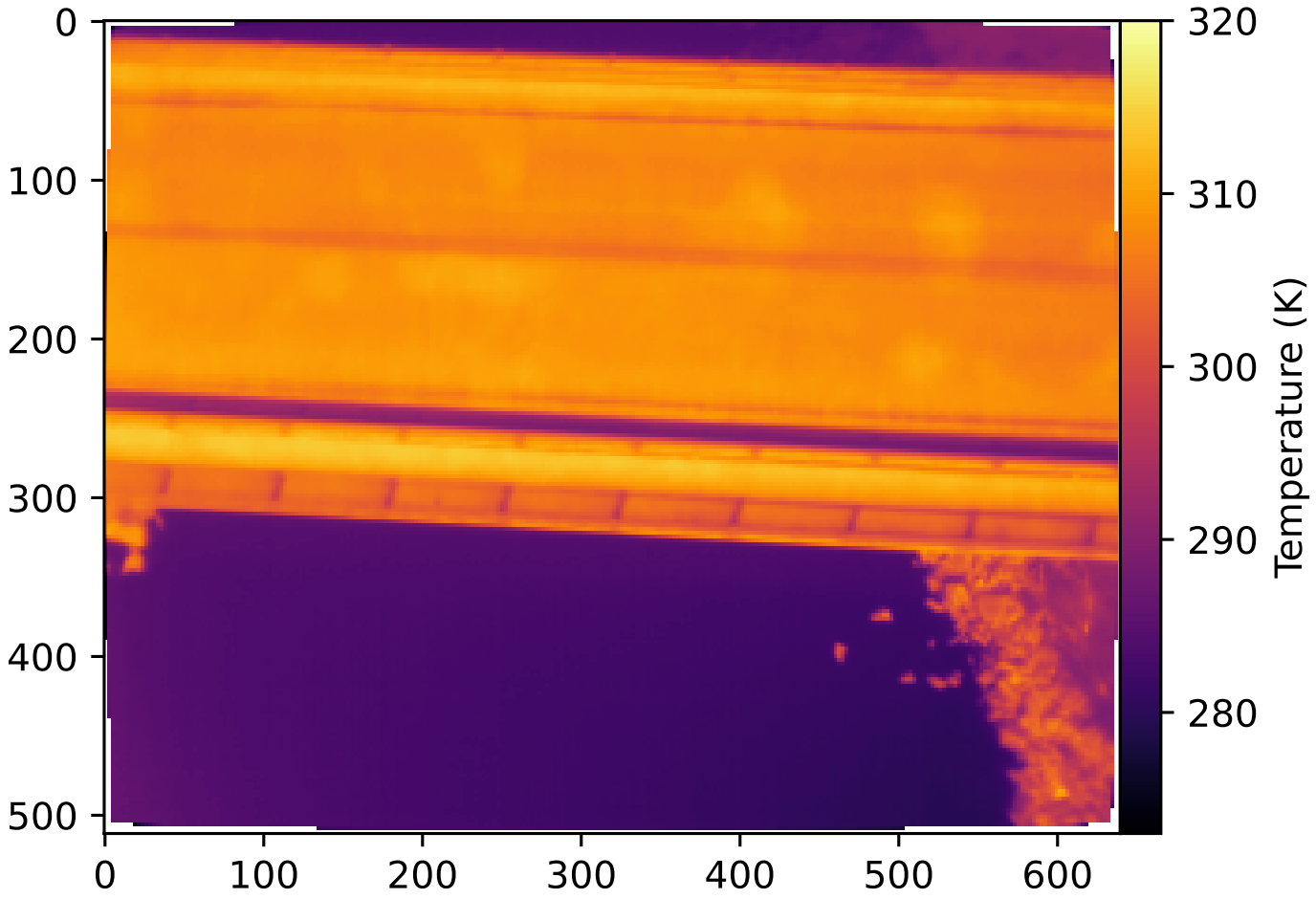


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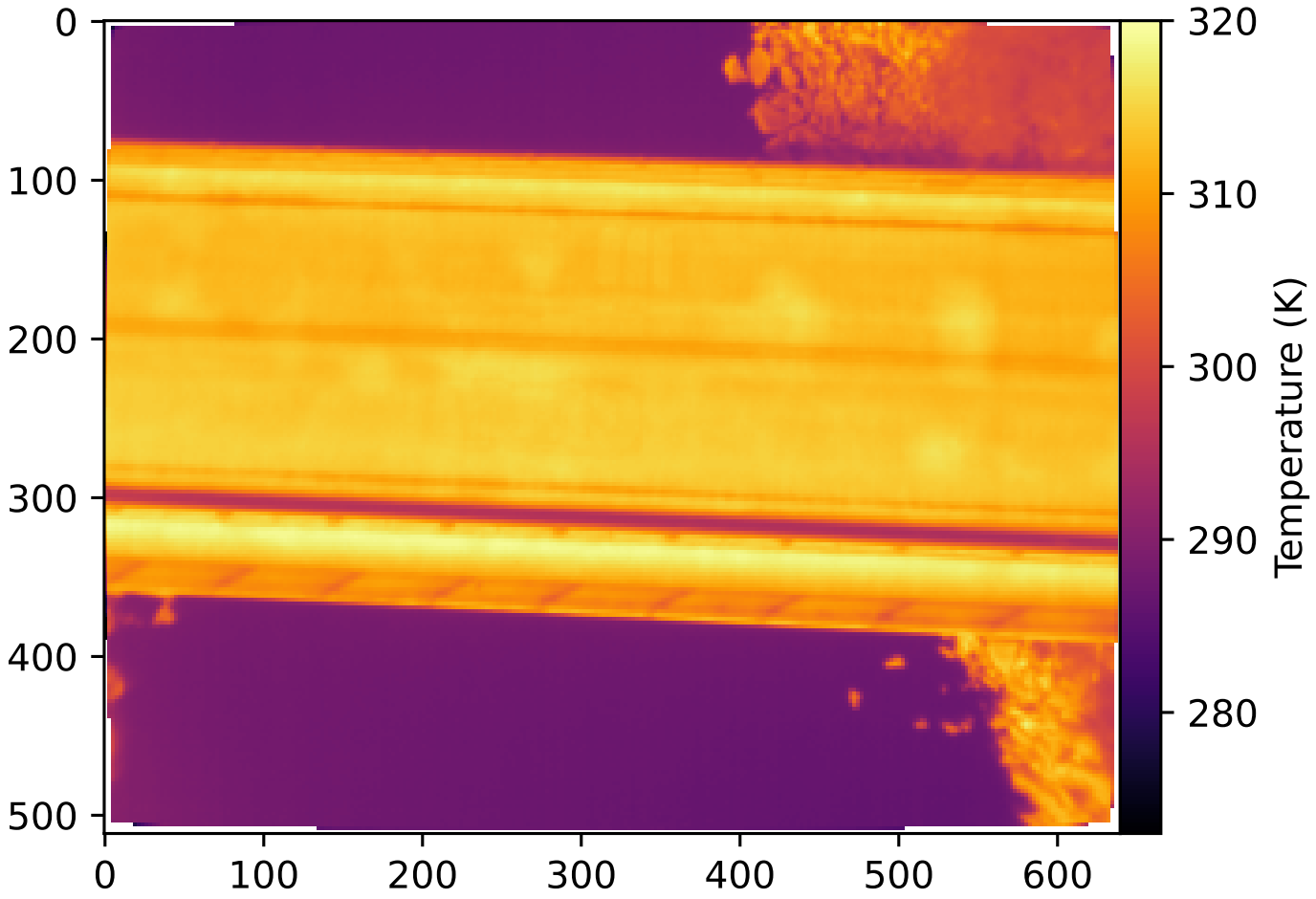


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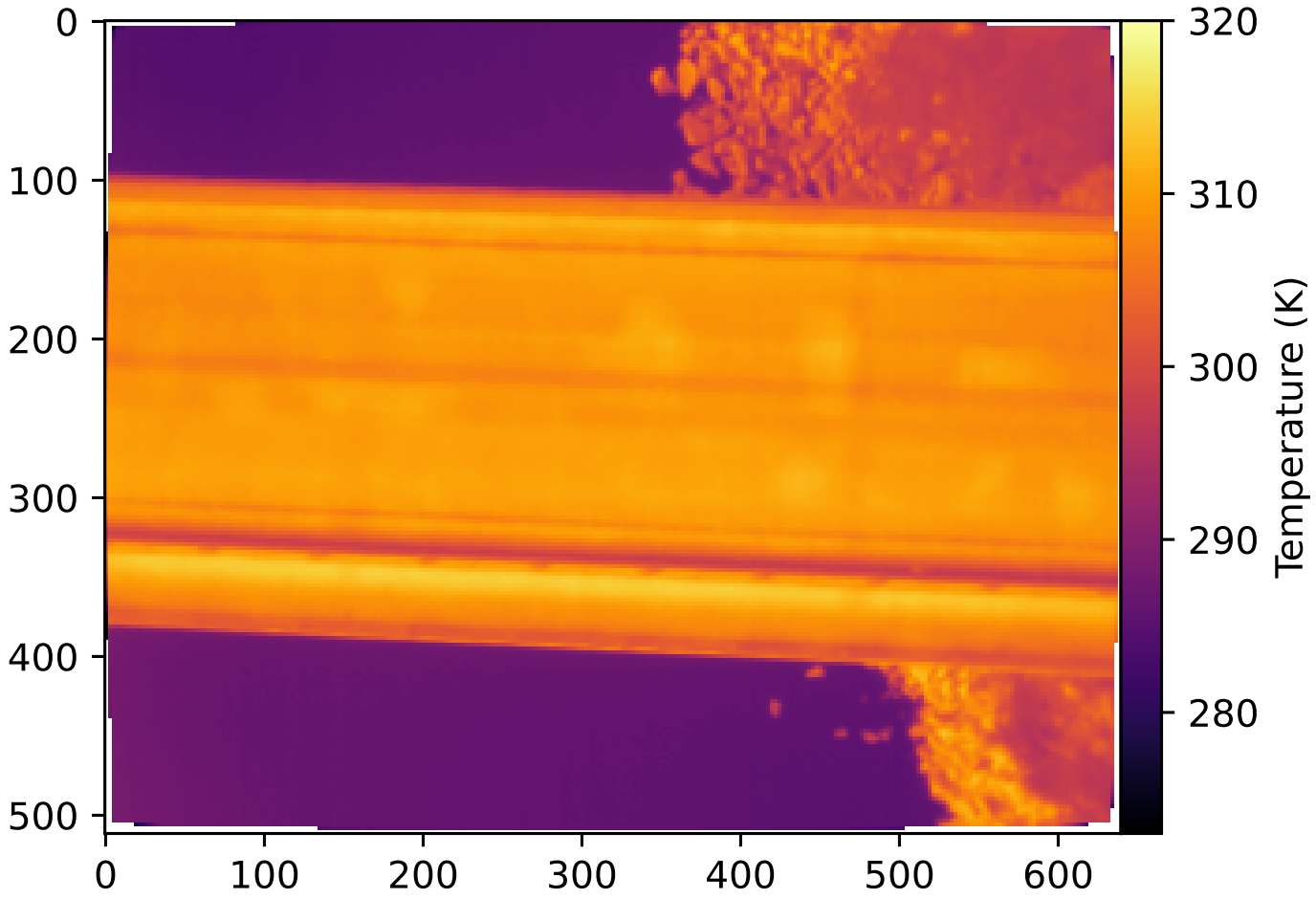


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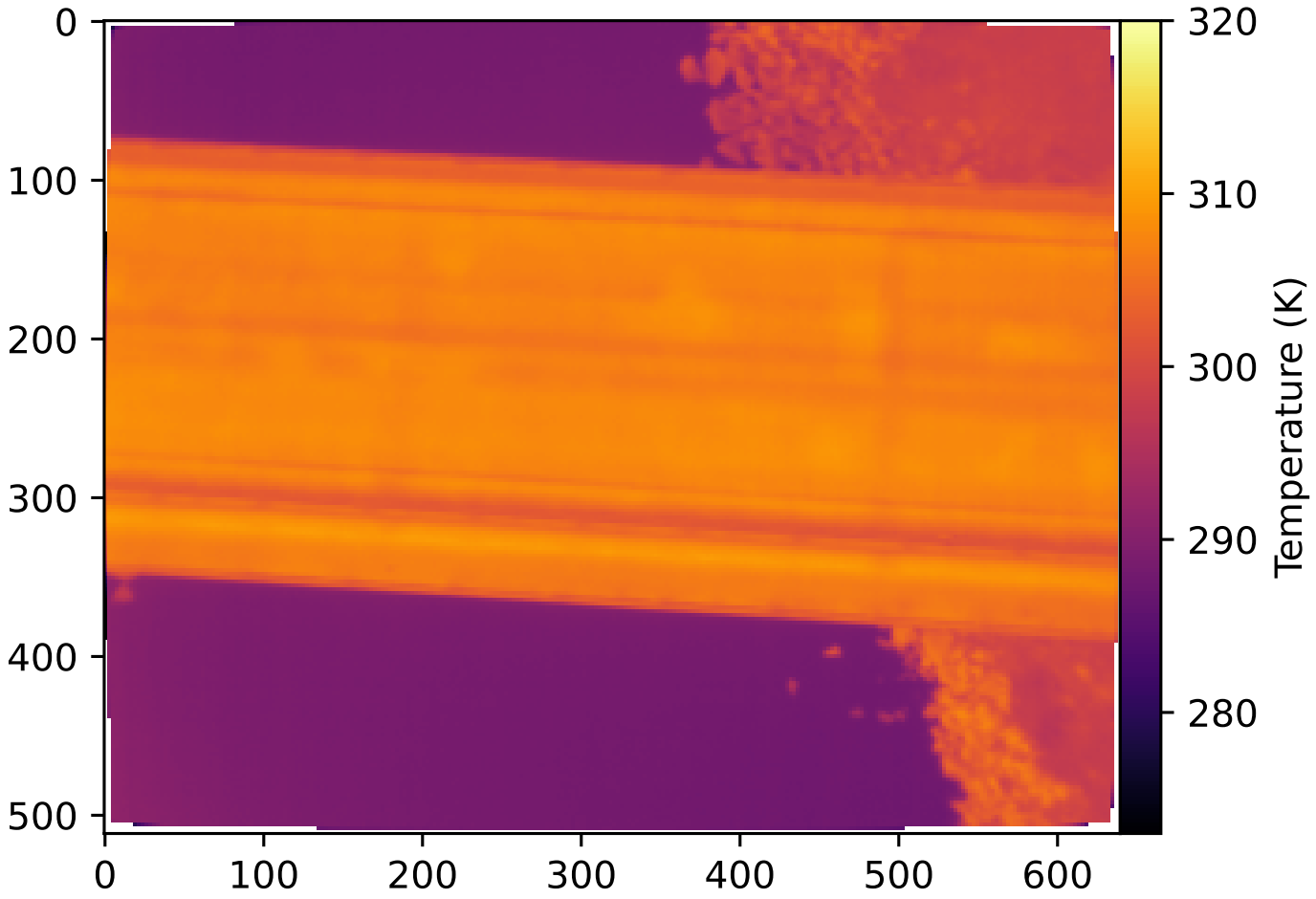


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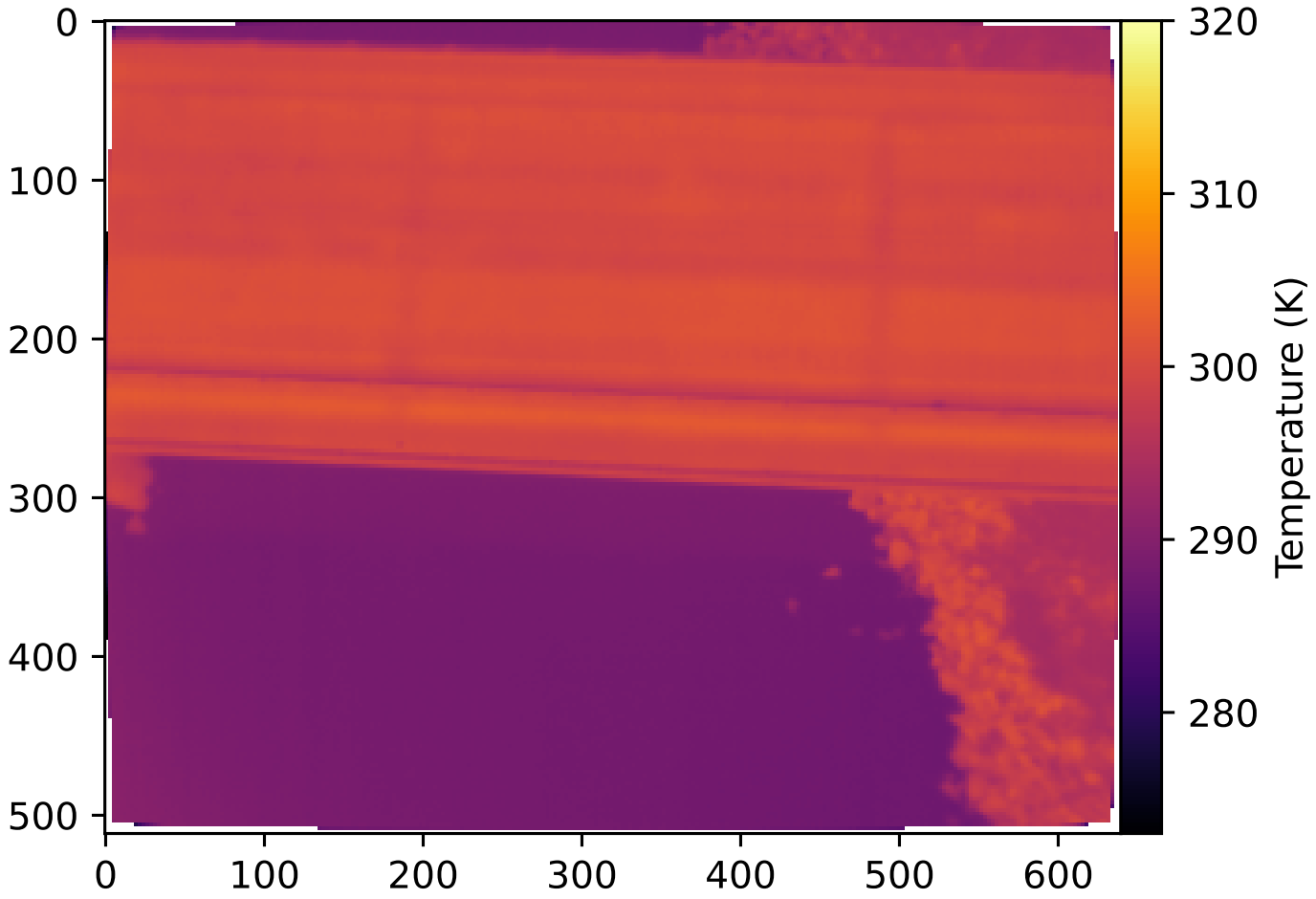
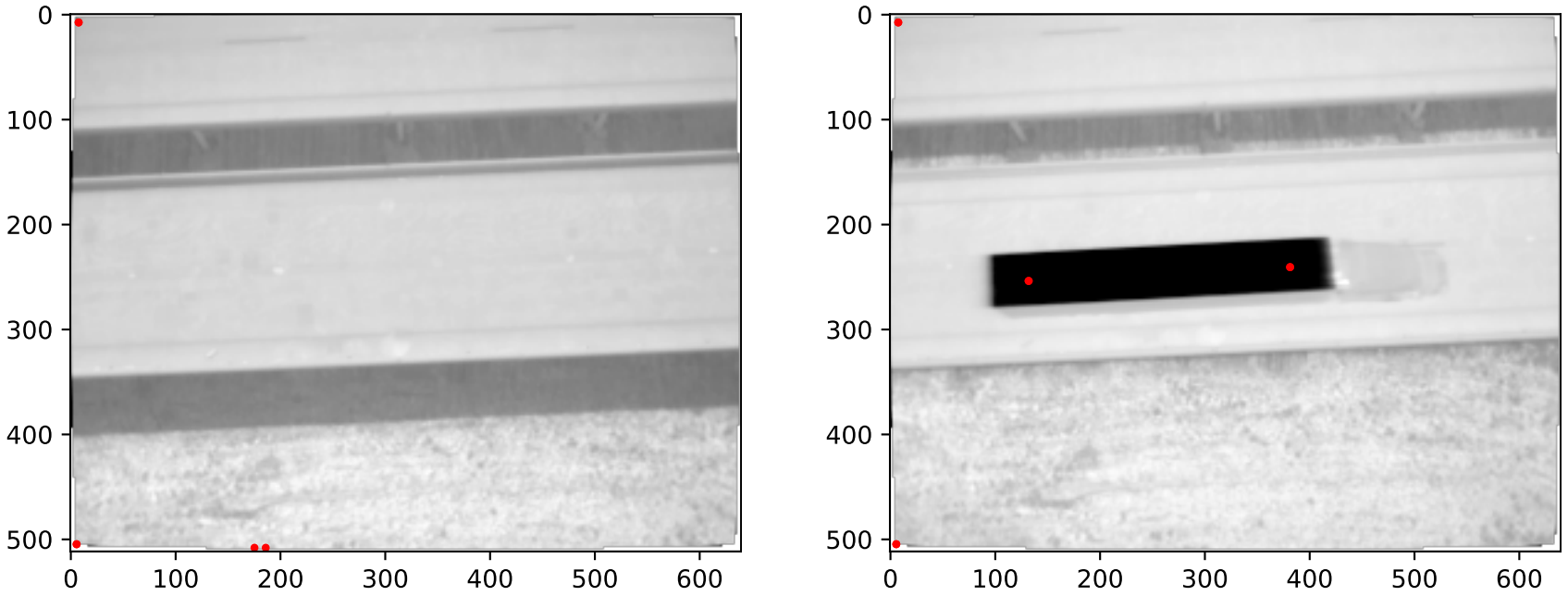



# Approaches to Registering IR Images

## AUTOMATED TIE-POINT FINDING







## PROS:

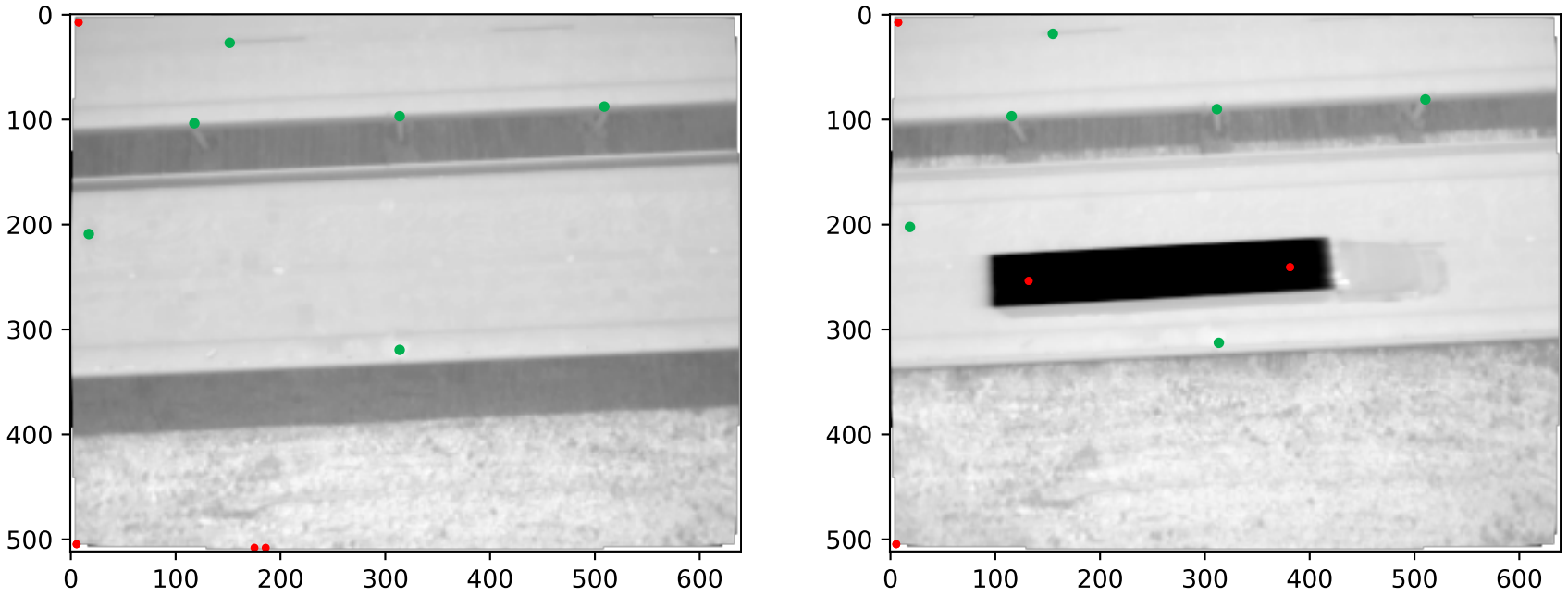
- Registration using only information already in the image, no metadata required

## CONS:

- IR images are low-contrast, even robust algorithms find few tie-points
- Tie-points that are found tend to be artefacts around the edge, or transient objects in the image

# Approaches to Registering IR Images

## MANUAL TIE-POINT FINDING







## PROS:

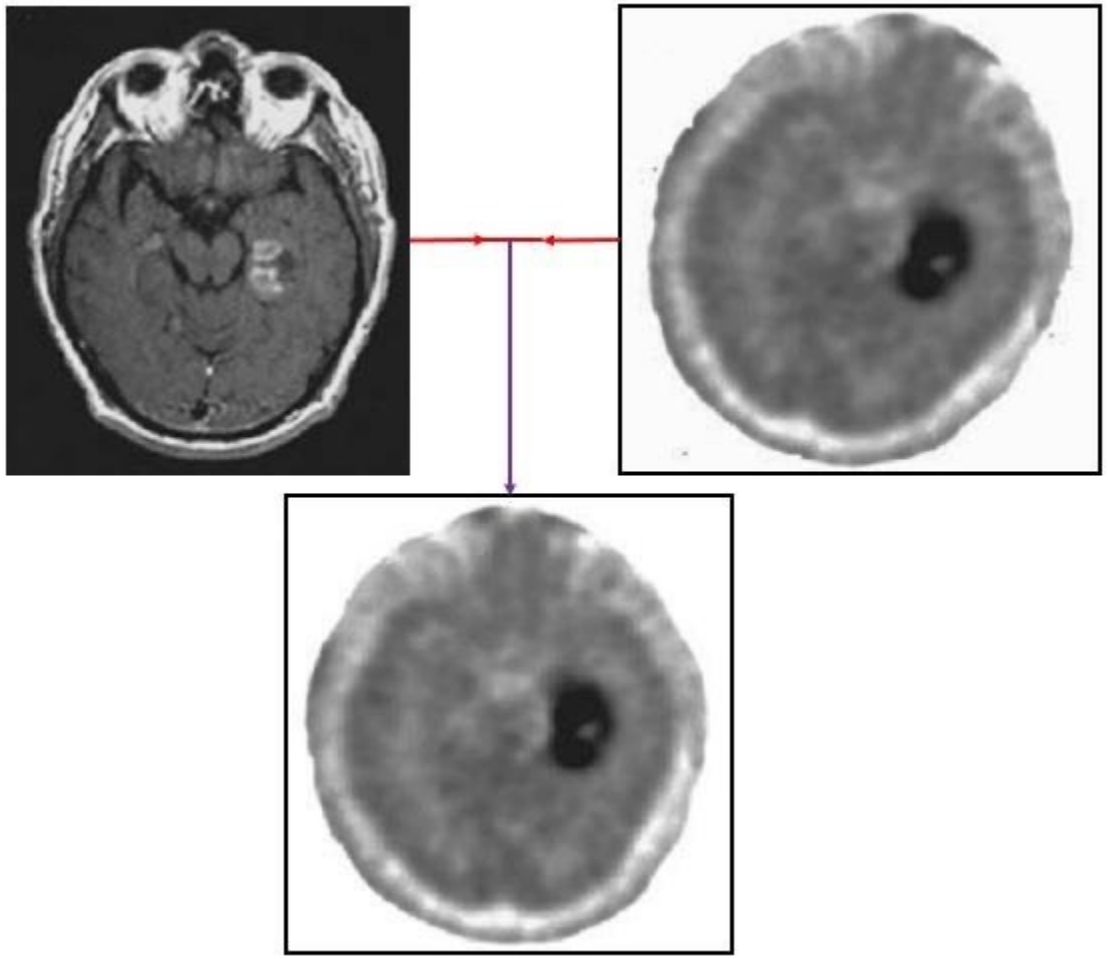
- Humans better at finding truly matching locations

## CONS:

- KTA project has 92 waypoints, each with 9 observations of 5 frames each, total of 4140 images. Not feasible for a human!
- Location probably less precise

# Approaches to Registering IR Images

## MUTUAL INFORMATION SCORE



*Nag (2017)*
*DOI: 10.17605/OSF.IO/RV65C*

# Approaches to Registering IR Images

## MUTUAL INFORMATION SCORE

### PROS:

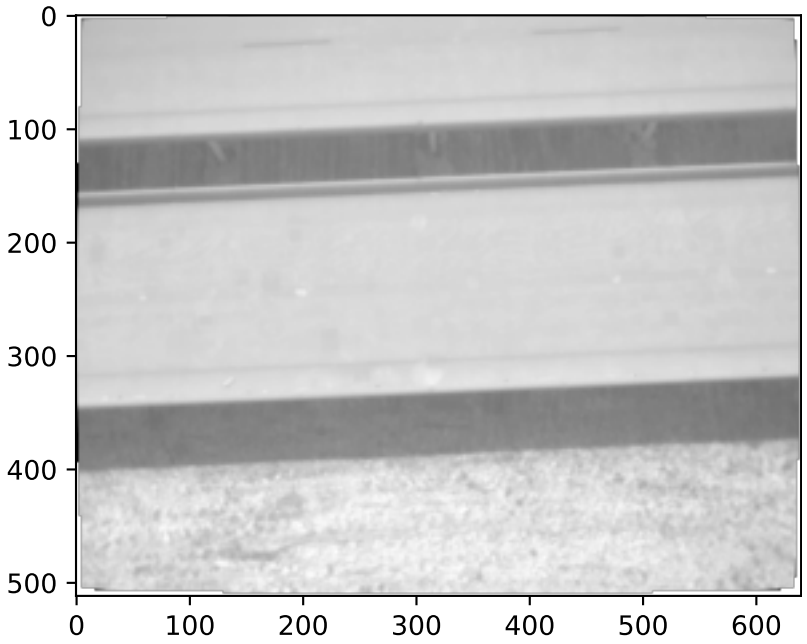
- Used in medicine to register scans
- Purely image-based

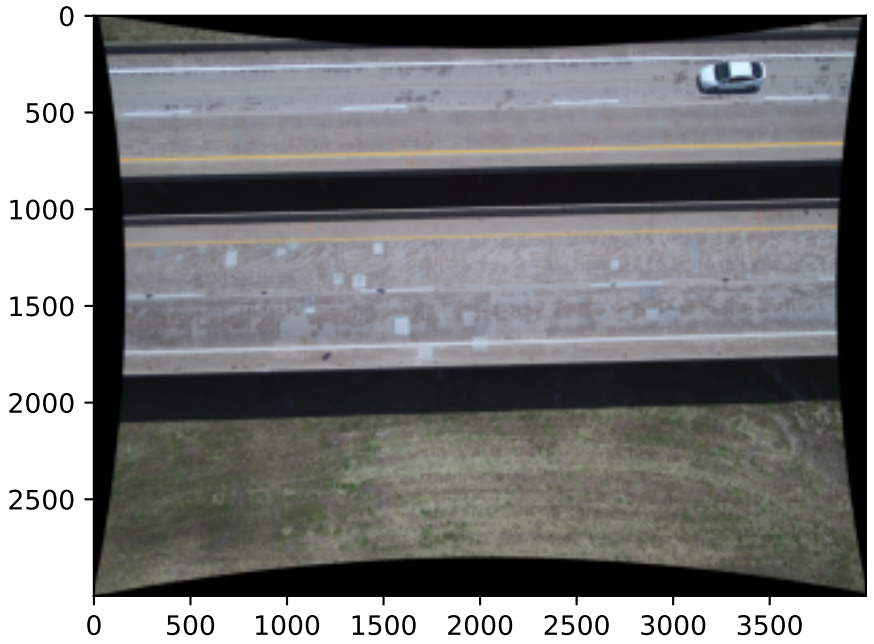
### CONS:

- MI `landscape' is not conducive to fitting algorithms, the best value has to be brute-forced
    - Very, very slow on large numbers of images
- Best value of MI is not always the best registration, sometimes catastrophically so

# Approaches to Registering IR Images

## MAPPING RGB REGISTRATION TO IR




### PROS:

- Many more tie points in the RGB
- Fairly reliable

### CONS:

- Doesn't work before sunrise/after sunset
    - Five to ten per cent of good IR images get thrown out
- Dramatically increases the run time and data storage requirements

# Approaches to Registering IR Images

## SUMMARY:

### AUTOMATED TIE-POINT FINDING IN IR

- Not reliable, not enough tie points

### MANUAL TIE-POINT FINDING IN IR

- Not scalable to the number of images

### MUTUAL INFORMATION

- Not reliable, and very slow

### MAPPING RGB REGISTRATION TO IR

- Best solution so far, but limits the amount of usable data

# Conclusions:

- REGISTERING THERMAL IMAGES TAKEN AT SIMILAR POSITIONS HOURS APART IS VITAL TO OUR WORK FINDING BRIDGE DELAMINATION

- NO SILVER BULLET FOR REGISTERING THERMAL IMAGES TAKEN AT SIGNIFICANTLY DIFFERENT TIMES

- USING THE RGB IMAGES IS A WORKABLE SOLUTION, BUT IT STILL HAS MAJOR DRAWBACKS

- NEEDS A NOVEL APPROACH!