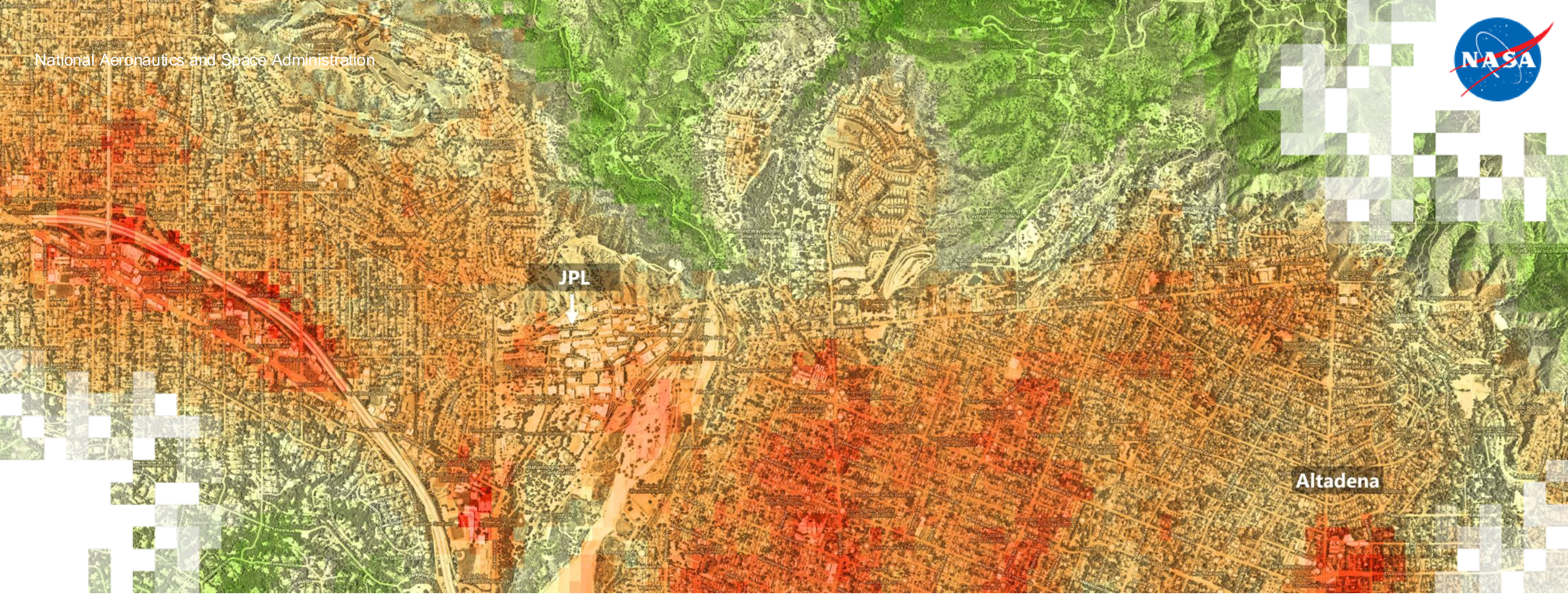
National Aeronautics and Space Administration



Introduction to Thermal Remote Sensing and Applications in Urban Heat Island Mapping

Part 2: Applications in Urban Heat Island Mapping

Savannah Cooley, Ph.D. (NASA Ames Research Center, Bay Area Environmental Research Institute),
Glynn Hulley, Ph.D., (NASA Jet Propulsion Laboratory, California Institute of Technology)

June 2, 2026

Part 1 – Trainers

Savannah Cooley
Research Scientist
NASA Ames Research Center / BAERI

Glynn Hulley
Research Scientist
NASA Jet Propulsion Laboratory

Part 2 Objectives

By the end of Part 2, participants will be able to:

- **Filter and visualize ECOSTRESS Land Surface Temperature (LST) data** using provided R-based data processing workflows.
- **Downscale native 70m ECOSTRESS LST data to a fine 10m spatial resolution** using a Random Forest machine learning model implemented on an interactive Google Earth Engine (GEE) interface to analyze neighborhood-level urban heat patterns.

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Review of Prior Knowledge

Temperature Type	Symbol	Definition	What it reflects
Kinetic Temperature	T_kin	True physical temperature of the surface (emissivity ε correction applied)	Actual molecular motion/ internal energy
Brightness Temperature	T_B	Temperature of a blackbody needed to emit the observed radiance at a given wavelength	Raw satellite measurement (assumes ε= 1)
Radiometric Temperature	T_rad	The "apparent" temperature across all wavelengths (via Stefan-Boltzmann)	Satellite-based LST products

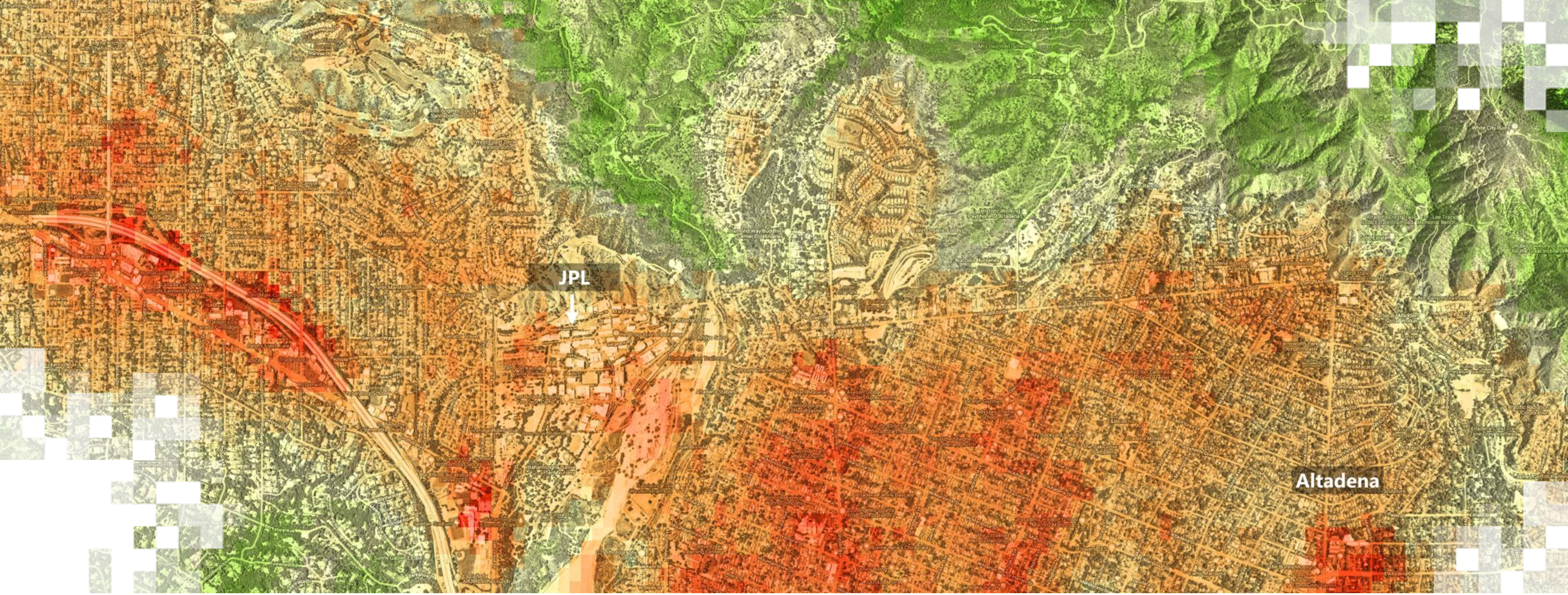
What is the **radiometric temperature (T_rad)** of a sandy desert surface with ε = 0.90 and T_kin = 320 K?

- A) 315.5 K
- B) 309.8 K
- C) 300.5 K
- D) 311.7 K

$$T_{rad} = \varepsilon^{\frac{1}{4}} \, T_{kin}$$

$$T_{rad} = (0.90)^{0.25} \times 320$$

$$\approx 0.974 \times 320 \approx \mathbf{311.7\ K}$$



Part 2: Introduction to Thermal Remote Sensing

Section 1: ECOSTRESS Land Surface Temperature

ECOSTRESS

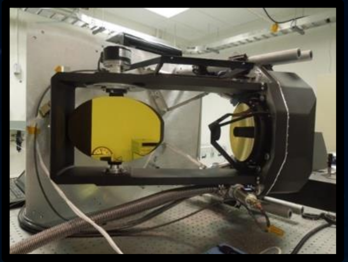
ECOSTRESS (Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station)

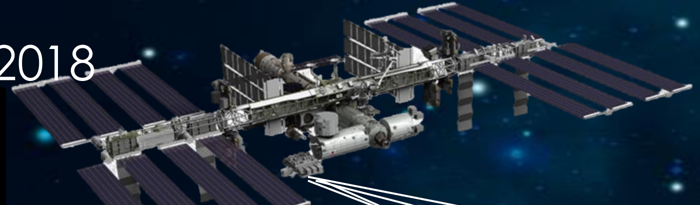
Launch: June 2018
End of mission: 2029
Spatial: 70m
Temporal: ~3 days, diurnal
Spectral: 5 TIR bands

ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

ISS JEM-EF launch, June 2018

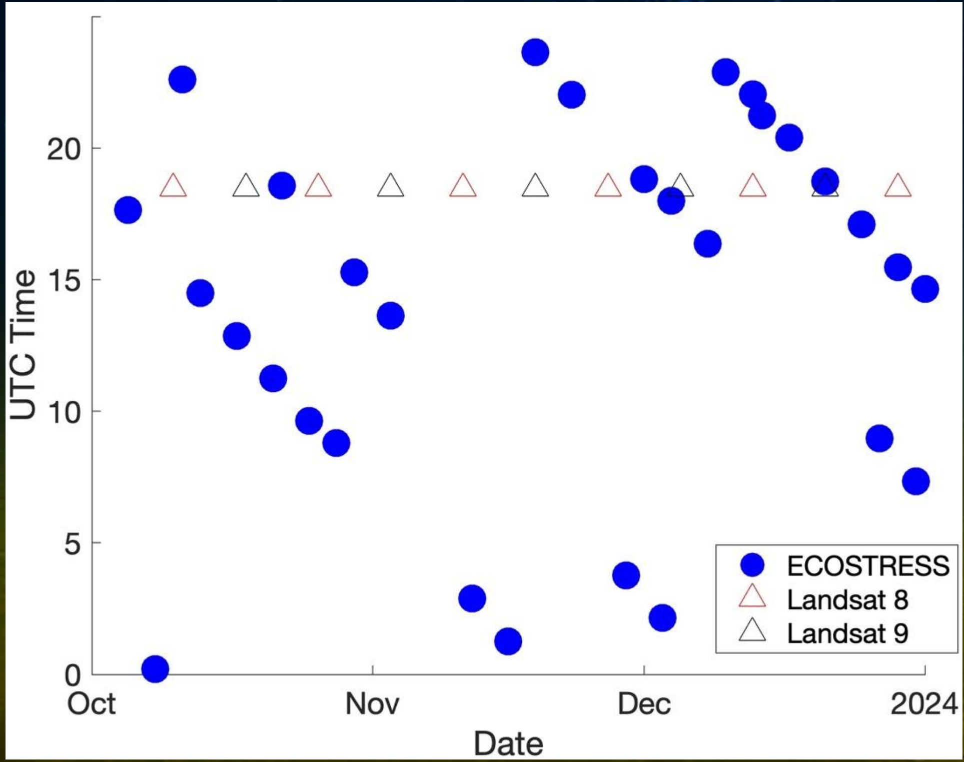




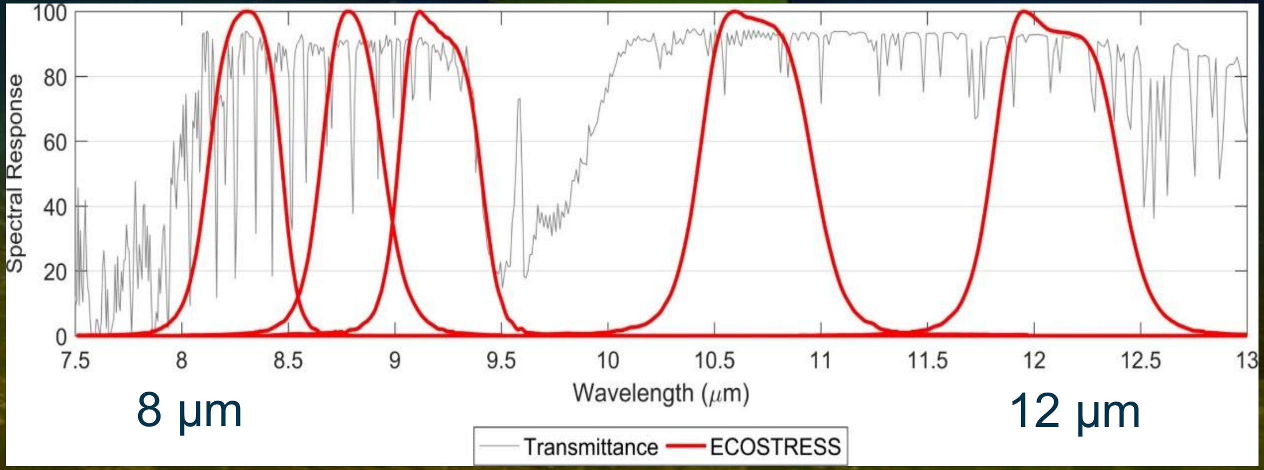
400 km

70 m resolution pixels

Observations over the diurnal cycle every 3-5 days



Five thermal infrared bands

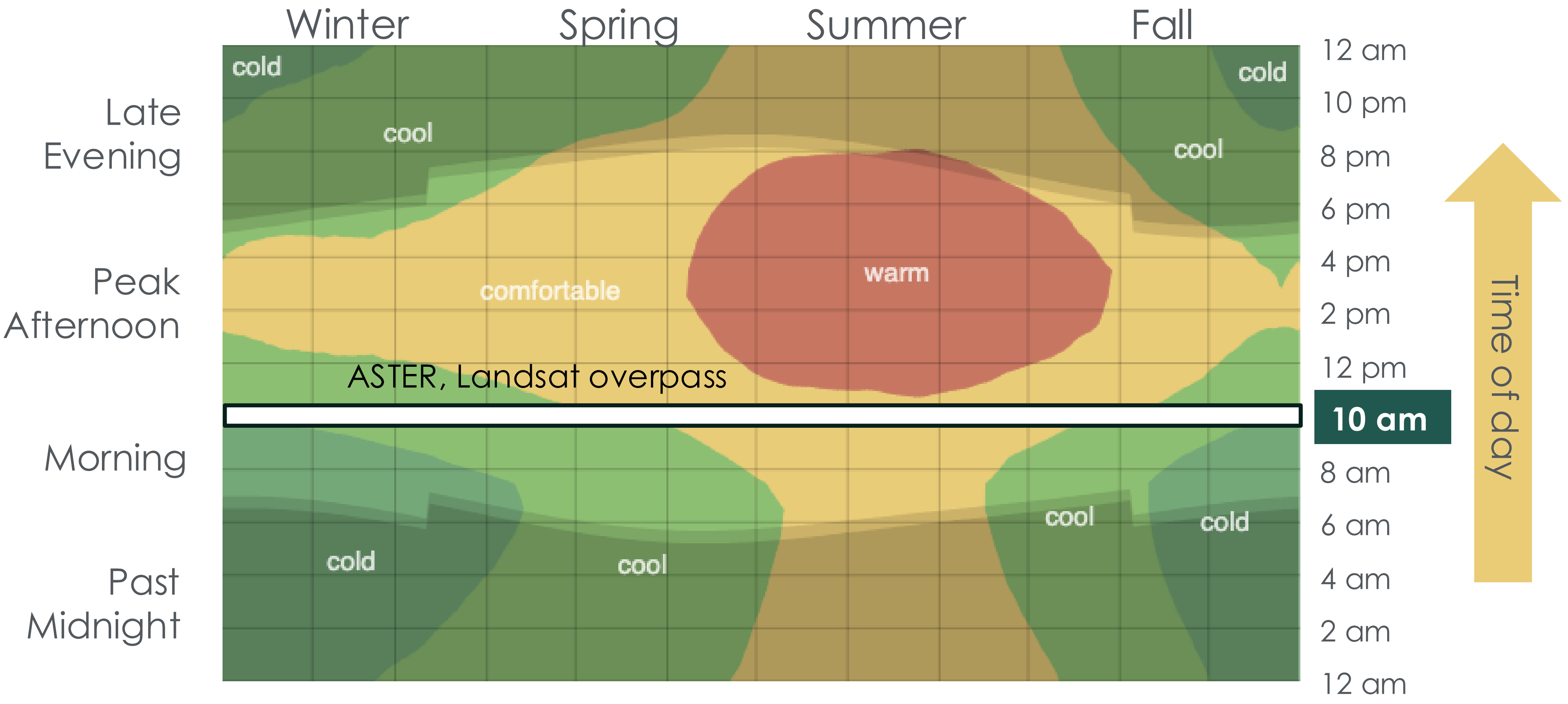


ECOSTRESS latest news

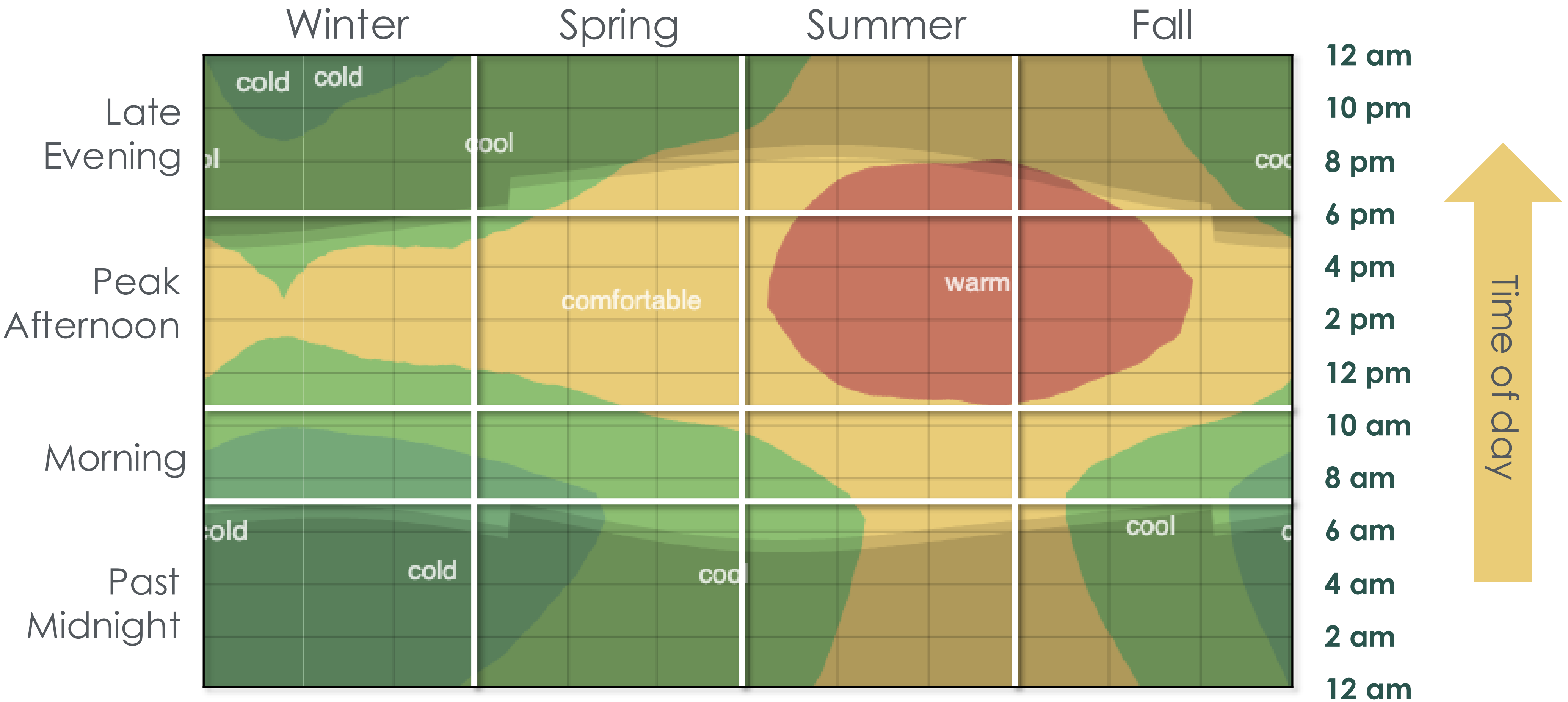
- Public release of Collection 3 science data products: L2 LST is imminent.
- Entire ECOSTRESS LST archive ingested by Google Earth Engine (GEE) over continental USA
- 1,000+ peer-reviewed ECOSTRESS publications!
- As of early 2026, ECOSTRESS has acquired over 606,000 400km x 400km scenes since launch, enough to cover the Earth's land surface more than 647 times.

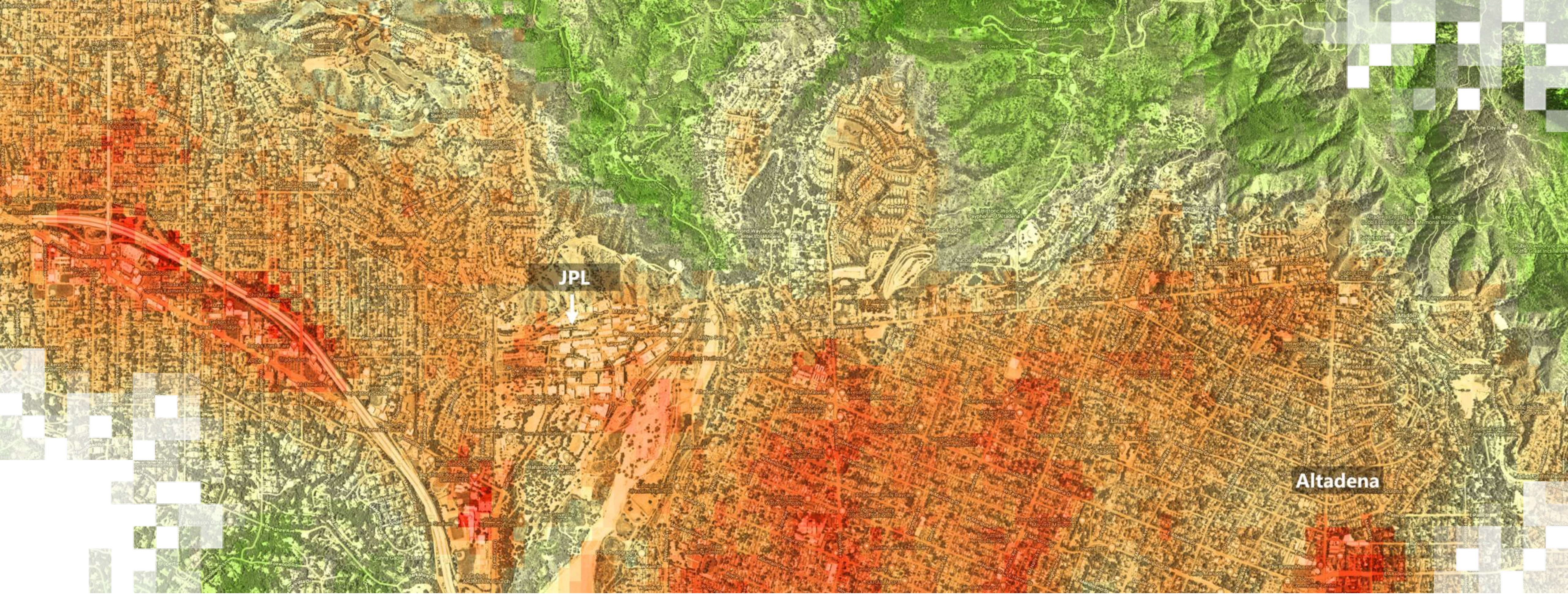
New ECOSTRESS applications page here

Peak diurnal and seasonal variations in temperature not captured by morning overpass TIR imagers



ECOSTRESS captures the diurnal and seasonal LST cycle

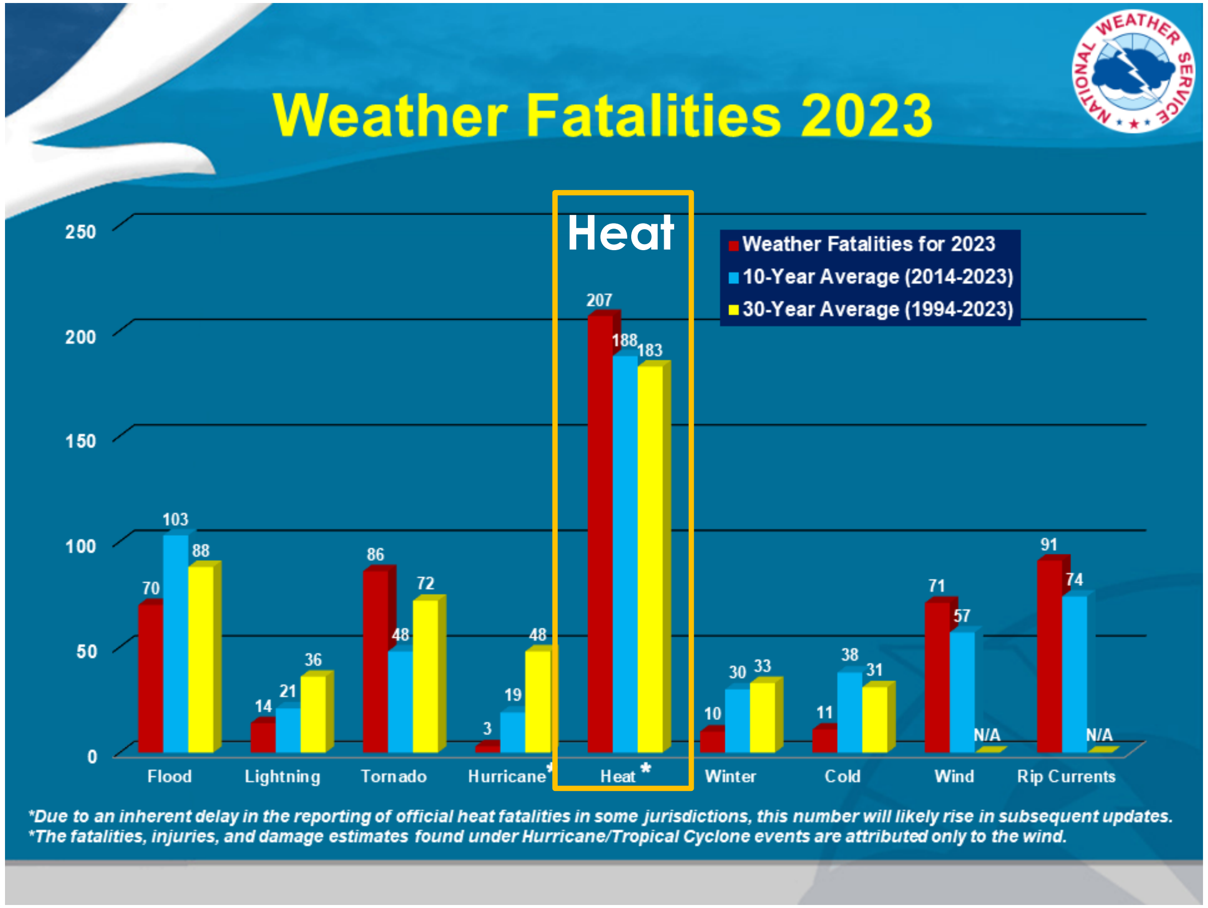




Part 2: Introduction to Thermal Remote Sensing

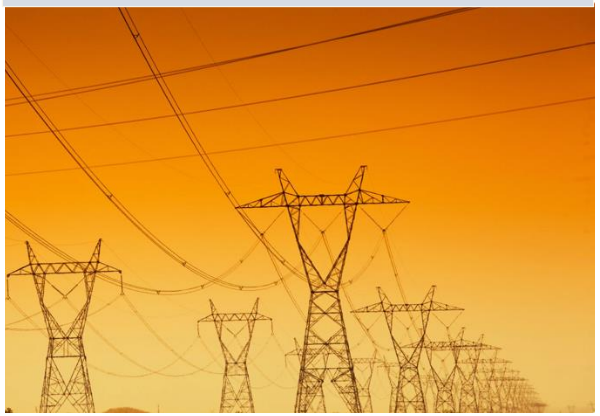
Section 2: Urban Heat Islands

Heatwaves are the leading cause of death among natural disasters



Risk of heat stroke

Increased electricity demand

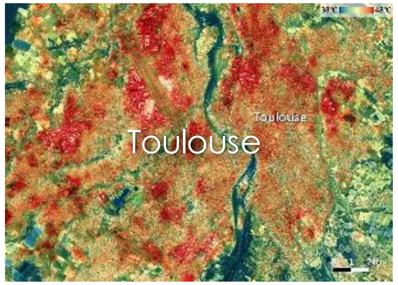


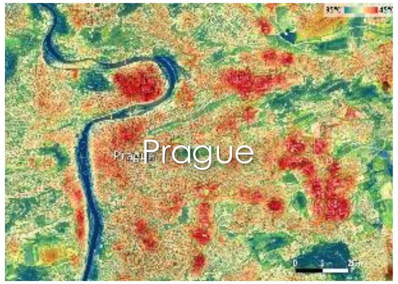
Higher wildfire risk

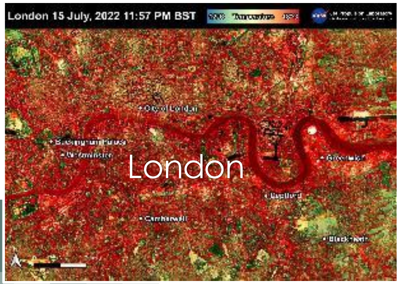
Reduced air quality and smog

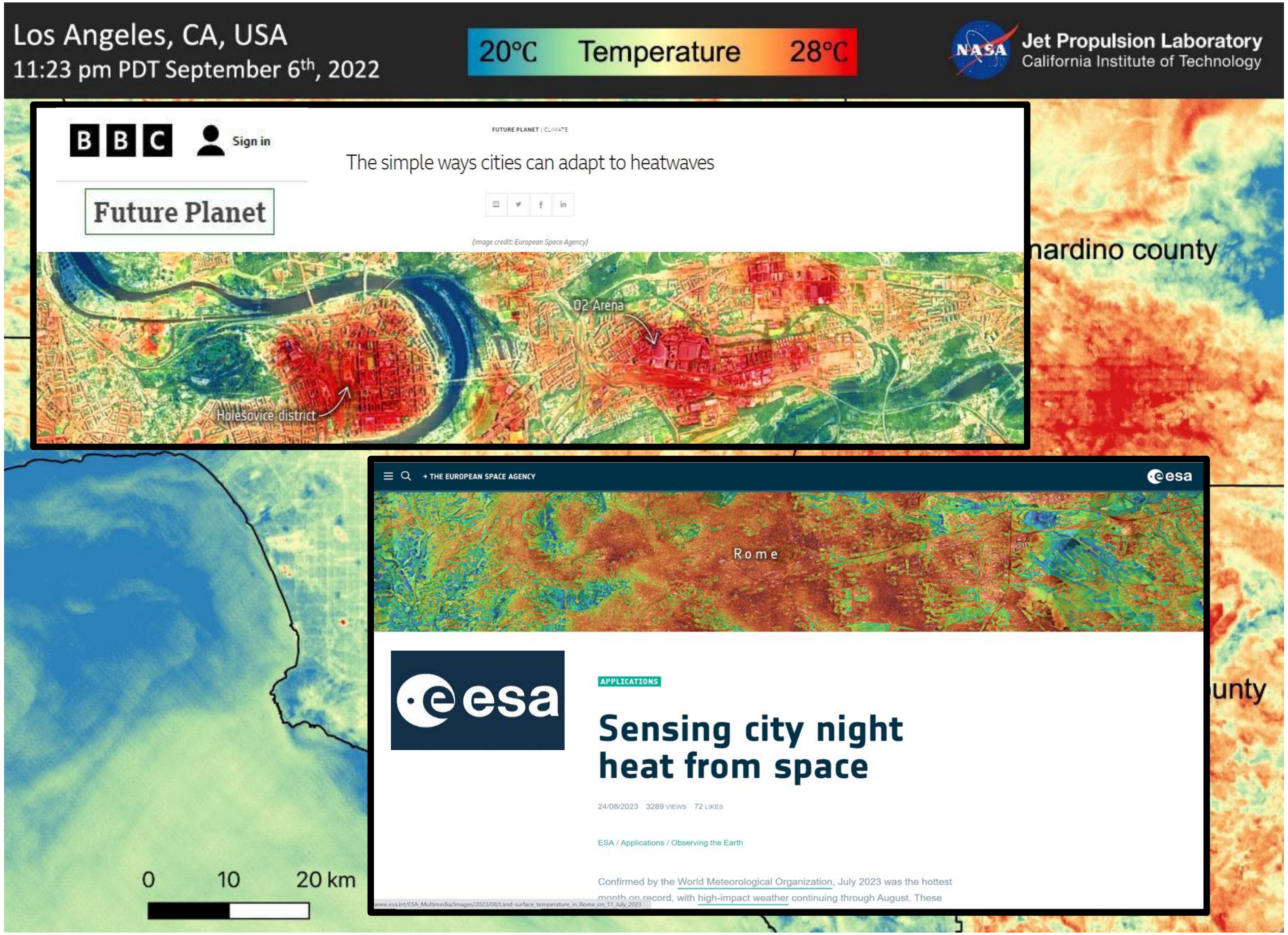
Heat cramps, and heatstroke (hyperthermia) are the most common ER visits.
Other underlying health issues often overlooked, e.g. mental health, cognitive function.

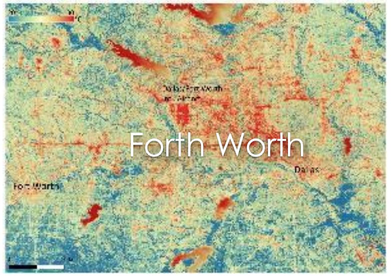
Mapping global extreme heat with ECOSTRESS

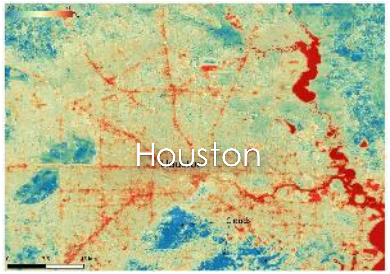










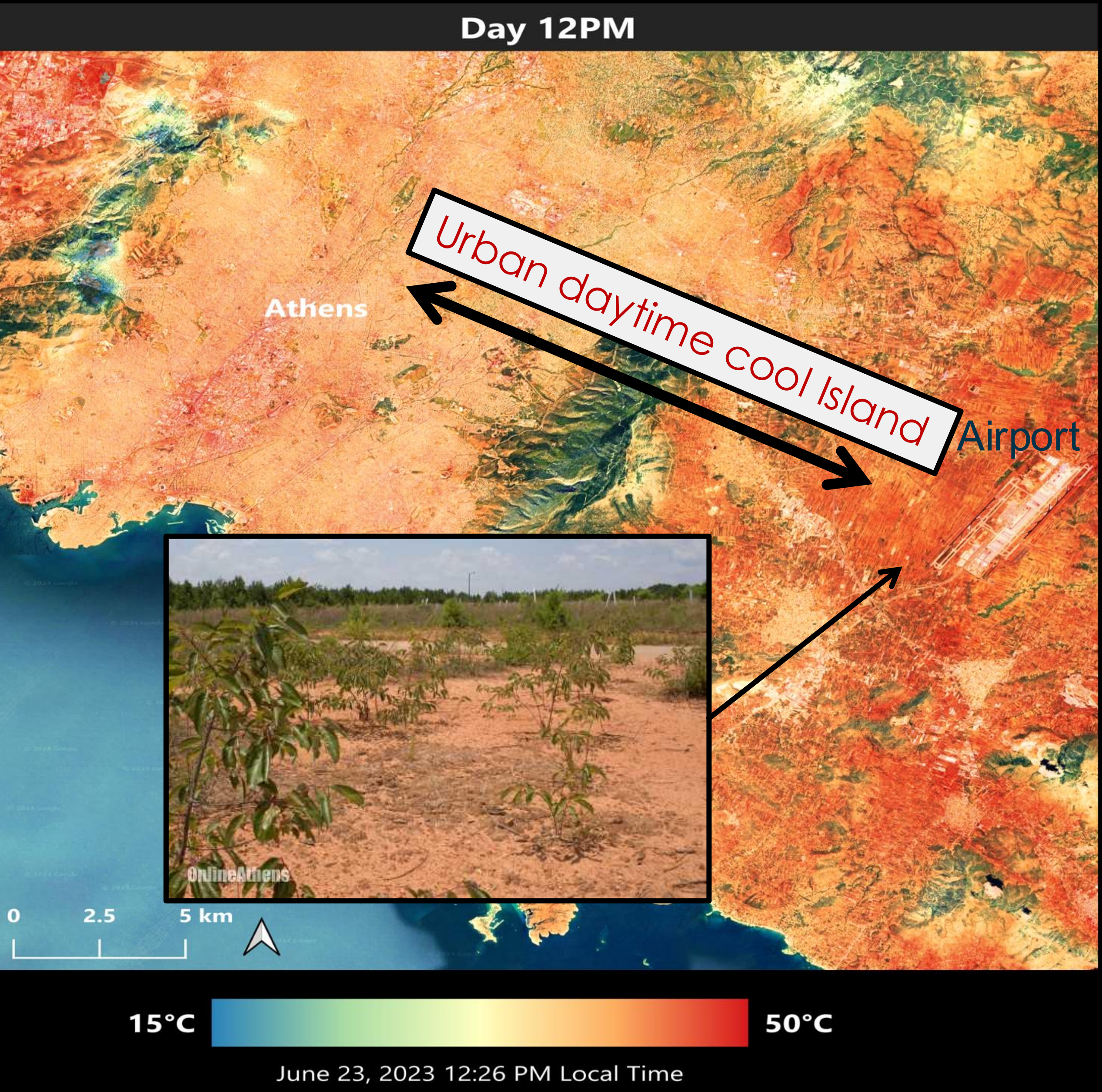


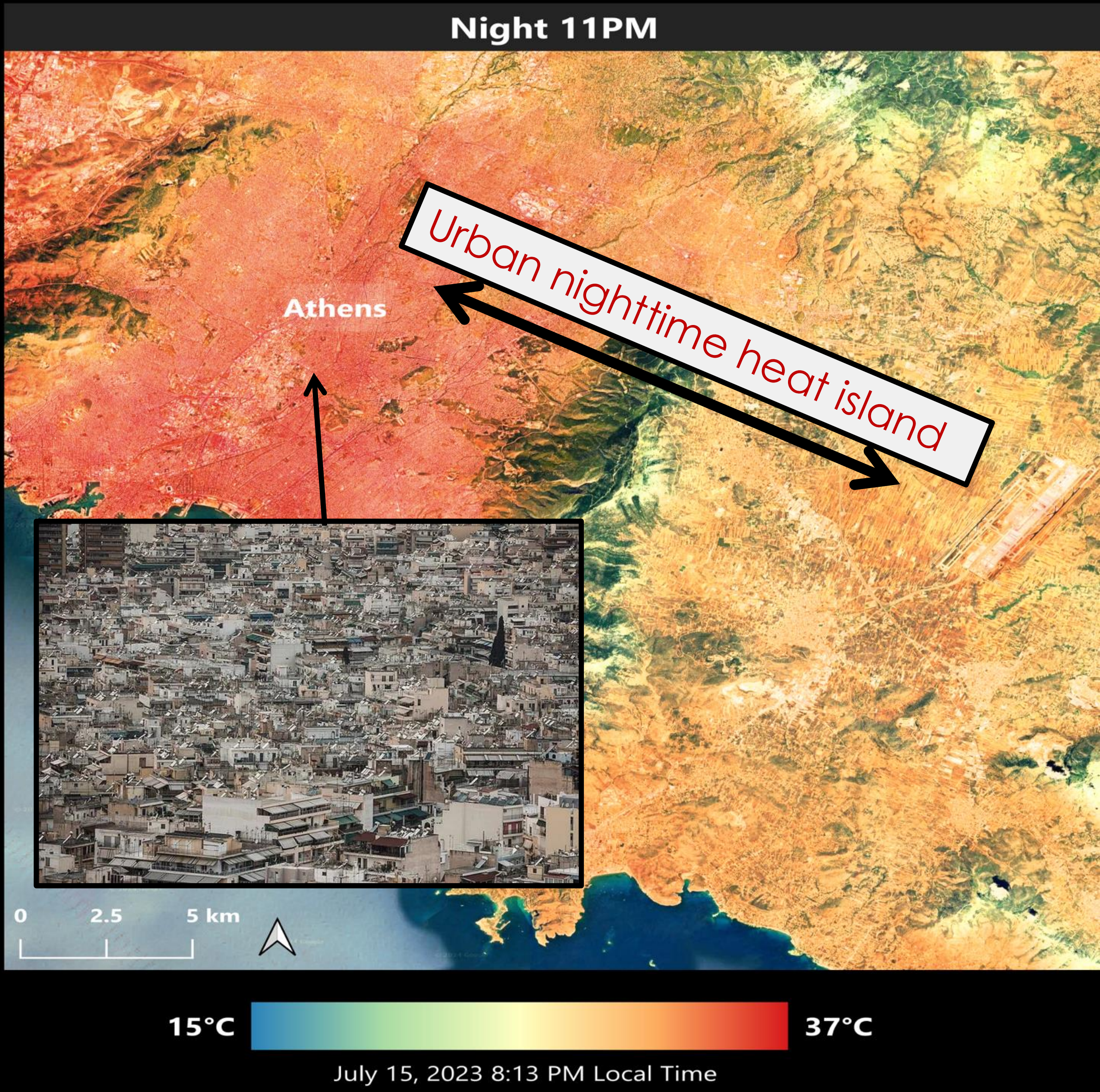
ECOSTRESS

ECOSTRESS Land Surface Temperature

European ‘Cerberus’ Heatwave: July 2023

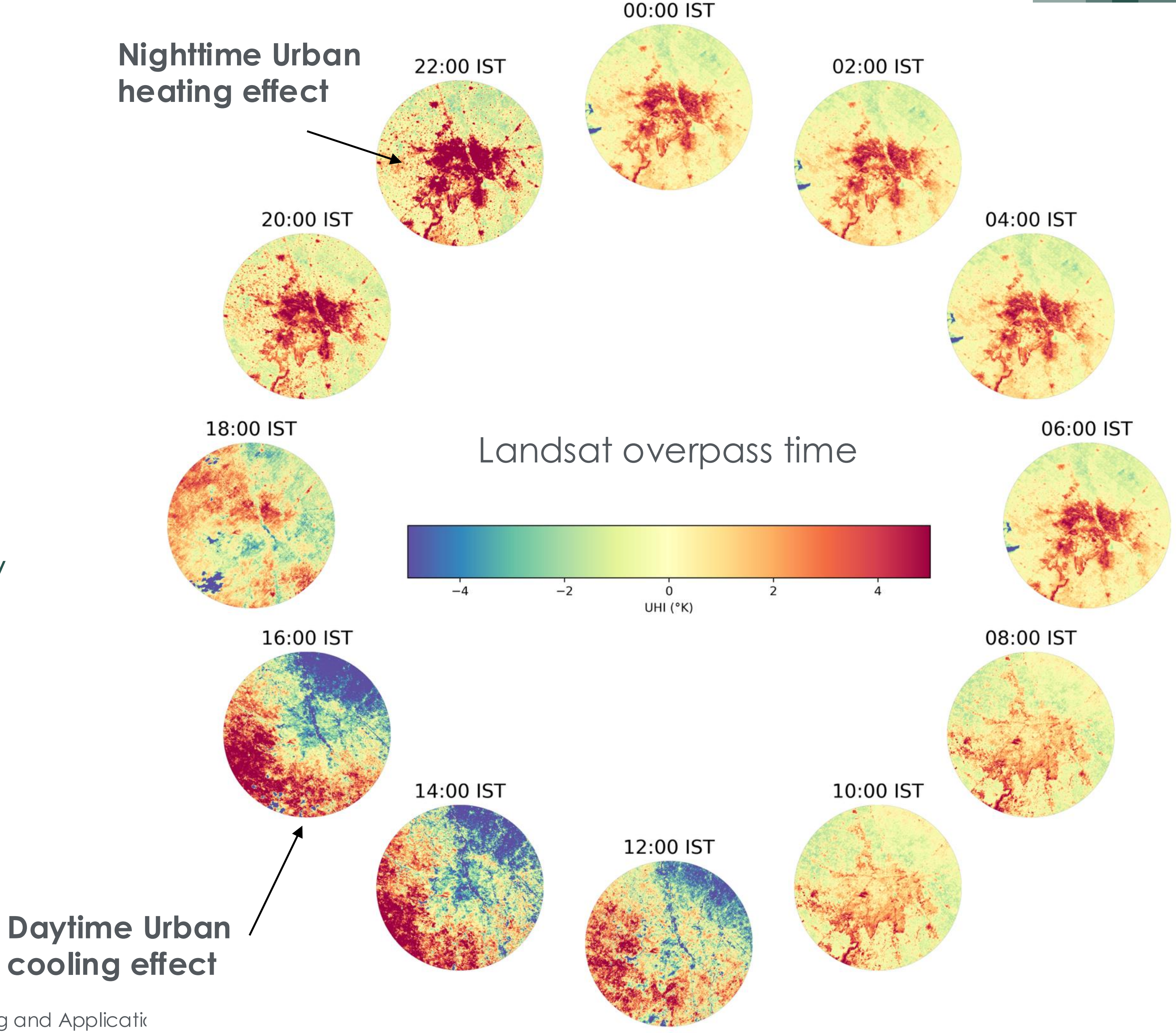
Jet Propulsion Laboratory
California Institute of Technology





Mapping changes in Urban Heat Island intensity over 24-hour period in Delhi, India

Maisey Runkel, Chapman University



Ashley Agatep, Chapman University

Blazing hot surfaces are a danger for catastrophic burn injuries in the urban desert Southwest

Sizzling sidewalks and unshaded playgrounds are a danger for catastrophic burn injuries as air temperatures reach new summer highs in desert cities like Phoenix and Las Vegas

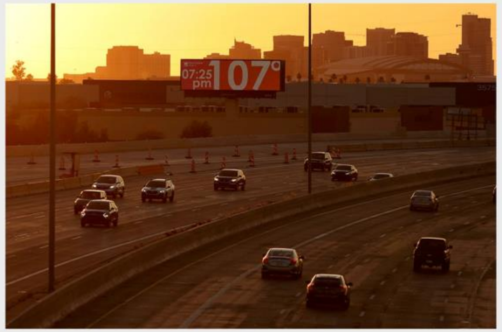
By ANITA SNOW Associated Press
July 2, 2024, 9:02 PM

JULY 3, 2024 | 4 MIN READ

New Heat Map Shows Scorching Streets that Can Burn Skin in Seconds

Under the scorching summer sun, pavement can reach temperatures hot enough to cause second-degree burns

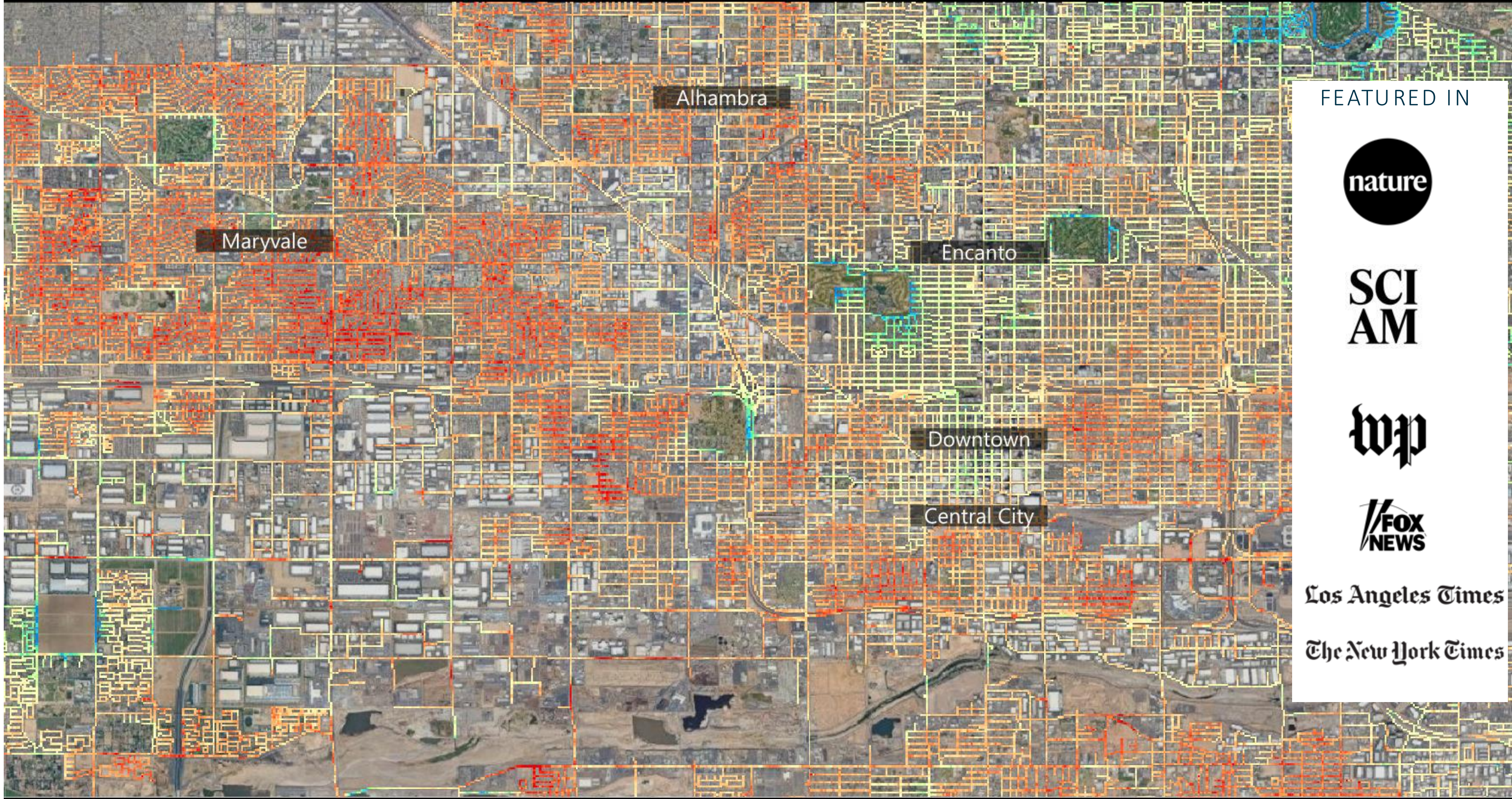
BY ANDREA THOMPSON



ECOSTRESS

ECOSTRESS Land Surface Temperature
Second-degree Burn Risk Exposure Map – Phoenix, Arizona

NASA Jet Propulsion Laboratory
California Institute of Technology



0 1 2 km

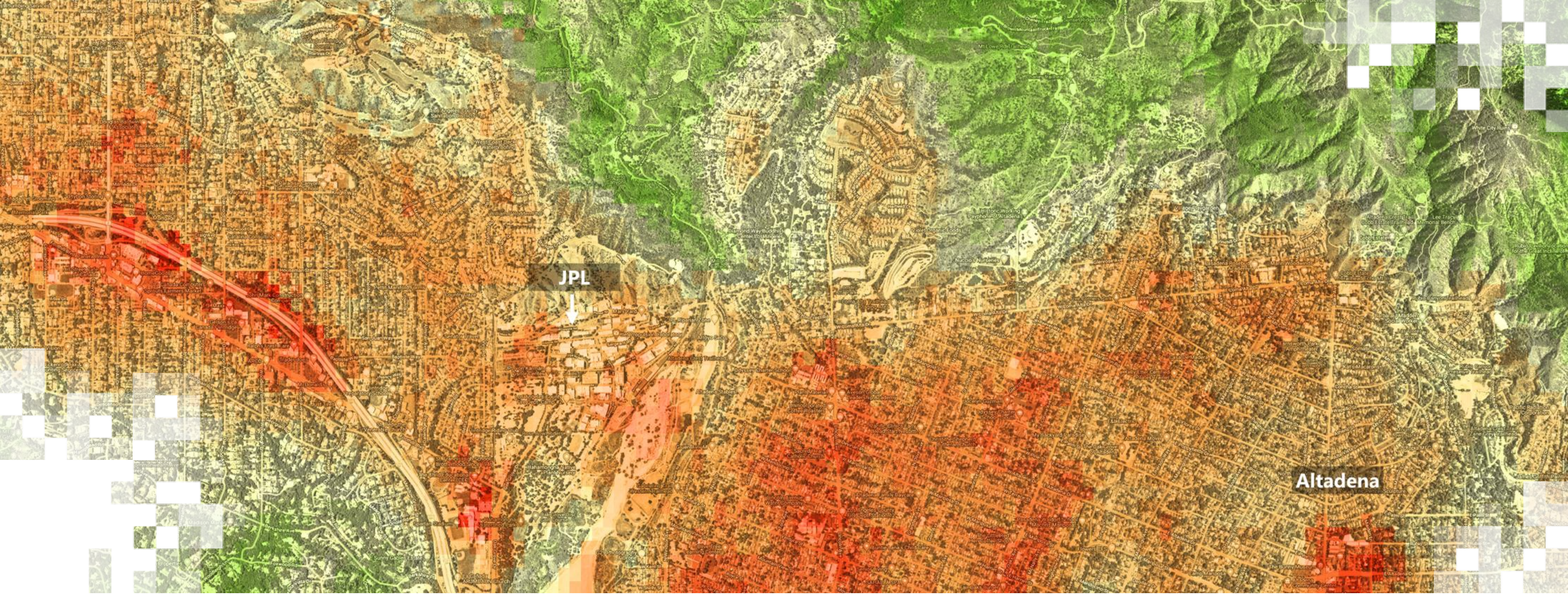
June 19, 2024
1:02 PM Local Time

<2 Minutes | <20 Seconds | <10 Seconds | <3 Seconds — Second Degree Burn Risk

125 (52 C) | 130 | 135 | 140 | 150 (65 C) — Surface Temperature °F

FEATURED IN

nature
SCI AM
wp
FOX NEWS
Los Angeles Times
The New York Times



Part 2: Introduction to Thermal Remote Sensing

Section 3: Hands-on Exercise with Land Surface Temperature in Los Angeles County

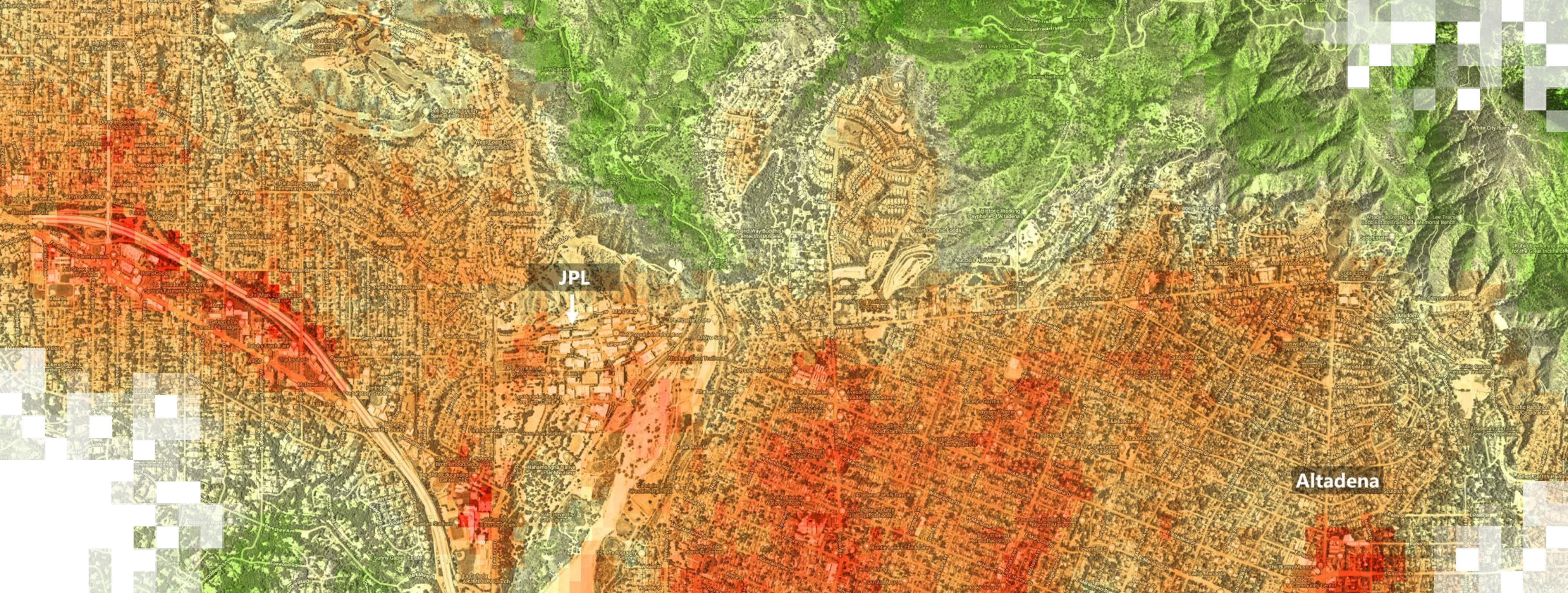
Demo 1: Exercise with Land Surface Temperature in Los Angeles County

Objective

- Access, filter, and visualize ECOSTRESS LST
- Interpret LST characteristics for assessing urban thermal resilience

Activities

- Preparation Steps: 1) Clone the GitHub repository, 2) Install R and QGIS (if not installed already), 3) Install required libraries
- Process ECOSTRESS L2T products with QA and cloud masks
- Make an LST map to analyze the differences in heat release between natural open spaces and impervious urban surfaces
- Generate temperature statistics to determine if the cooling benefits of urban green spaces "hold" or erode as heat accumulates over multiple days of extreme temperatures

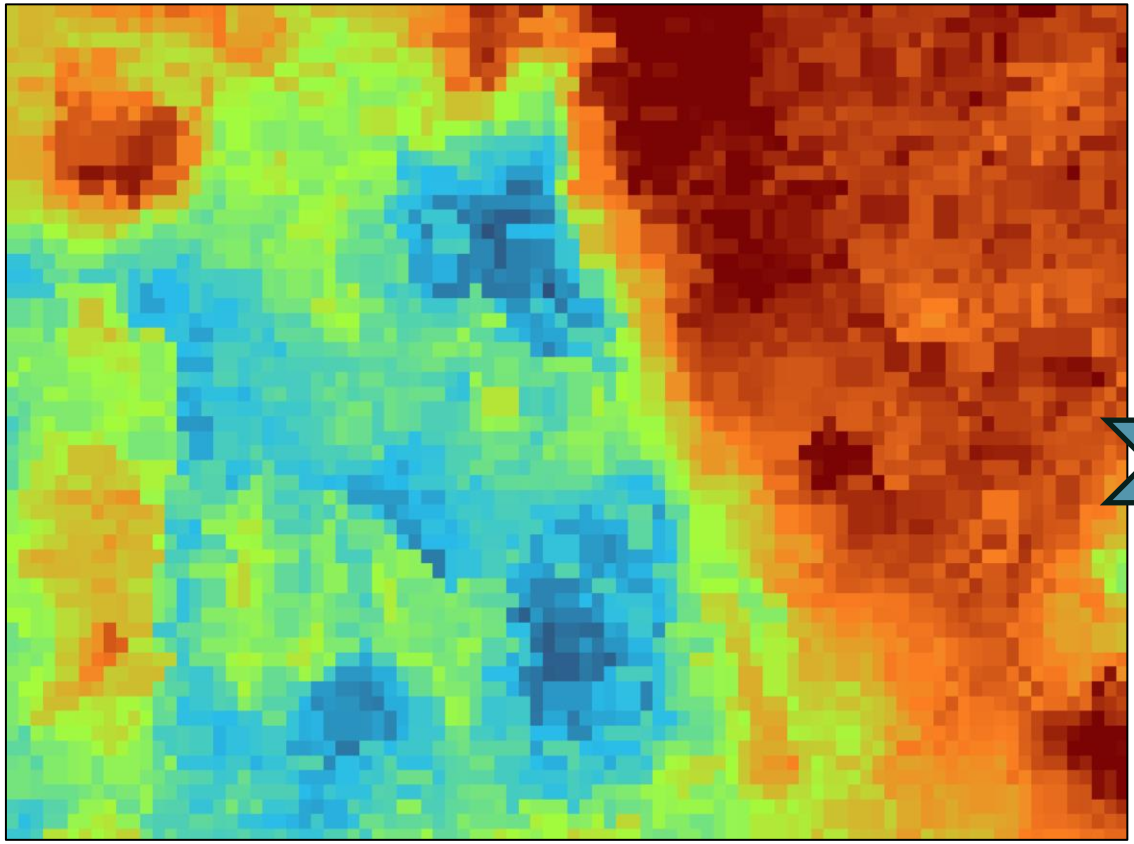


Part 2: Introduction to Thermal Remote Sensing

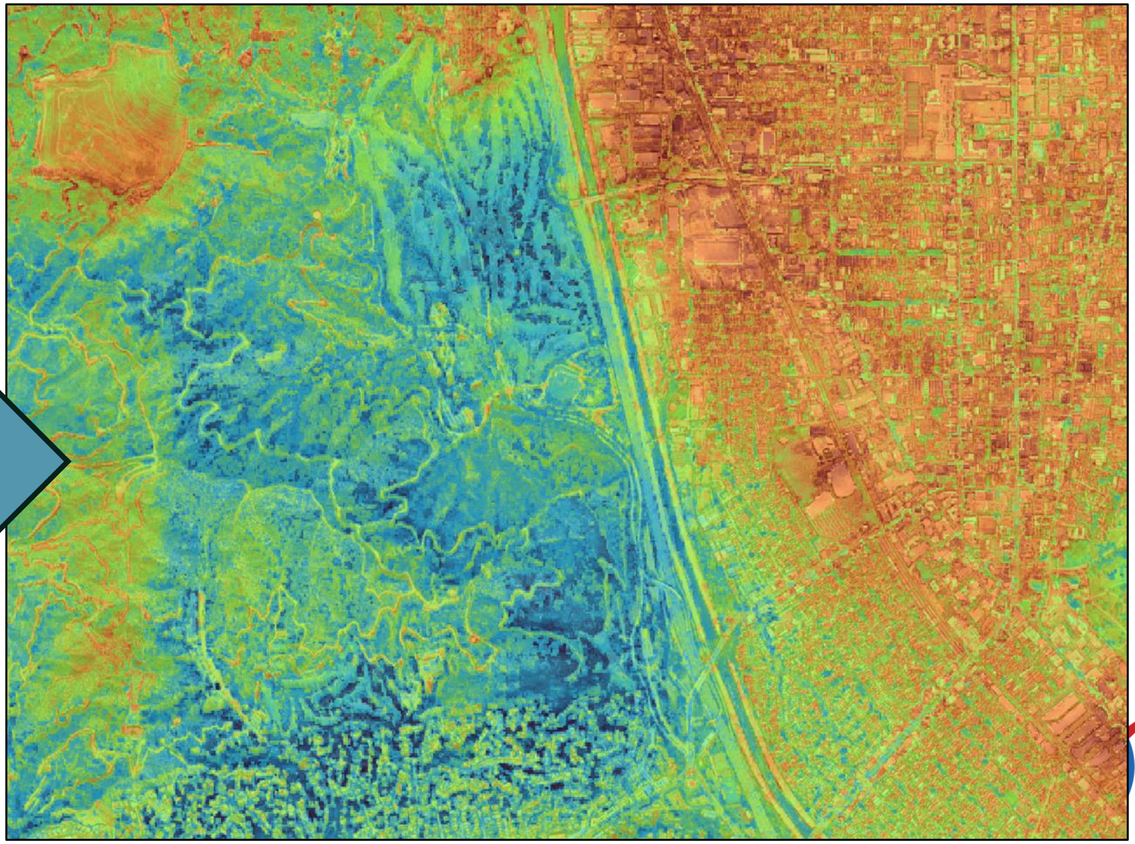
Section 4: Land Surface Temperature Downscaling

ECOSTRESS Land Surface Temperature Sharpening in Google Earth Engine

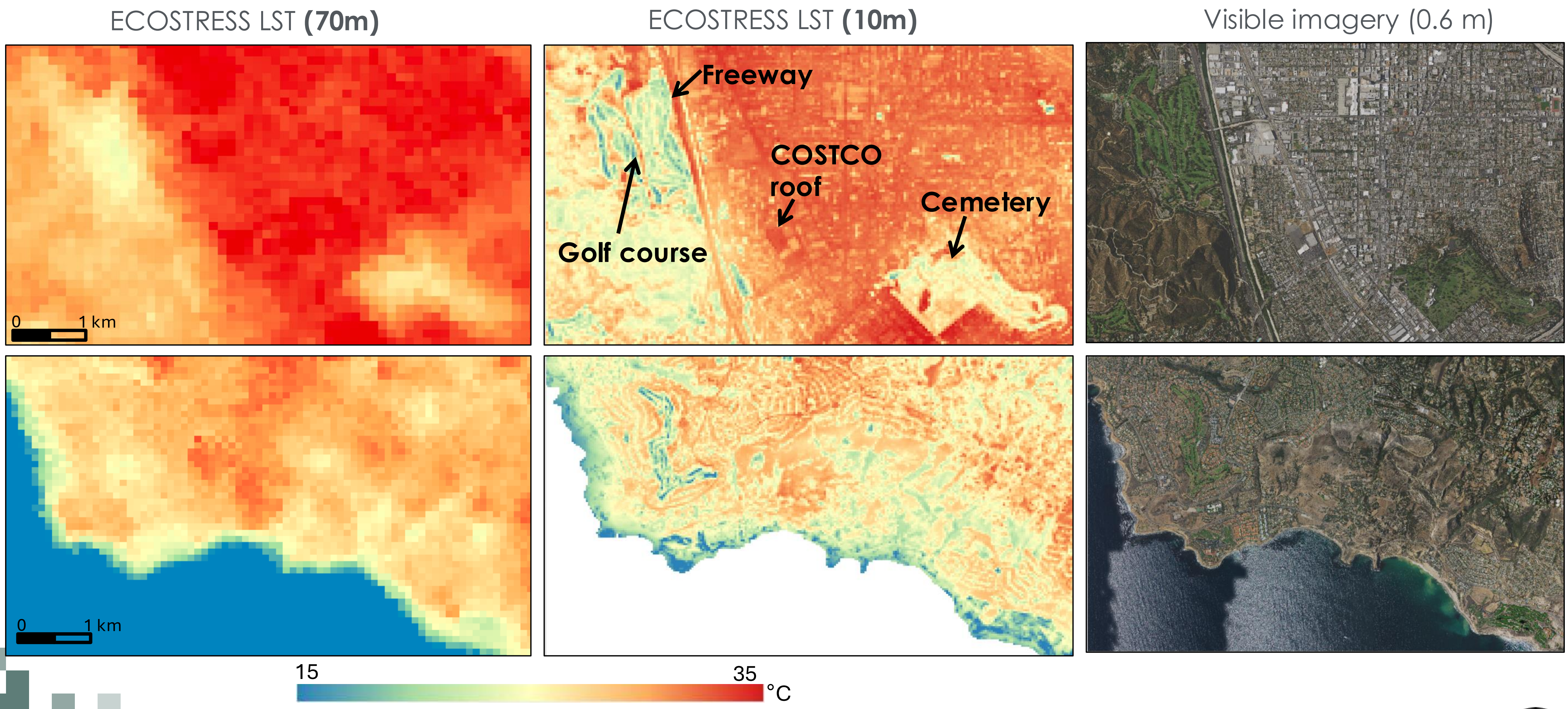
ECOSTRESS LST at 70m

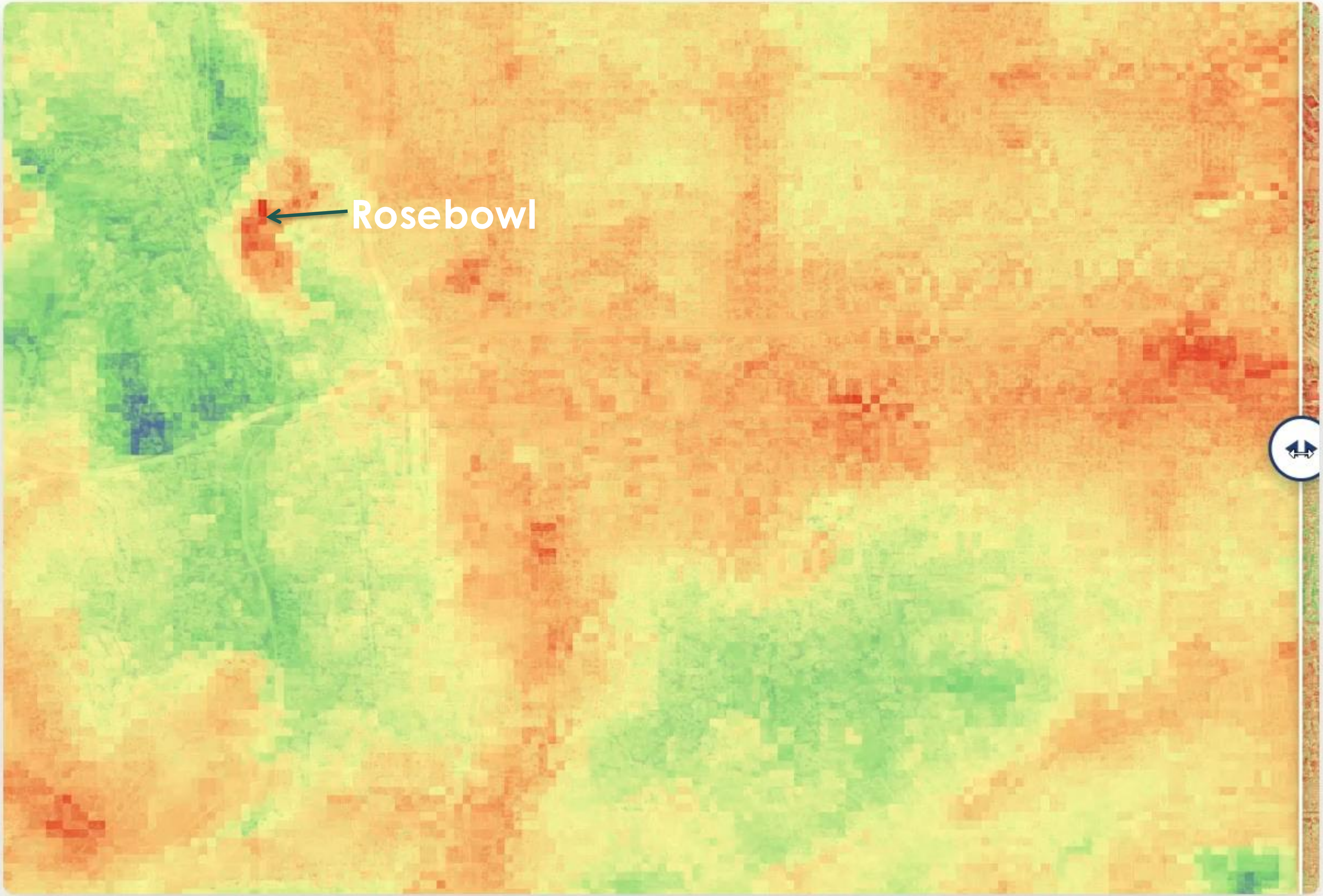


ECOSTRESS LST at 10m



LST Downscaling or ‘thermal sharpening’ using Sentinel-2




Rosebowl


ECOSTRESS LST
18 June, 2022,
2:49pm
Downscaled to 20m
Google Earth Overlay
32°C
48°C
Paris
0
1
2km

ECOSTRESS

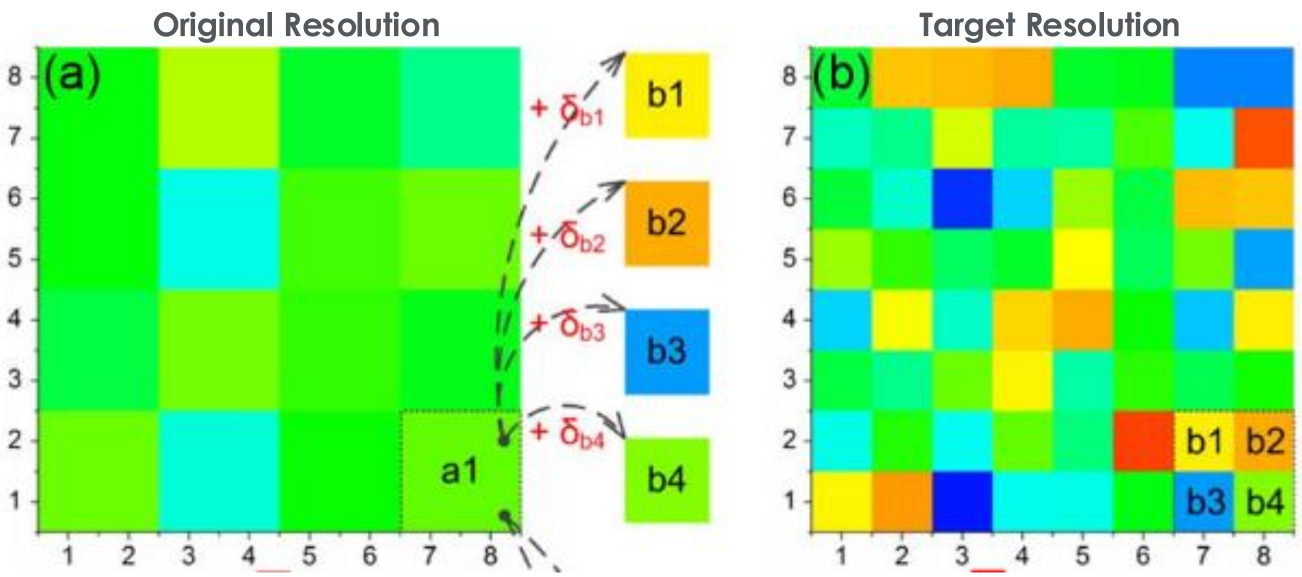
Urban Heat Patterns Revealed for Los Angeles Olympic Games

Potential value for designing heat mitigation approaches, planning and execution

Land Surface Temperature (LST) Downscaling

Statistical downscaling **disaggregates** coarse-scale LST to its components.

It uses auxiliary data of **superior** spatial resolution are statistically correlated to the LST.



Chen et al., 2014

Land Surface Temperature (LST) Sharpening Workflow Overview

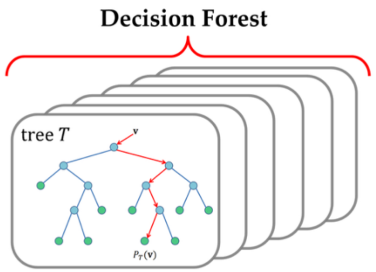
ECOSTRESS LST (70 m)

Sentinel-2 + Ancillary predictors (10 m)

Sentinel-2 Surface Reflectance (B2, B3, B4, B8)

ESRI Land Cover Type
GHSL Built-up fraction
SRTM Elevation

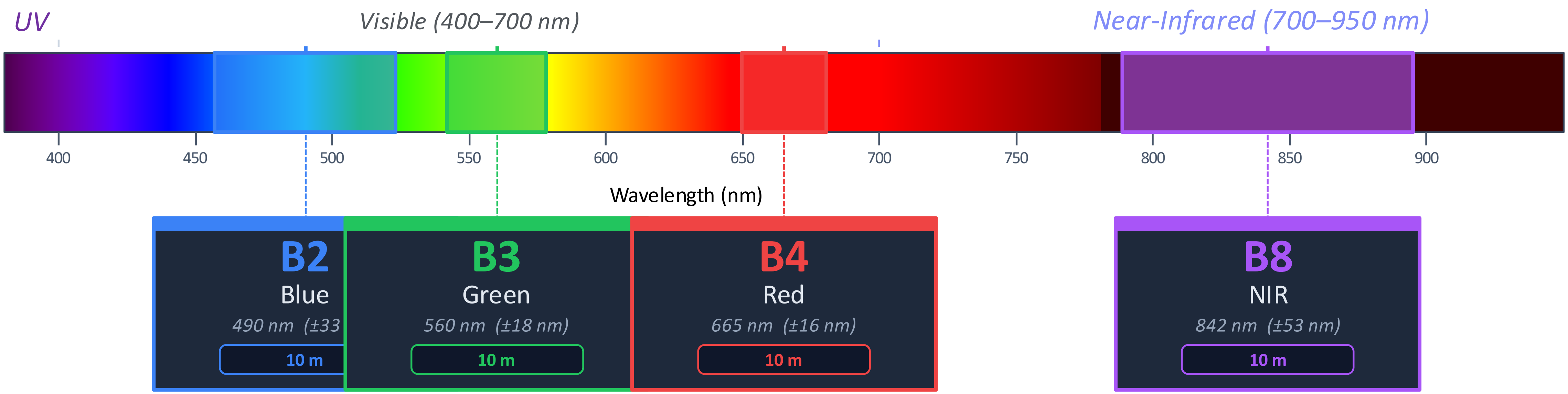
Random Forest Regression
(Train: 70 m | Predict: 10 m)



Sharpened LST (10 m)

Sentinel-2 Spectral Reflectance Bands

Band locations on the visible and near-infrared spectrum | All four bands at 10 m resolution



Why these four bands?

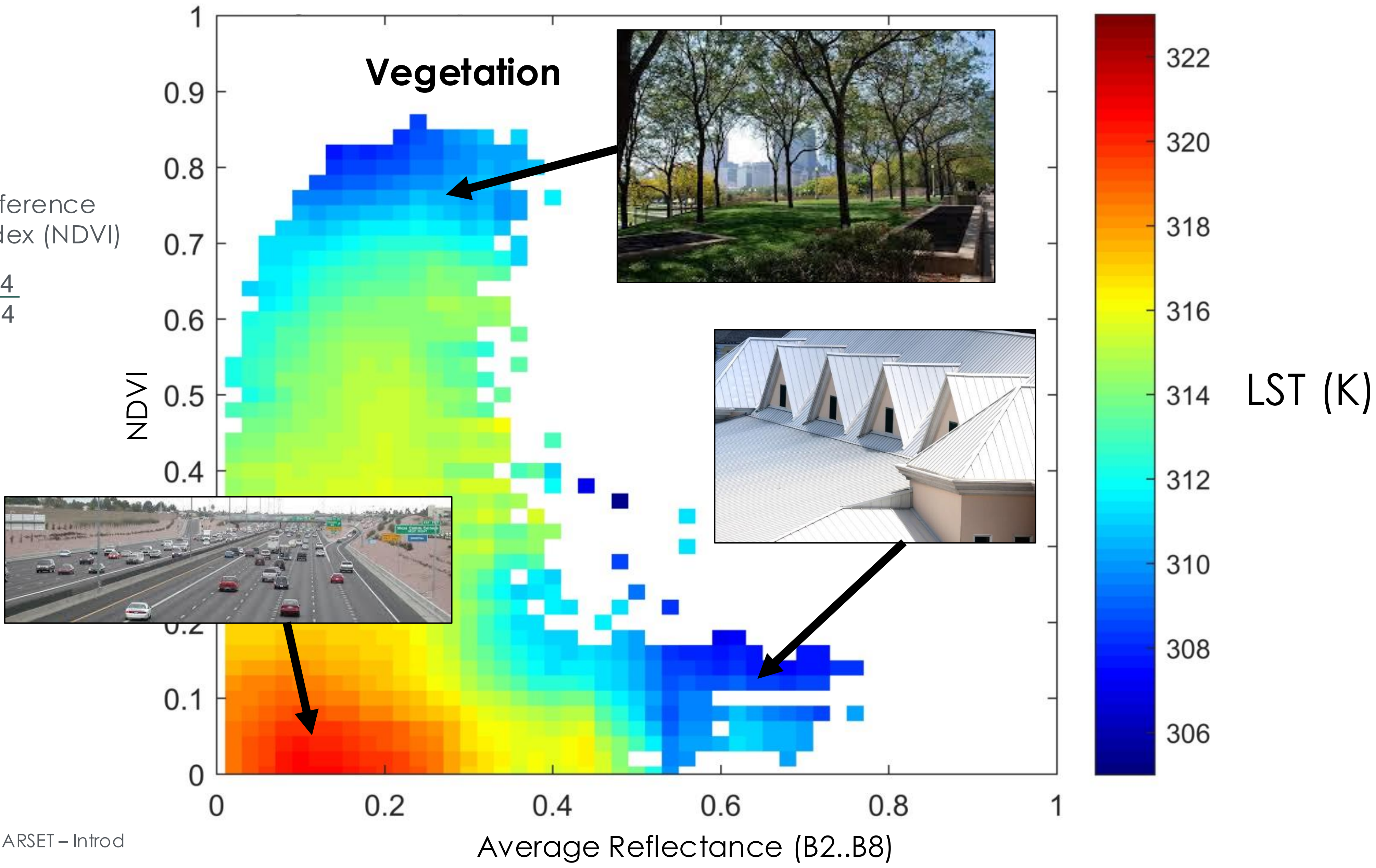
B2 Blue, B3 Green, B4 Red: capture surface reflectance patterns that correlate with thermal emission (impervious surface, vegetation, bare soil)

B8 NIR: sensitive to vegetation health, water content and biomass — strongest predictor of LST spatial variability in urban-rural gradients

Surface Temperature and Reflectance Dependencies

Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{B8 - B4}{B8 + B4}$$



Why Sharpen ECOSTRESS LST for Urban Applications?

ECOSTRESS provides thermal data at 70 m — sharpening to 10 m unlocks intra-urban detail critical for heat research and city planning.

Resolves Fine-scale Urban Features

Supports Heat Intervention Validation

Reduces Spatial Mixing

Aligns with City Planning Data

Improves Heat Vulnerability Mapping

Preserves Radiometric Accuracy

ECOSTRESS native: 70 m → ~1 pixel per city block

After RF sharpening: 10 m → ~49 pixels per city block

~50× improvement in spatial resolution — same ECOSTRESS thermal accuracy, dramatically finer spatial detail

Sharpening Model: Random Forest (RF) Regression

How Random Forest Works

Tree 1
Random feature subset

Tree 2
Random feature subset

• • •

Tree N
(100–500 trees)

Note: a feature subset = combination of random set of predictor bands, and training pixels

Average all tree predictions → final LST estimate

Key RF properties for LST sharpening:

Resolves non-linear relationships
Complex LST–surface patterns

Robust to outliers
Ensemble reduces variance

Feature importance
Identifies key LST predictors

Scale transfer
Train 70 m → predict 10 m

Sharpening Model: Random Forest (RF) Regression

LST Sharpening Pipeline in GEE

1. Training data at 70 m
ECOSTRESS LST (target) + S2 spectral bands + LULC + GHSL + SRTM (predictors at 10m)

▼

2. Train RF model at 70 m
LST ≈ f(Reflectances, LULC, GHSL, Elevation)

▼

3. Predict LST at 10 m
Apply trained RF to 10 m Sentinel-2 predictors → initial sharpened LST (RF_LST)

▼

4. Residual correction (radiometric normalization)
LST(70m) − RF_LST (upscaled to 70m) → add residual at 10 m → radiometric consistency

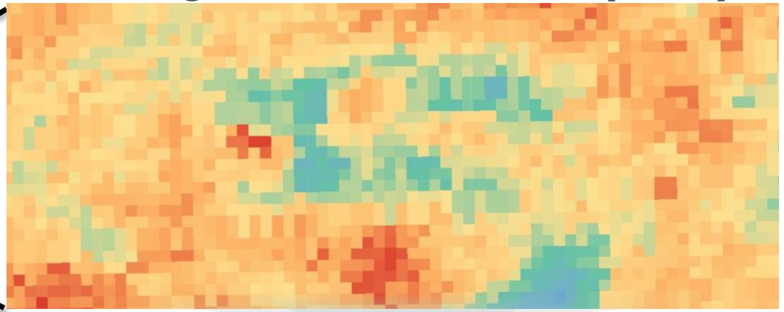
▼

Output: Sharpened ECOSTRESS LST at 10 m

GEE-based ECOSTRESS LST Downscaling

Sentinel-2 RGB imagery

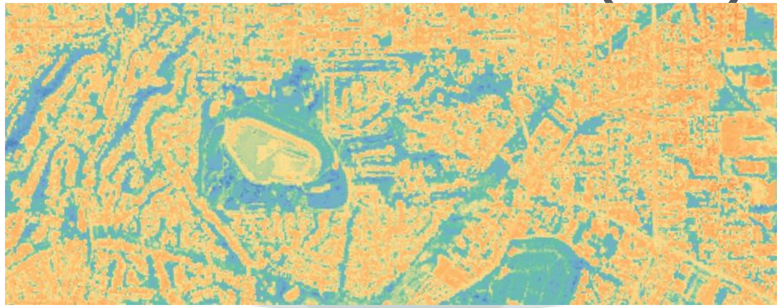
Original ECOSTRESS LST (70 m)



Output from Machine Learning

```
var DLST = collection10m
.select(band_names_indep).classify(model)
```

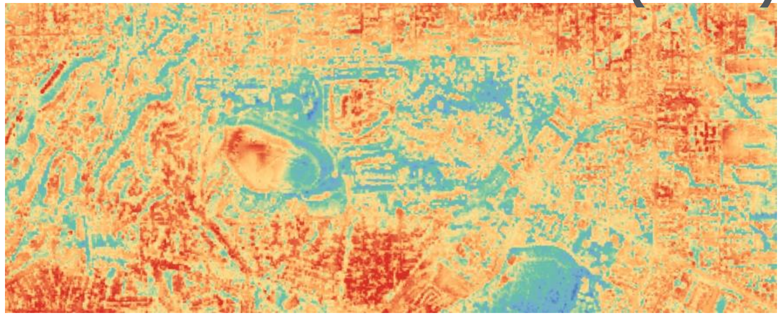
Initial Downscaled LST (10 m)



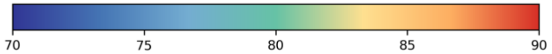
Residual Correction

```
var diff =temp_f.subtract(DLST70)
.resample('bilinear').reproject(projectionDLST);
var FinalDLST = DLST.add(diff);
```

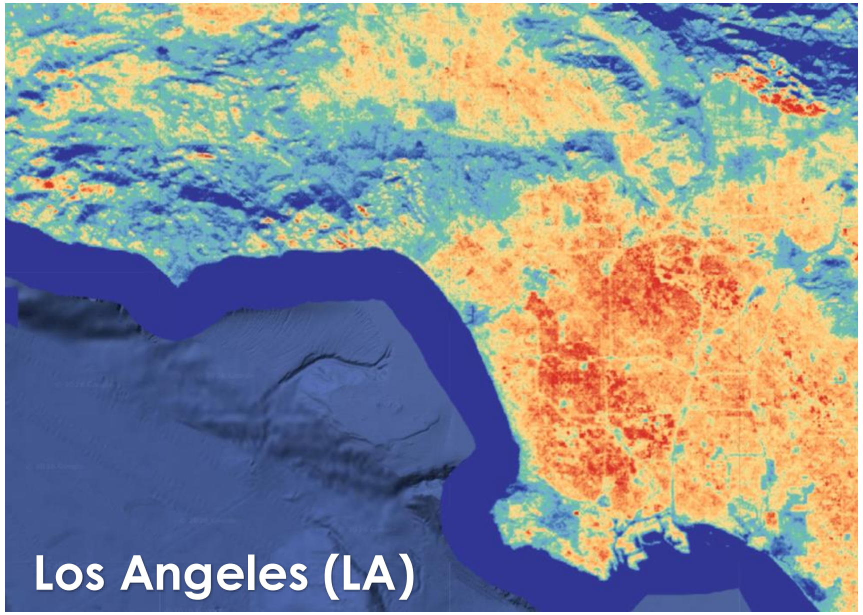
Residual-corrected LST (10 m)



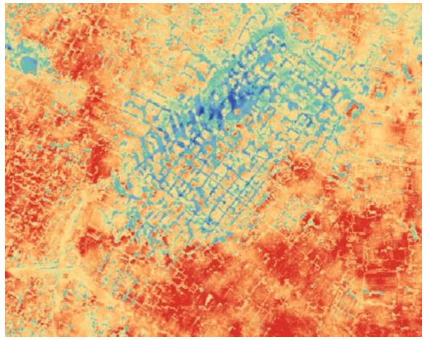
Land Surface Temperature (°F)



Final Downscaled LST (10 m)



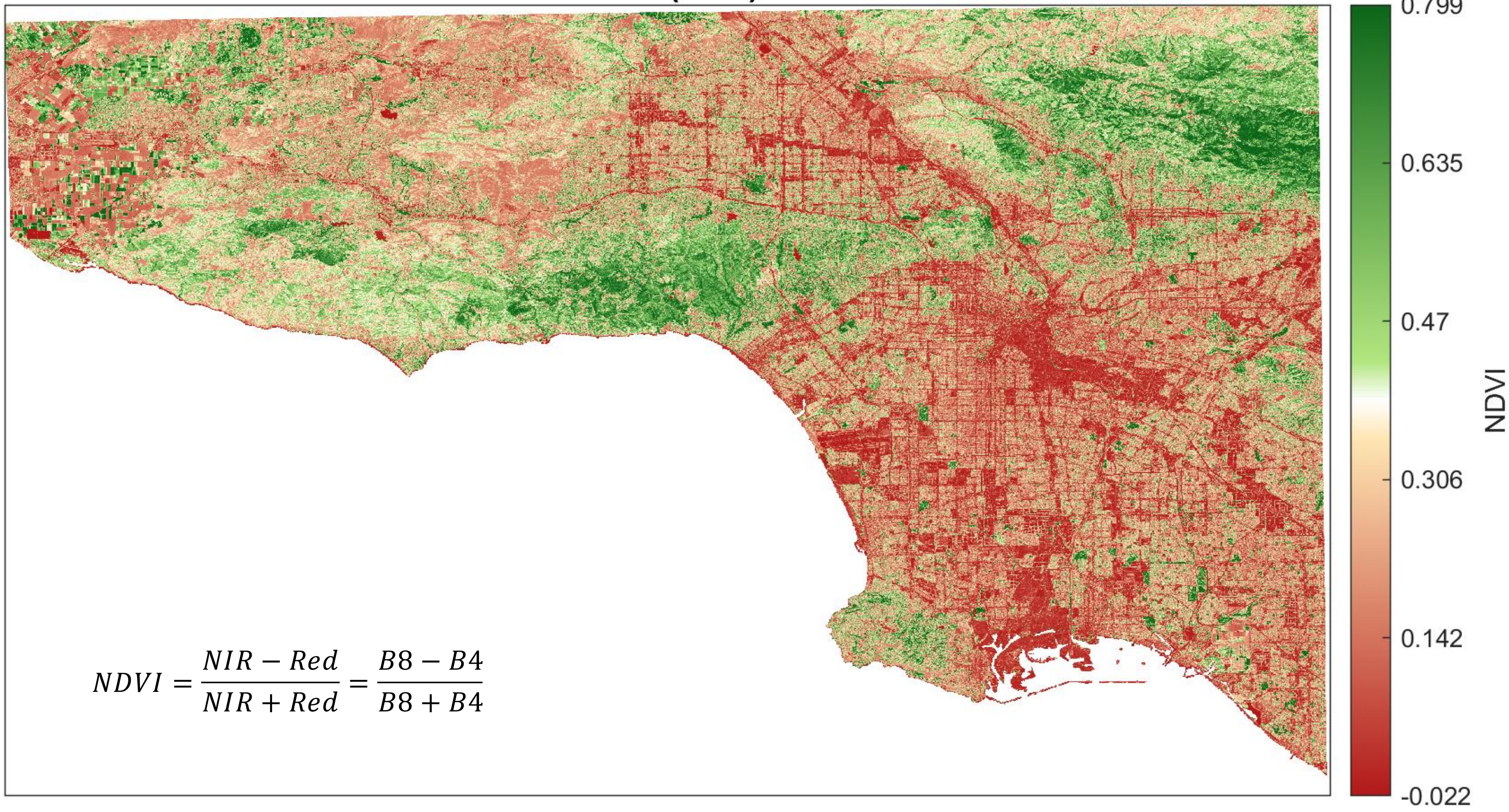
Downtown LA



Sentinel-2 B8 NIR (10m)

mean = 26.3 | p2 = 12.5 | p98 = 47.2

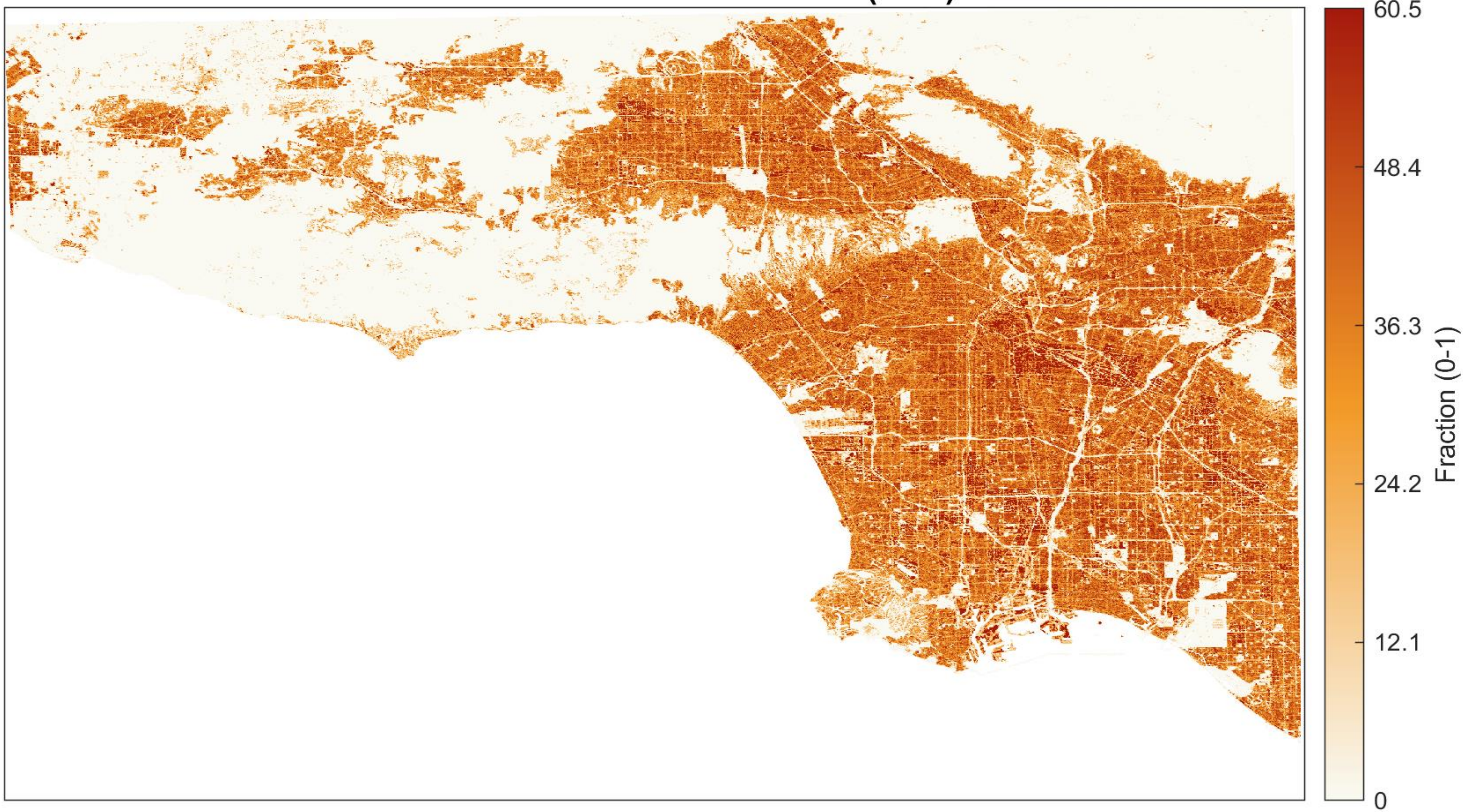
NDVI (10m)



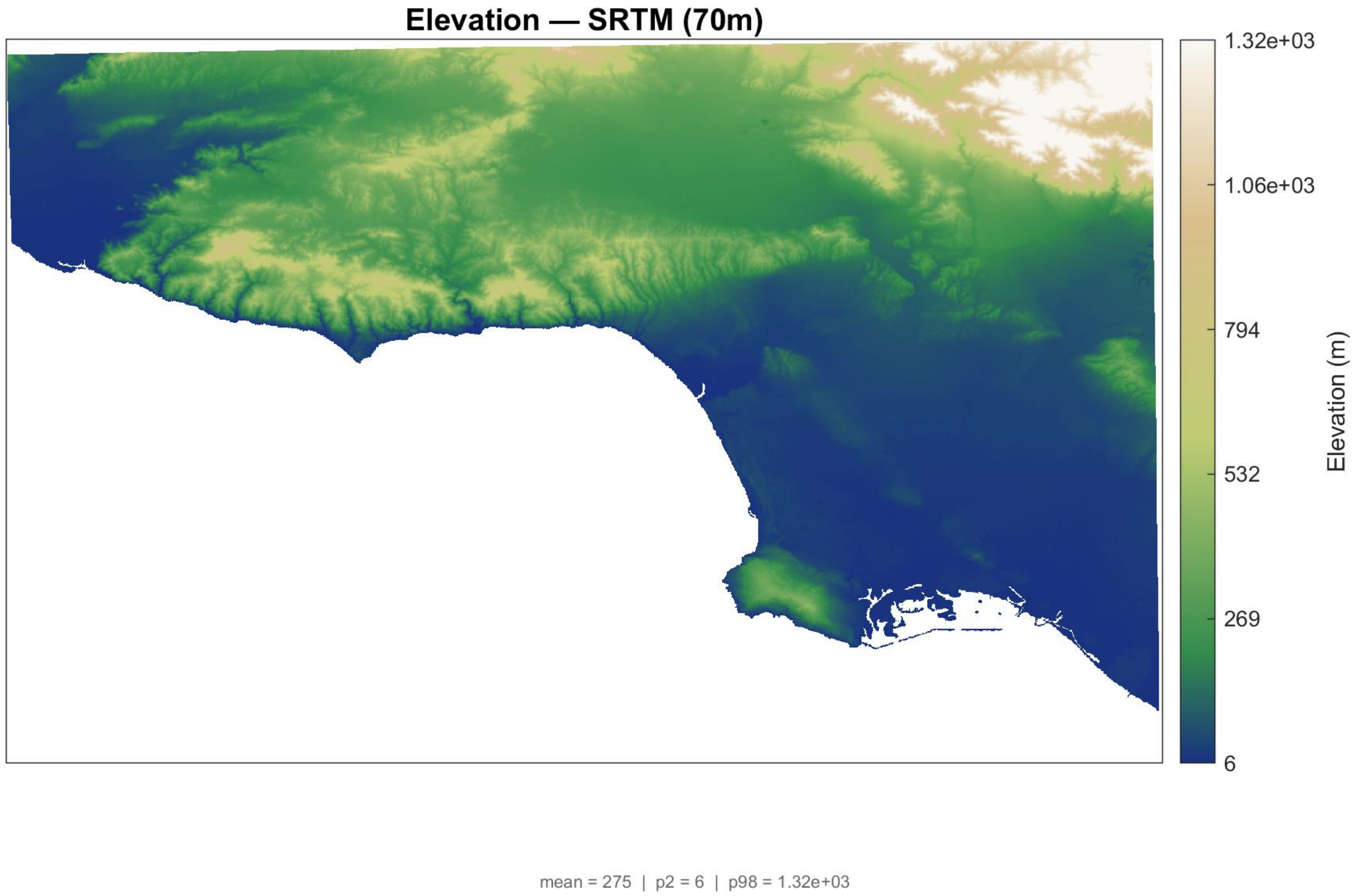
$$NDVI = \frac{NIR - Red}{NIR + Red} = \frac{B8 - B4}{B8 + B4}$$

mean = 0.31 | p2 = -0.022 | p98 = 0.799

Built Surface Fraction — GHSL (70m)

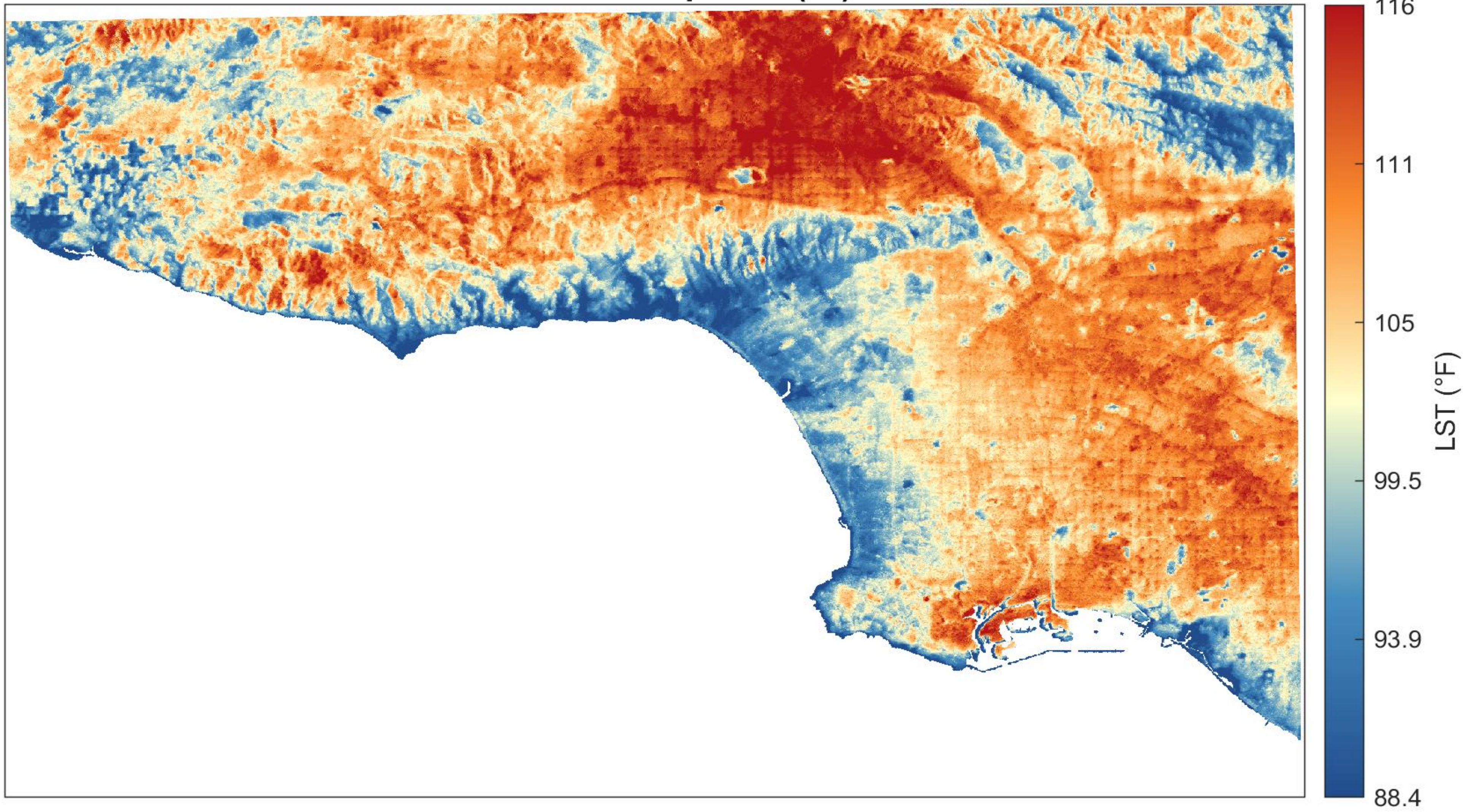


mean = 18.4 | p2 = 0 | p98 = 60.5



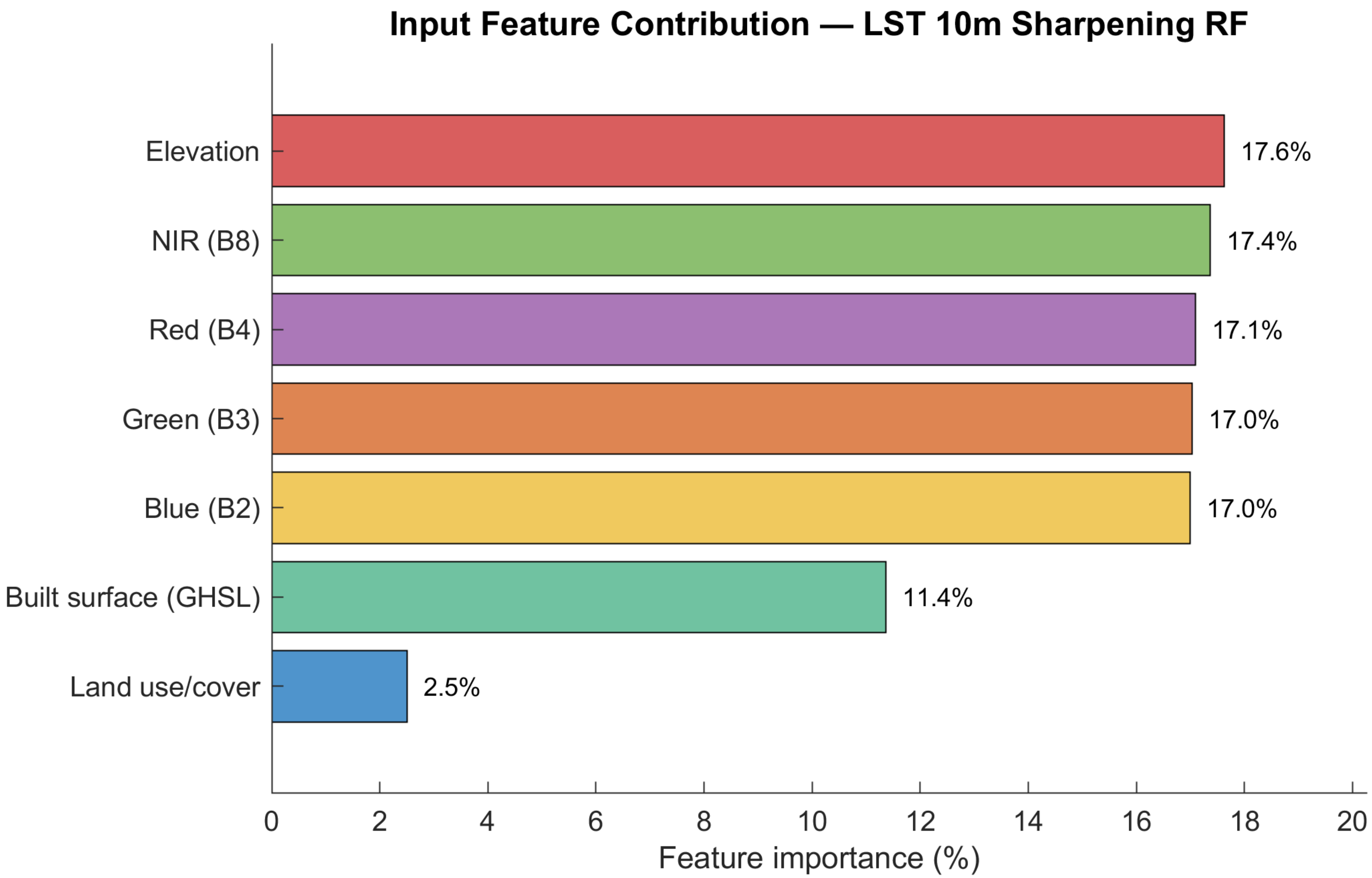
Elevation — SRTM (70m)
1.32e+03
1.06e+03
794
532
269
6
Elevation (m)
mean = 275 | p2 = 6 | p98 = 1.32e+03

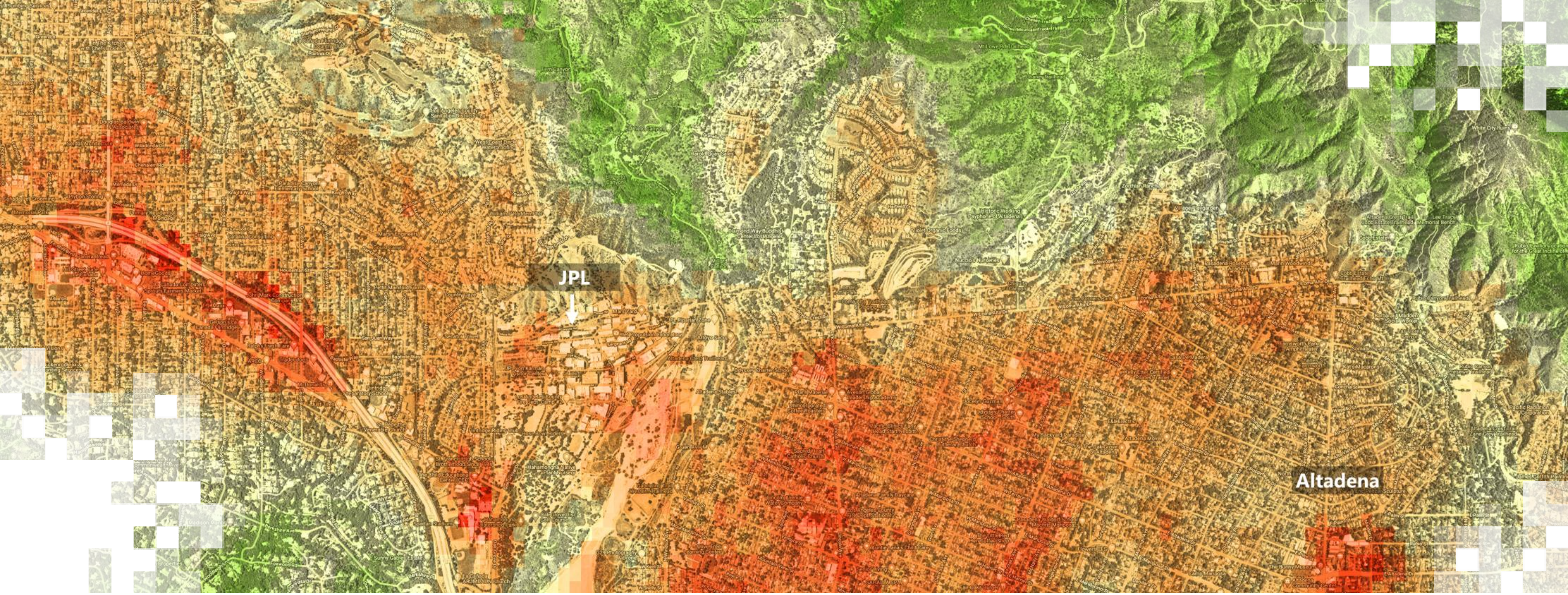
LST 70m Composite (°F)



mean = 104 | p2 = 88.4 | p98 = 116

Sharpening Model: Feature (Predictor) Importance





Part 2: Introduction to Thermal Remote Sensing

Section 5: Hands-on Exercise with the ECOSTRESS LST Downscaling Tool

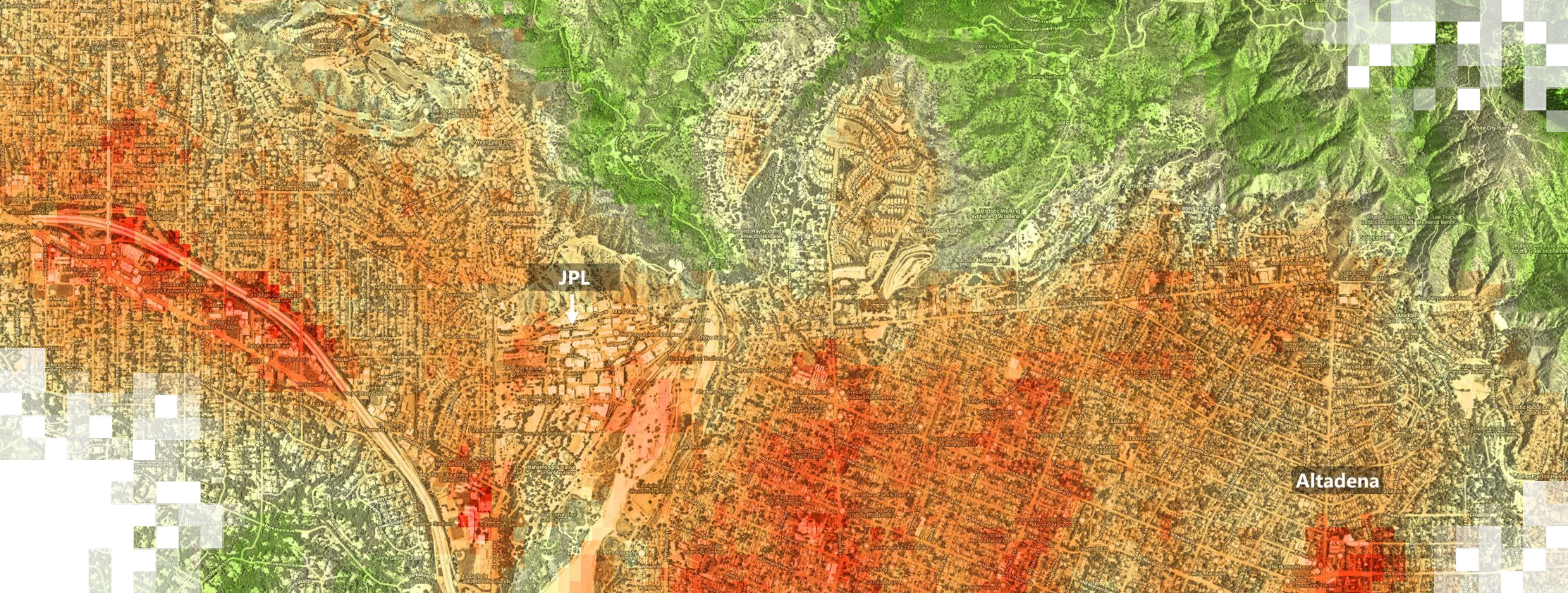
Demo 2: Downscaling ECOSTRESS Land Surface Temperature

Objective

- Downscale ECOSTRESS LST data from 70m native resolution to 10m resolution using a Random Forest on Google Earth Engine
- Visualize the 10m downscaled LST data with QGIS and interpret LST characteristics

Activities

- Preparation Steps: 1) Create Google Earth Engine account, 2) Open GEE script (GitHub repository), 3) Install QGIS (if not installed already)
- Produce two ECOSTRESS land surface temperature (LST) products for a user-selected area: 1) LST 70m — a mean composite of all clear ECOSTRESS granules in the date range, in the selected temperature units; 2) LST 10m — the 70m composite sharpened to 10m spatial resolution using a Random Forest model trained on Sentinel-2 spectral bands and auxiliary data
- Both products are exported as GeoTIFFs to Google Drive for visualization and analysis in QGIS software



Introduction to Thermal Remote Sensing and Applications in Urban Heat Island Mapping

Training Summary

Training Summary

- **The physics of thermal emission**
  - Planck's Law, Wien's Displacement Law, and the Stefan-Boltzmann Law govern emitted energy.
- **Emissivity: the hidden variable in every LST product**.
  - Emissivity ($\varepsilon < 1$) encodes surface composition, roughness, and mineralogy
- **What thermal RS can do that optical RS cannot**.
  - Thermal sensors detect emitted surface radiation day and night.
- **A rich and expanding portfolio of thermal missions**.
  - Each mission trades off spatial resolution, temporal frequency, and spectral coverage to meet mission goals.
- **LST and emissivity as Swiss Army knives for Earth science**.
  - Accurate TIR retrievals are consequential for climate projections, ecological conservation and public health decision-making.
- **Hands-on ECOSTRESS data processing in R**.
  - Demonstration of nighttime LST at the Chatsworth Nature Preserve during September 2024 LA heatwave.
- **Downscaling ECOSTRESS to neighborhood scale with Machine Learning**.
  - To address thermal emission limits of spaceborne TIR resolution, a demo of Random Forest downscaling workflow in GEE leveraging high-resolution Sentinel-2 spectral indices (NDVI, NDBI, MNDWI, SWIR) as predictors of LST to sharpen ECOSTRESS imagery to 10 m and reveal block-level urban heat patterns invisible in the native product.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 02/06/2026
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 16/06/2026**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

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Resources

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- Hulley, G. C., Hook, S. J., et al. (in review). Validation of the Hyperspectral Thermal Emission Spectrometer (HyTES) land surface temperature and emissivity products.
- Meerdink, S. K., Hook, S. J., Roberts, D. A., & Abbott, E. A. (2019). The ECOSTRESS spectral library version 1.0. *Remote Sensing of Environment*, *230*, 111196. https://doi.org/10.1016/j.rse.2019.05.015
- (2019). *ARSET - New Sensor Highlight: ECOSTRESS*. NASA Applied Remote Sensing Training Program (ARSET). https://www.earthdata.nasa.gov/learn/trainings/new-sensor-highlight-ecostress.

Quick Links

- ECOSTRESS website
- Search for ECOSTRESS data
- ECOSTRESS online tutorials
- Create a free Google Earth Engine account
- Download QGIS software
- MGRS tiling system explained

Thank You!