

Satellite Remote Sensing for Urban Heat Islands

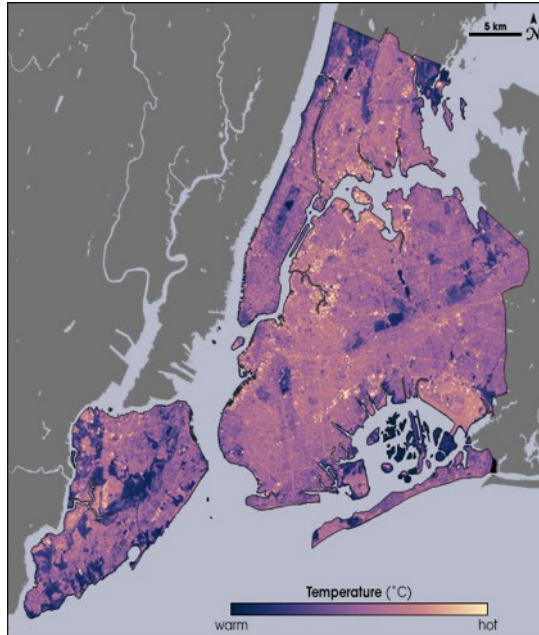
Sean McCartney & Amita Mehta

November 10, 2020



Training Outline

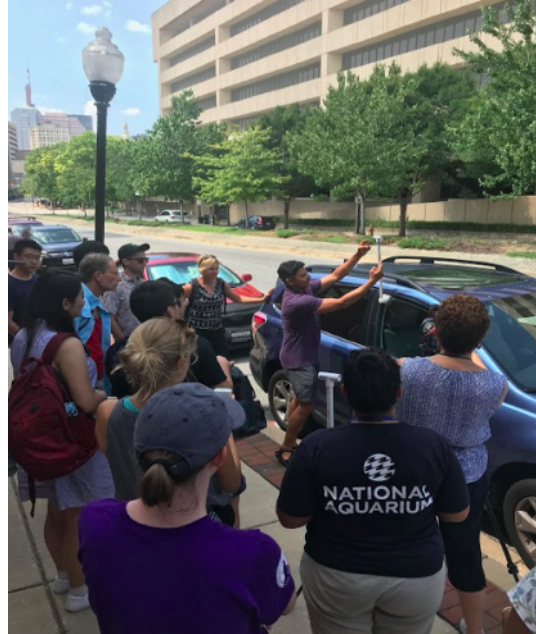
10 November 2020



Credit: [NASA Earth Observatory](#)

Land Surface Temperature-based Urban Heat Island Mapping

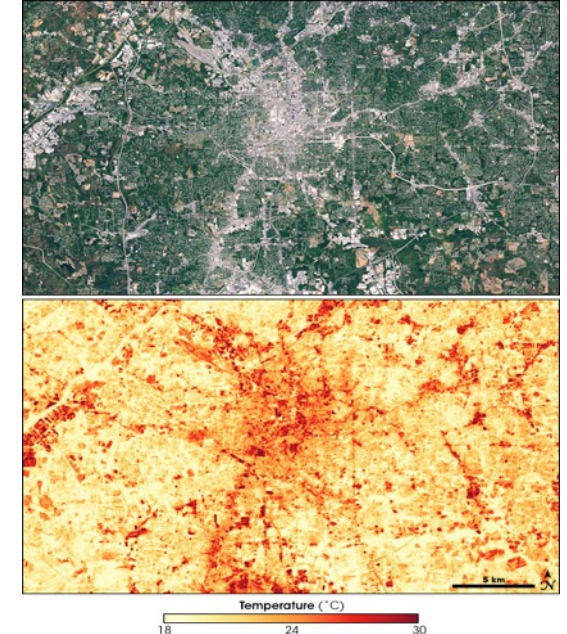
17 November 2020



Credit: [Frank Niepold/NOAA](#)

Integrating In-situ Observations with Satellite Imagery for Mapping Urban Heat

24 November 2020



Credit: [NASA Earth Observatory](#)

Mitigating Urban Heat Islands via Long-term Climate Monitoring



Course Structure and Materials

- Three, 1.5-hour sessions including presentations and question and answer sessions
- The same content will be presented at two different times each day:
 - Session A: 10:00-11:30 ET (UTC-4)
 - Session B: 16:00-17:30 ET (UTC-4)
- **Please only sign up for and attend one session per day.**



Course Structure and Materials

- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/satellite-remote-sensing-urban-heat-islands>



Homework and Certificate

- One homework assignment:
 - Homework submitted via Google Forms
 - **Due date: December 1, 2020**
- A certificate of completion will be awarded to those who:
 - Attend all live webinars
 - Complete the homework assignment by the deadline (access from [website](#))
 - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com



Prerequisites

- Create an account with Google Earth Engine: <https://earthengine.google.com/>
- Fundamentals of Remote Sensing: <https://appliedsciences.nasa.gov/join-mission/training/english/fundamentals-remote-sensing>

Optional:

- Google Earth Engine Tutorials: <https://developers.google.com/earth-engine>



DESCRIPTION

These webinars are available for viewing at any time. They provide basic information about the fundamentals of remote sensing, and are often a prerequisite for other ARSET trainings.

OBJECTIVE

Participants will become familiar with satellite orbits, types, resolutions, sensors and processing levels. In addition to a conceptual understanding of remote sensing, attendees will also be able to articulate its advantages and disadvantages. Participants will also have a basic understanding of NASA satellites, sensors, data, tools, portals and applications to environmental monitoring and management.

DETAILS

LANGUAGES: [English](#)

TRAINING TYPE: [Online Training](#)

LEVEL: [Introductory](#)

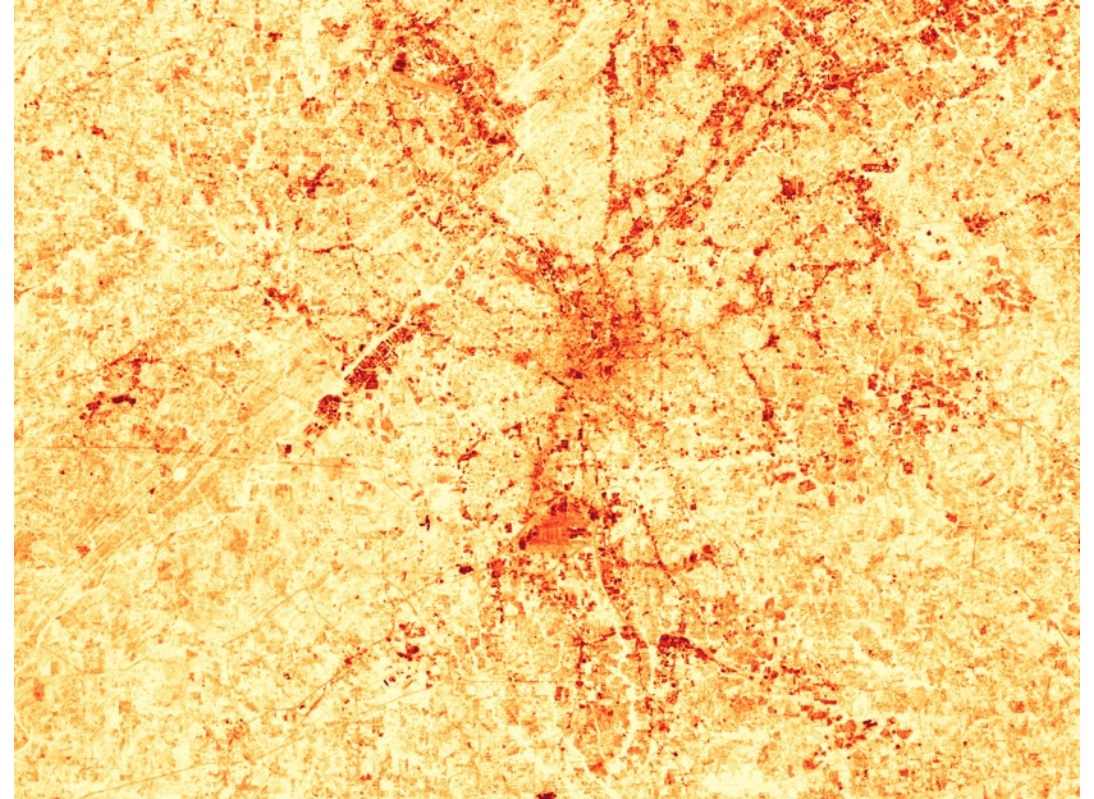
TRAINING SOURCE: [ARSET](#)



Learning Objectives

After participating in this training, attendees should be able to:

- Summarize the characteristics, causes, and impacts of Urban Heat Islands
- Identify the satellites and sensors used in analyzing Urban Heat Islands
- Replicate the steps of converting data from the Landsat series of satellites to Land Surface Temperature estimates using Google Earth Engine
- Recognize the limitations of satellite data for Urban Heat Island analysis



Credit: [NASA Earth Observatory](https://www.nasa.gov/earth-observatory)



List of Abbreviations

ARSET – Applied Remote Sensing Training Program

ASTER GED – Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Emissivity Database

AUHI – Atmospheric Urban Heat Island

BLHI – Boundary Layer Heat Island

CLHI – Canopy Layer Heat Island

CM-SAF – Climate Monitoring Satellite Application Facility

EM – Electromagnetic

ETM+ – Enhanced Thematic Mapper Plus

GEE – Google Earth Engine

JPL – Jet Propulsion Laboratory

LST – Land Surface Temperature

NASA – National Aeronautics and Space Administration

NCAR – National Center for Atmospheric Research

NCEP – National Center for Environmental Prediction

OLI – Operational Land Imager

SMW – Statistical Mono-Window

SUHI – Surface Urban Heat Island

TOA – Top of Atmosphere

TIRS – Thermal Infrared Sensor

TM – Thematic Mapper

TIR – Thermal Infrared

UHI – Urban Heat Island

USGS – U.S. Geological Survey



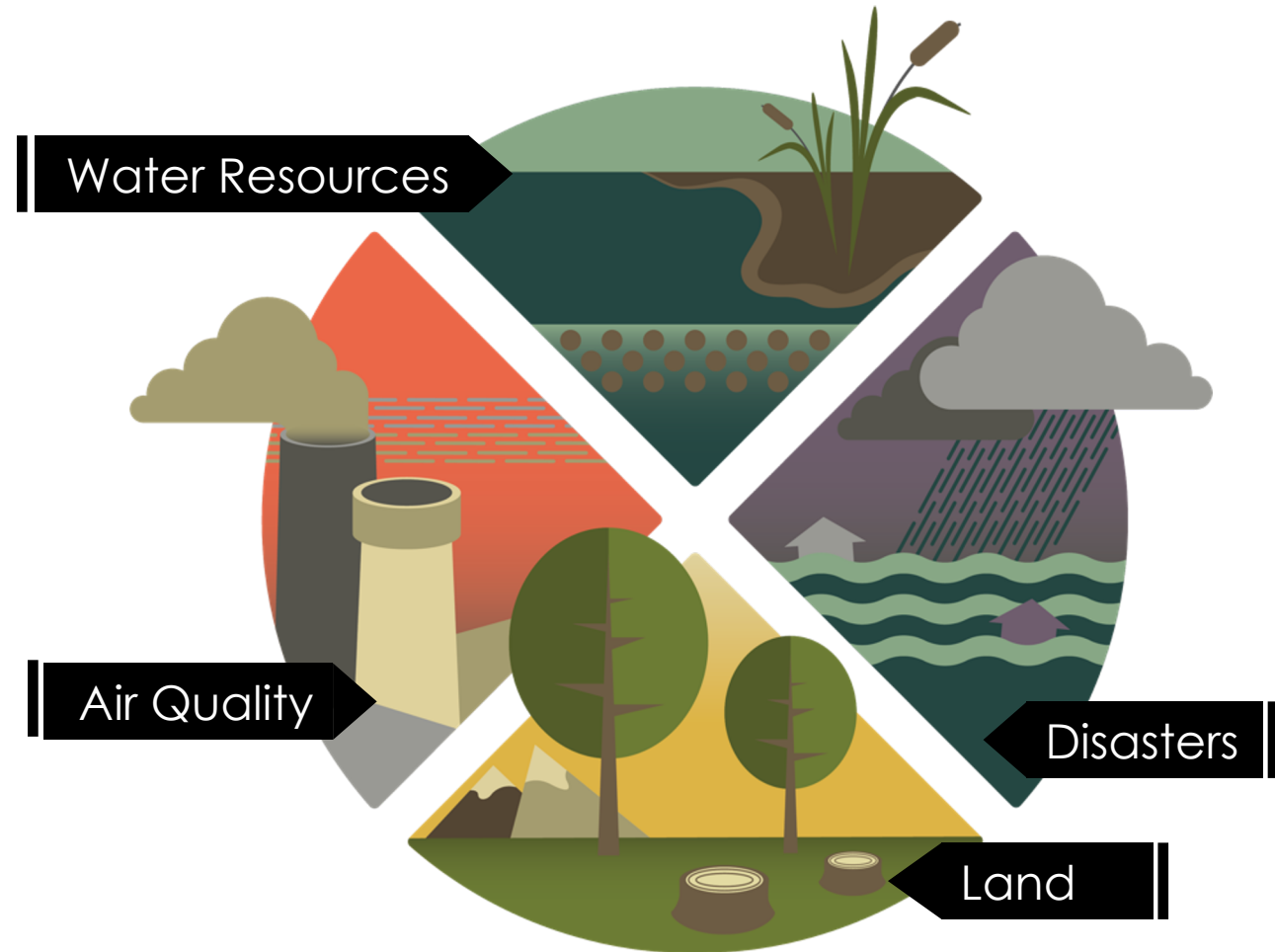


About ARSET

NASA's Applied Remote Sensing Training Program (ARSET)

<https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>

- Part of NASA's Applied Sciences Capacity Building Program
- Empowering the global community through online and in-person remote sensing training
- Topics for trainings include:
 - Water Resources
 - Air Quality
 - Disasters
 - Land



NASA's Applied Remote Sensing Training Program (ARSET)





<https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>

- ARSET's goal is to increase the use of Earth science in decision-making through training for:
 - Professionals in the public and private sector
 - Environmental managers
 - Policy makers

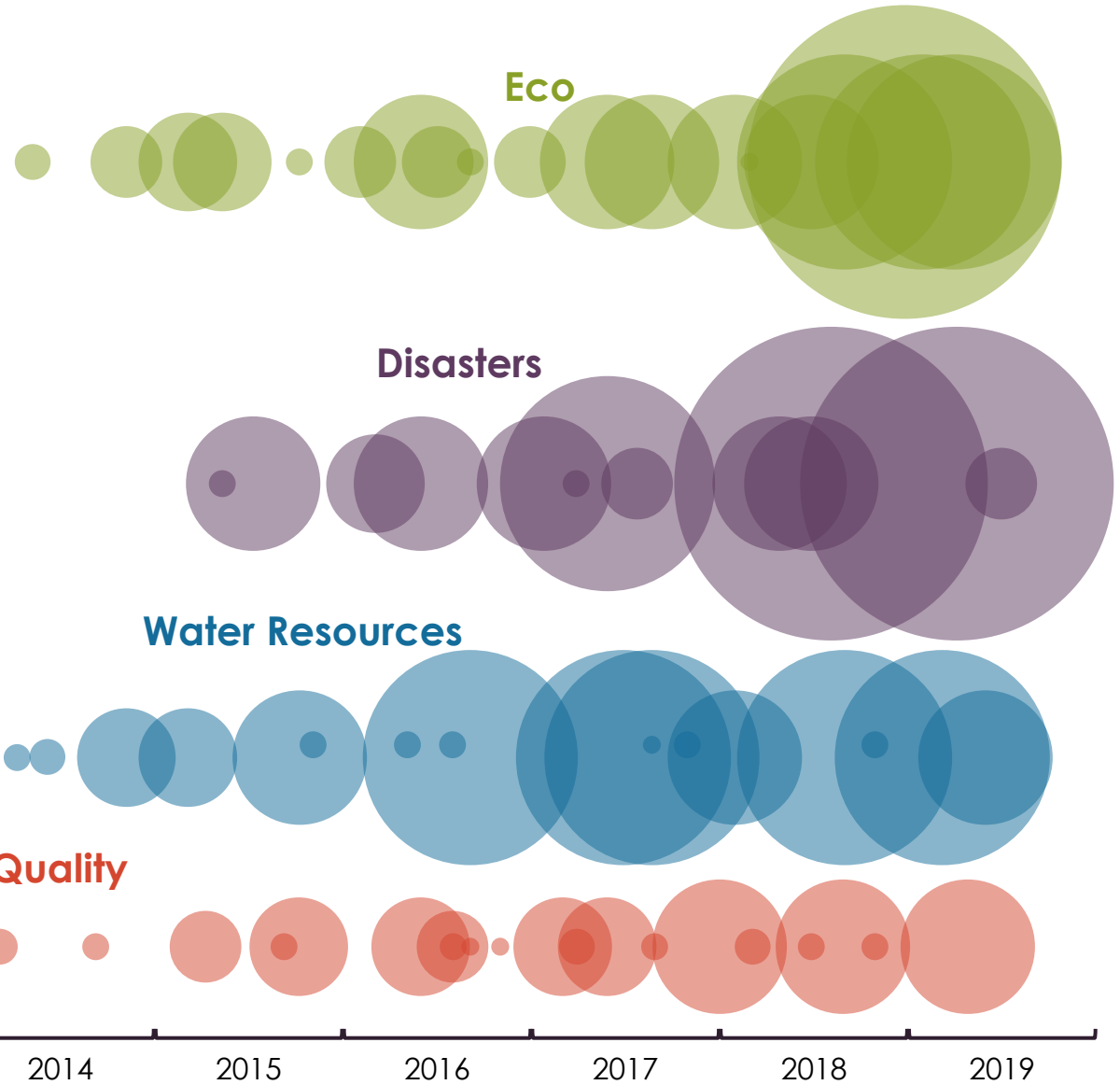
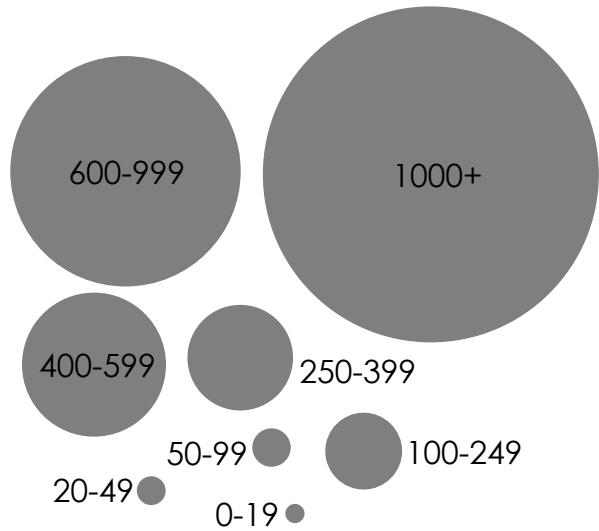
All ARSET materials are freely available to use and adapt for your curriculum. If you use the methods and data presented in ARSET trainings, please acknowledge the NASA Applied Remote Sensing Training (ARSET) program.



ARSET Trainings

 40,000+ participants
  170+ countries
 140+ trainings
  9,000+ organizations

Circle size corresponds to number of participants

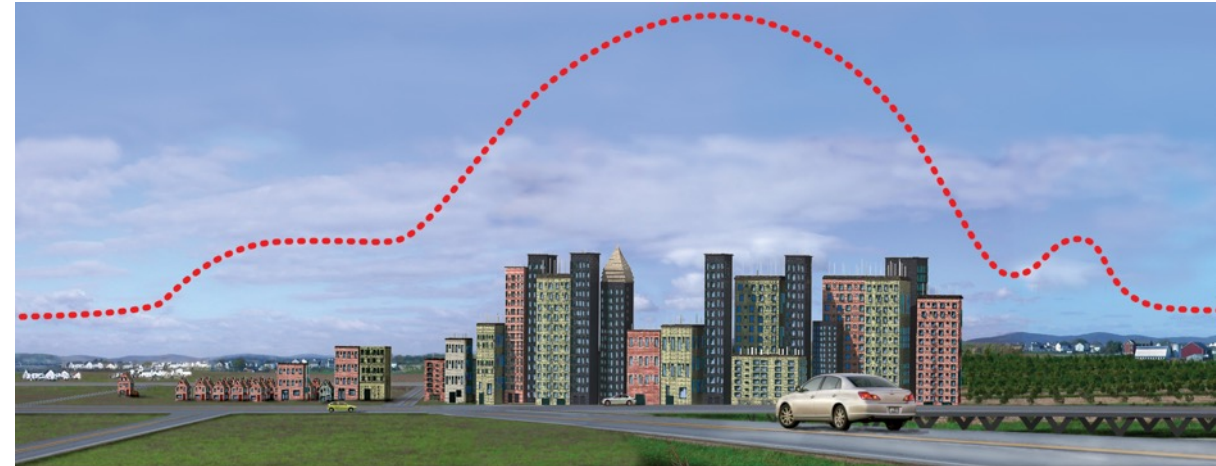




Overview of Urban Heat Islands

Urban Heat Islands

- Urban areas experience higher temperatures than outlying areas. This difference in temperature is what constitutes an urban heat island (UHI).
- Difference in temperature has to do with changes in radiative and thermal properties of impervious surfaces (i.e. heat-absorbing buildings and pavement).
- Temperatures vary within cities due to the spatial distribution of water, soil, vegetation, and impervious surfaces.

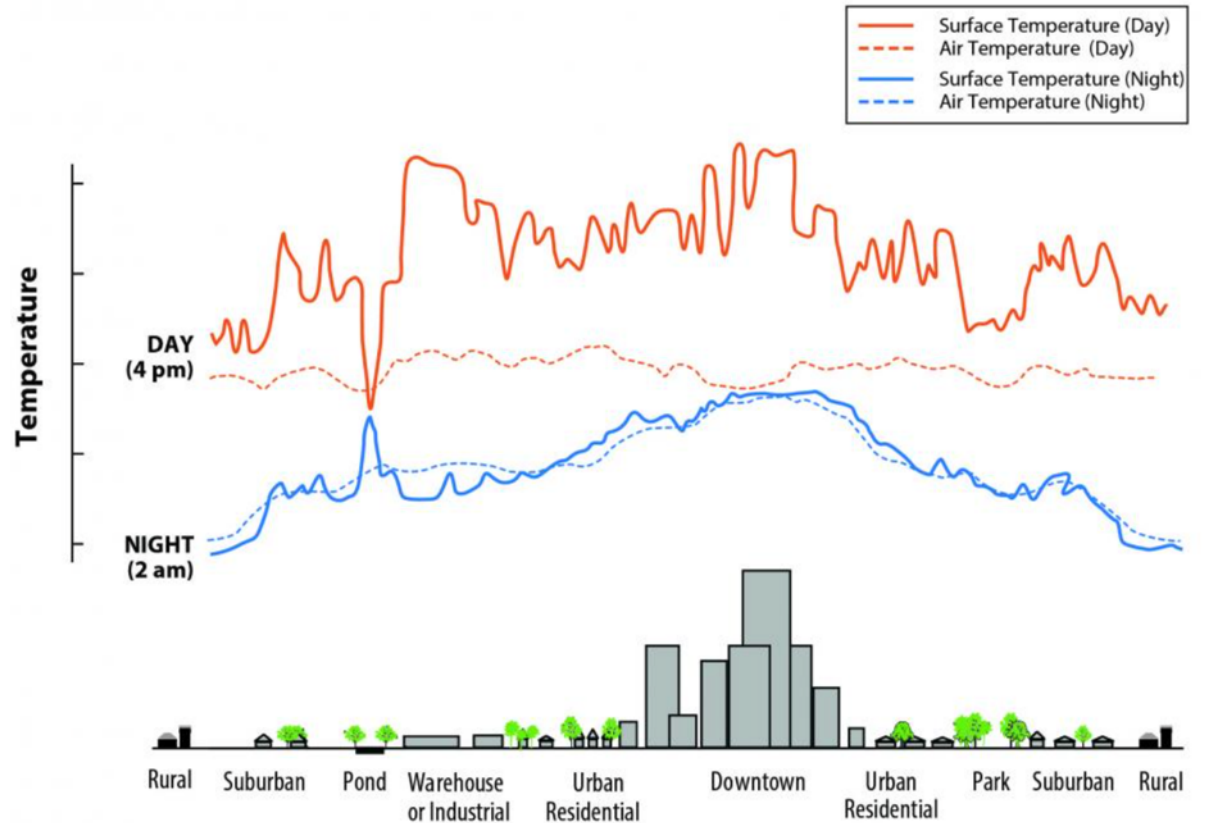


Credit: [NASA](#)



Urban Heat Islands

- Urban heat islands can form during the day or night, in small or large cities, and in any season.
- There are two types of urban heat islands:
 - Surface Urban Heat Islands
 - Atmospheric (i.e. air) Urban Heat Islands
- Surface temperatures vary more than air temperatures during the day but are more pronounced after sunset due to the slow release of heat from impervious surfaces.

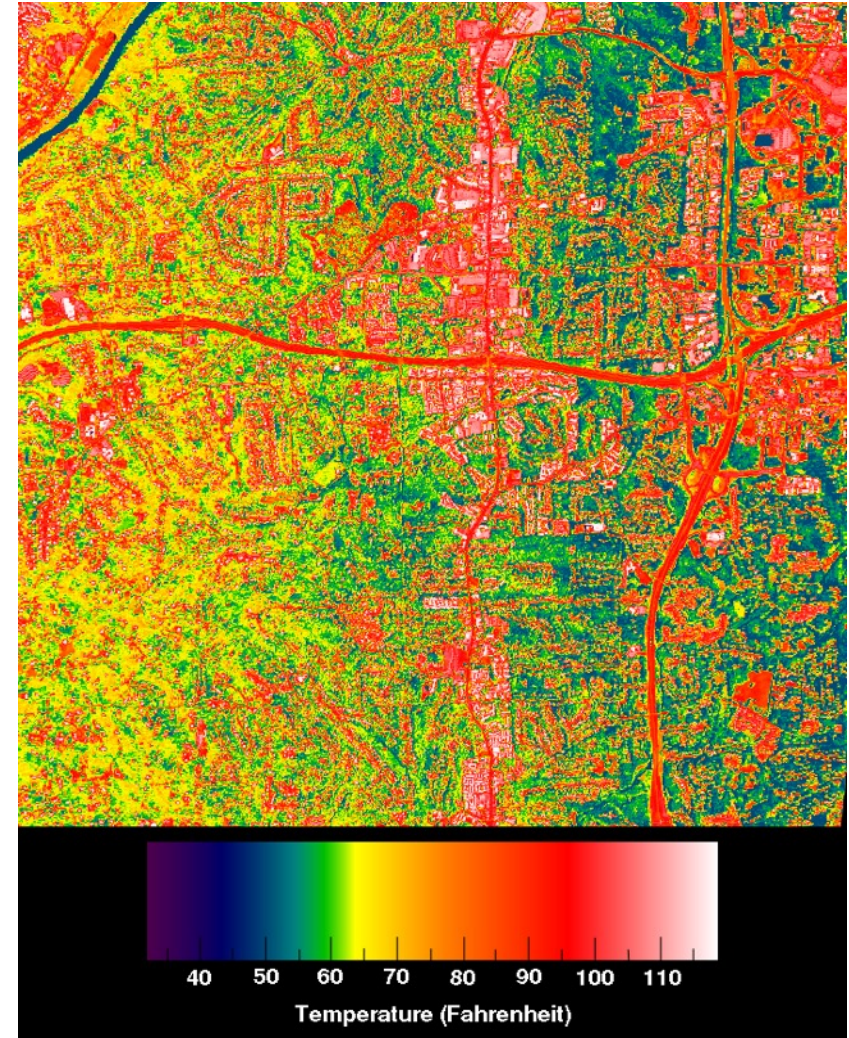


Credit: [EPA](#)



Surface Urban Heat Islands

- Surface Urban Heat Islands (SUHI) represent the radiative temperature difference between impervious and natural surfaces.
 - SUHIs tend to be most intense during the day when the sun is shining.
 - Magnitude varies with seasons, but it is typically largest in the summer.
 - SUHIs are primarily measured by remote sensing in the thermal infrared (TIR) region of the electromagnetic (EM) spectrum.



Credit: [NASA Goddard's Scientific Visualization Studio](#)



Atmospheric Urban Heat Islands

- Atmospheric Urban Heat Islands (AUHI) refer to effects in the **canopy layer** or **boundary layer**.
 - **Canopy layer** heat island (CLHI) is the layer of air from the surface to treetops/rooftops.
 - Measured by in situ sensors mounted on fixed meteorological stations or mobile traverses.
 - **Boundary layer** heat islands (BLHI) extend from treetops/rooftops to where urban landscapes no longer influence the atmosphere (~1.5 km).
 - Measured by tall towers, radiosondes, and aircraft.



Credit: [NOAA](#)



Causes of Urban Heat Islands

- Albedo & Infrastructure
 - Asphalt, concrete, and brick absorb—rather than reflect—the sun's heat, causing surface temperatures and air temperatures to rise due to their thermal storage capacity.
- Reduced vegetation in urban areas
 - Minimizes the natural cooling effects of shading and evapotranspiration from soil and vegetation.
- Anthropogenic heat
 - Vehicles, air-conditioning units, buildings, and industrial facilities all emit heat into the urban environment.



Credit: [Anthony Quintano](#)



Causes of Urban Heat Islands

- Urban geometry
 - Tall buildings act as obstacles and reduce wind flow which would bring cooling effects.
- Weather
 - Calm and clear weather conditions result in maximizing amounts of solar energy reaching urban surfaces. Conversely, strong winds and cloud cover suppress heat island formation.
- Geography
 - Large bodies of water can moderate temperature while nearby mountains can block wind or create wind patterns that pass through a city.



Credit: [Pikrepo](#)

<https://www.epa.gov/heat-islands/heat-island-compendium>



Why are Urban Heat Islands a problem?

- Increased risk of heat-related mortality and morbidity
 - Children, older adults, and those with existing health conditions are particularly at risk.
 - UHIs contribute to respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.
- Increased energy consumption
 - Heat islands increase both overall electricity demand as well as peak energy demand.
 - During extreme heat events, demand for cooling can overload systems and require a utility to institute controlled, rolling brownouts or blackouts to avoid power outages.



Credit: [NIEHS](#)



Why are Urban Heat Islands a problem?

- Elevated emissions of air pollutants and greenhouse gases
 - Electricity suppliers typically rely on fossil fuel power plants to meet demand.
 - Elevated air temperatures increase the rate of ground-level ozone formation.
- Water quality
 - Surface urban heat islands degrade water quality, mainly by thermal pollution.
 - Water temperature affects all aspects of aquatic life, especially the metabolism and reproduction of many aquatic species.



Credit: [NOAA](#)



Monitoring Urban Heat Islands – CLHI

- Canopy layer heat island (CLHI) is the layer of air from from ground to the tops of trees and buildings.
- Useful in mitigating public health risks since it is the best indicator of conditions experienced by people.
- Measured by in situ sensors on fixed meteorological stations or traverses, and by climate models to estimate temperatures in places where no field data are available.
- Due to limited monitoring stations, measured CLHI provides insufficient spatial detail for urban planning (Anniballe et al., 2014).

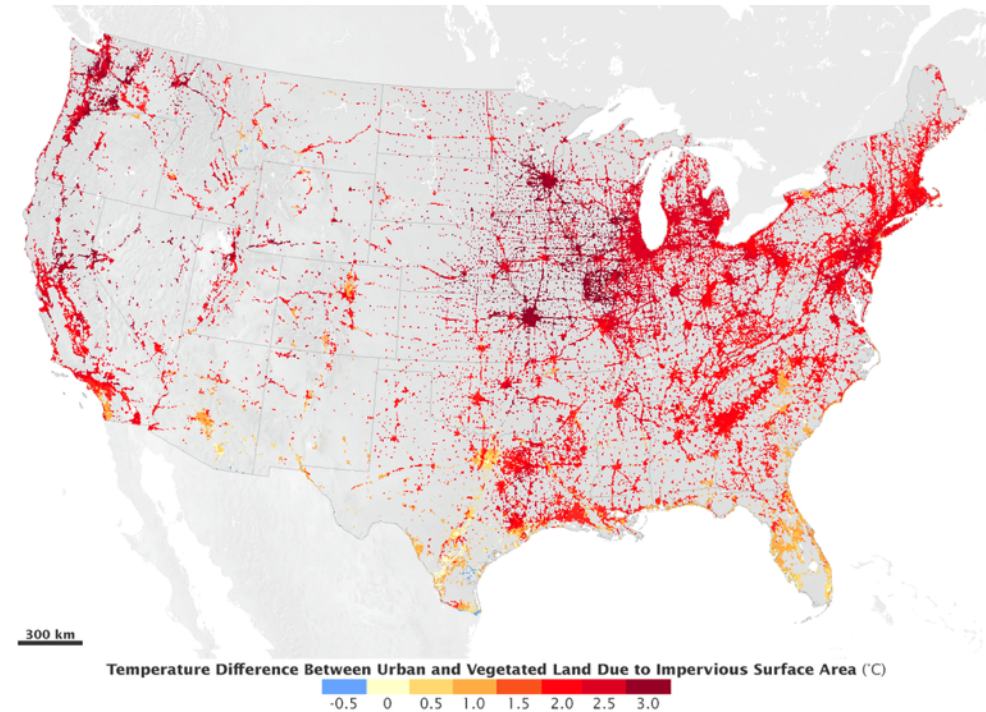


Credit: [David Sailor/Edison-Eastlake Measurement Campaign/Associated Press](#)



Monitoring Urban Heat Islands – SUHI

- Surface Urban Heat Islands (SUHI) represent the difference of land surface temperature (LST) in urban relative to non-urban areas, as well as “hot spots” within urban areas, and are usually measured using satellite data.
- Satellite thermal remote sensing measures SUHI and provides consistent and repeatable observations of the Earth’s surface.
- Remote sensing offers the ability to study the urban thermal environment at various spatial (from local to global) and temporal (diurnal, seasonal, and inter-annual) scales (Weng, 2009).



Credit: [NASA](#)





Satellites and Sensors Used in Analyzing Urban Heat Islands

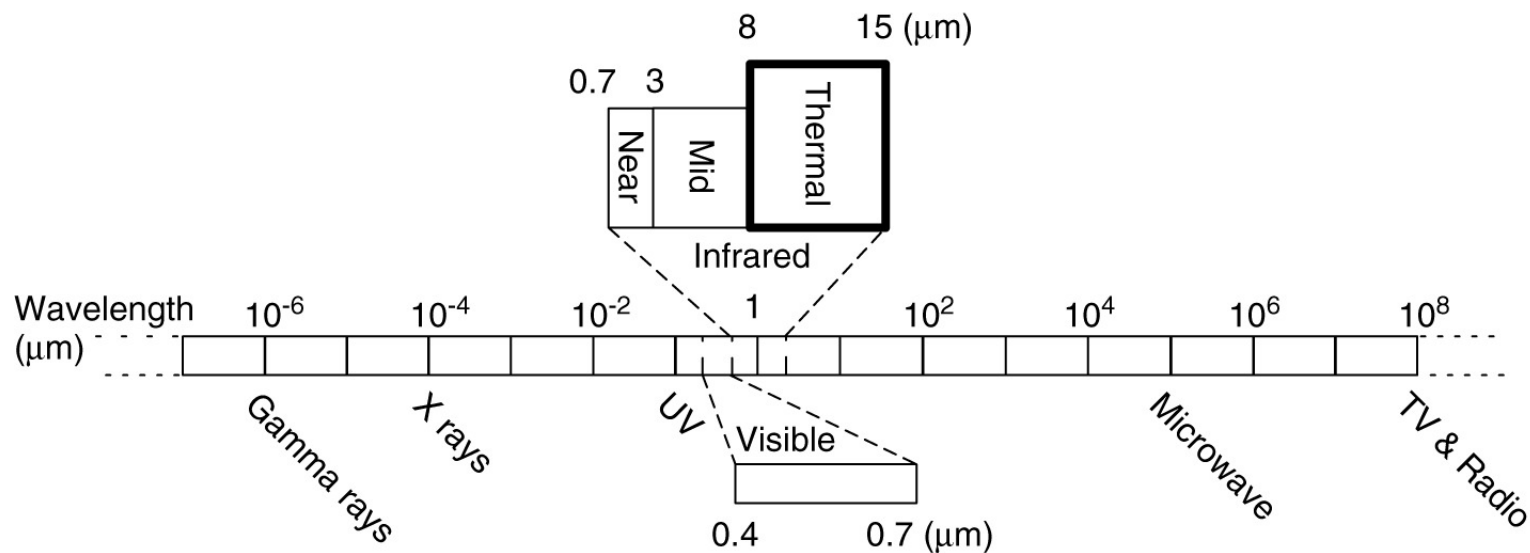
Outline

- Remote Sensing of Land Surface Temperature (LST) for Surface Urban Heat Island (SUHI) Monitoring
- Satellites and Sensors for Estimating LST
- LST Data Products
- Ancillary Data for UHI Vulnerability and Impact Analysis
- Benefits and Limitations of Satellite Measurements for Monitoring UHI



Remote Sensing of LST

- Thermal Infrared (TIR) wavelengths between 8 to 15 micrometers (μm) are commonly used for LST estimation.

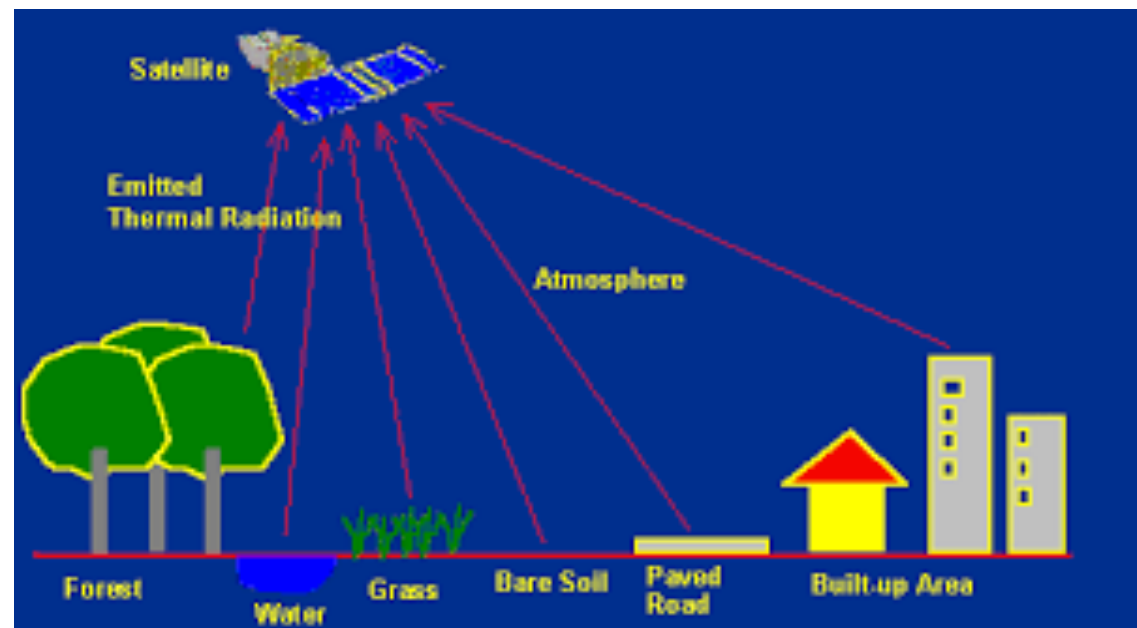


Tomlinson et al., (2011)



Remote Sensing of LST

- Satellite TIR sensors measure top of the atmosphere (TOA) radiance emitted by the Earth's surface and atmosphere.
- The TOA radiances are affected by:
 - Surface emissivity (built-up areas, vegetation, bare soil, etc.)
 - Atmospheric attenuation (water vapor and aerosols)
 - Angle at which a satellite sensor receives the radiation.

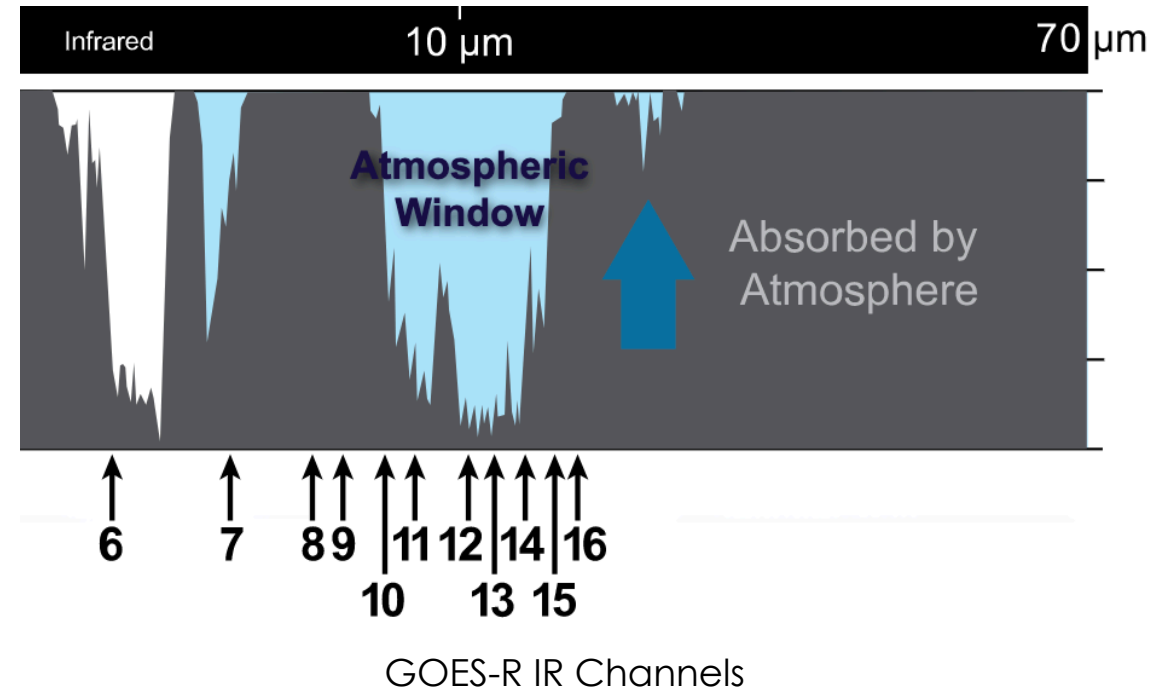


<https://crisp.nus.edu.sg/~research/tutorial/infrared.htm>



Remote Sensing of LST

- Atmospheric Window: Around 10-12 micrometers the atmosphere has relatively low absorption of IR radiation emitted by the land surface. Therefore, this spectral region is used to derive LST.
- Using either one or multiple IR bands, techniques are developed to obtain LST (Rosenstein et al, 2014).
- A review of methodologies for retrieving LST and land surface emissivity can be found in Zhou and Cheng (2020).



<https://www.weather.gov/jetstream/satellites>

Several polar orbiting and geostationary satellites have sensors observing in one or multiple bands in this IR spectral range.



Satellites and Sensors for Estimating LST

Satellite	Sensor	Temporal Coverage
*Landsat 4 Landsat 5 Landsat 7 Landsat 8	Thematic Mapper (TM) Enhanced Thematic Mapper (ETM+) ¹ Operational Land Imager (OLI) Thermal Infrared Sensor (TIRS)	7/1982 -12/1993 3/1984 - 01/2013 4/1999 - Present 02/2013 - Present
Terra	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) & MODIS	12/1999 - Present
Aqua	MODerate-resolution Imaging Spectroradiometer (MODIS)	04/2002 - Present
International Space Station/ ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)	Prototype HypsIRI Thermal Infrared Radiometer (PHyTIR)	06/2018 - Present

*Landsats 1, 2, and 3 had a Multi Spectral Scanner that did not have thermal IR bands.

¹Used for land cover/NDVI/impermeable surface



Satellites and Sensors for Estimating LST

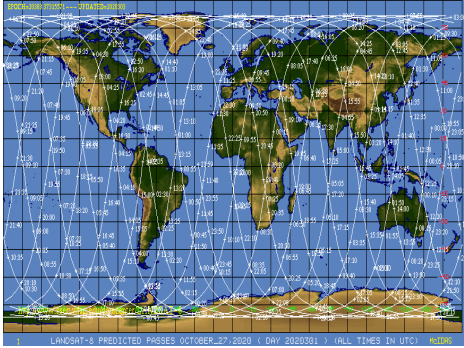
Satellite	Sensor	Temporal Coverage
*Suomi National Polar Partnership (NSPP) Joint Polar Satellite System-1 (NOAA 20)	Visible Infrared Imaging Radiometer Suite (VIIRS)	10/2011 - Present 11/2018 - Present
NOAA Operational Series Current: NOAA 15,18,19 ESA- Metop-A & B	Advance Very High-Resolution Radiometer (AVHRR)	1979 - Present
NOAA Geostationary Operational Environmental Satellites (GOES) Current: GOES-16 & GOES-17	Imager & Sounder Advance Baseline Imager (ABI)	1975 - Present
ESA - Sentinel 3A & 3B	Sea and Land Surface Temperature Radiometer (SLSTR)	02/2016 - Present 04/2018 - Present
ESA - Sentinel 2A & 2B	¹ MultiSpectral Instrument (MSI)	07/2015 - Present 03/2017 - Present

*NOAA Prime PM mission since 05/2014

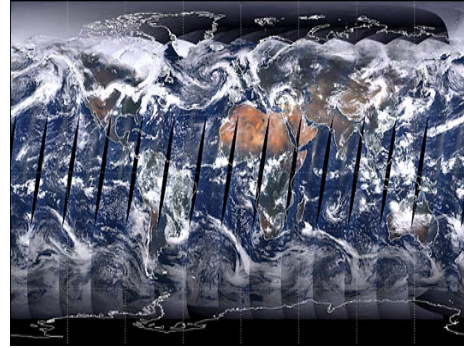
¹Used for land cover



Satellites and Sensors for Estimating LST



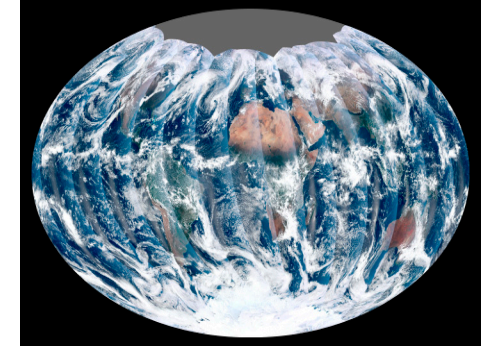
Credit: [University of Wisconsin-Madison Space Science and Engineering Center](#)



Credit: [Earth Observatory](#)



Credit: [NASA JPL](#)



Credit: [NASA Earth Observatory](#)

Landsat series: TM, ETM+, OLI, TIRS:
Orbit: Polar, 10 am/pm
Swath: 185 km

Terra & Aqua: MODIS
Orbit: Polar, 10:30 (Terra) & 1:30 (Aqua) am/pm
Swath: 2330 km

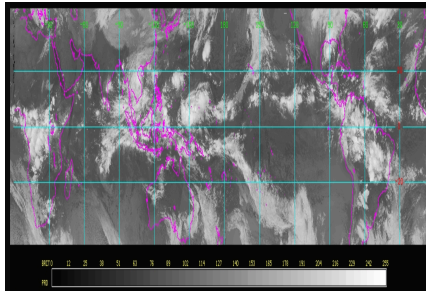
Terra: ASTER
Swath: 60 km

ISS: ECOSTRESS
Swath: 385 to 415 km
Varying temporal samplings

SNPP & JPSS: VIIRS
Orbit: Polar, 1:30 am/pm
Swath: 3000 km



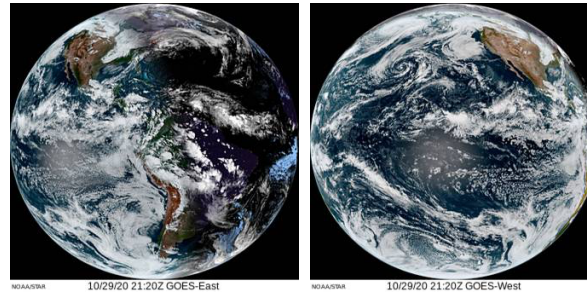
Satellites and Sensors for Estimating LST



Credit: [NOAA](#)

NOAA 19: AVHRR

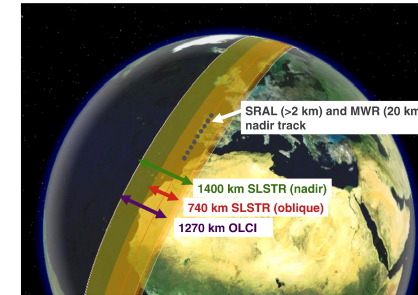
Orbit: Polar, 2:00 am/pm
Swath: 2900 km



Credits: [NOAA](#)

GOES: East (16) & West (17)

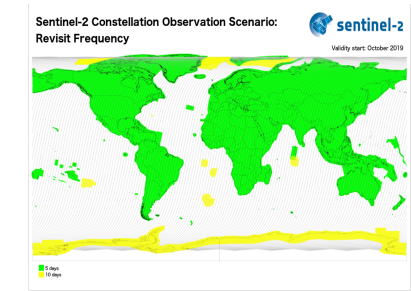
Orbit: Geostationary
10-minute Image Updates



Credit: [ESA](#)

Sentinel 3: SLSTR

Orbit: Polar, 10 am/pm
Swath: > 740 km



Credit: [ESA](#)

Sentinel 2: MSI

Orbit: Polar, 10:30 am/pm
Swath: 290 km



Spectral Bands for LST

- Each sensor (TM, ETM+, OLI/TIRS, MODIS, VIIRS, ABI, LSLTR, and PHyTIR) has **TIR spectral bands**.

Sensor	Spectral Bands (μm)	Spatial Resolution	Temporal Resolution	Sensor	Spectral Bands (μm)	Spatial Resolution	Temporal Resolution
TM	10.40 - 12.50	120 m (30 m resampled)	16 days	VIIRS	10.26 - 11.26 11.54 - 12.49	750 m	12 hours
ETM+ TIRS	10.40 - 12.50 10.6 - 11.19 11.50 - 12.51	60 m (30 m) 100 m 100 m					
MODIS	10.78 - 11.28 11.77 - 12.27	1 km	12 hours	AVHRR	10.30 - 11.30 11.5 - 12.50	1 km & 4 km	
ASTER	10.25 - 10.95 10.95 - 11.65	90 m	12 hours	VISSR ABI	10.10 - 10.60 10.80 - 11.60 11.80 - 12.80 13.0 - 13.6	2 km CONUS and Full Disk	minutes, hours, day/night
PHyTIR	8.28, 8.79, 9.06, 10.5, 12.05	60 m CONUS only	varies/every few days	SLSTR	10.45 - 11.24 11.57 - 12.48	1 km	12 hours



Satellite Radiance Data Access

Landsat TIRS & OLI: <https://earthexplorer.usgs.gov/>

Terra & Aqua MODIS: <https://modis.gsfc.nasa.gov/tools/>

Terra ASTER: https://lpdaac.usgs.gov/products/ast_09tv003/

ECOSTRESS: <https://ecostress.jpl.nasa.gov/data>

SNPP/JPSS VIIRS: <https://ladsweb.modaps.eosdis.nasa.gov/>

NOAA AVHRR: <https://www.ncdc.noaa.gov/cdr/fundamental/avhrr-radiances-nasa>

GOES: https://www.bou.class.noaa.gov/saa/products/search?datatype_family=GRABIPRD

Sentinel-3 SLSTR & Sentinel-2 MSI: <https://scihub.copernicus.eu/dhus/#/home>

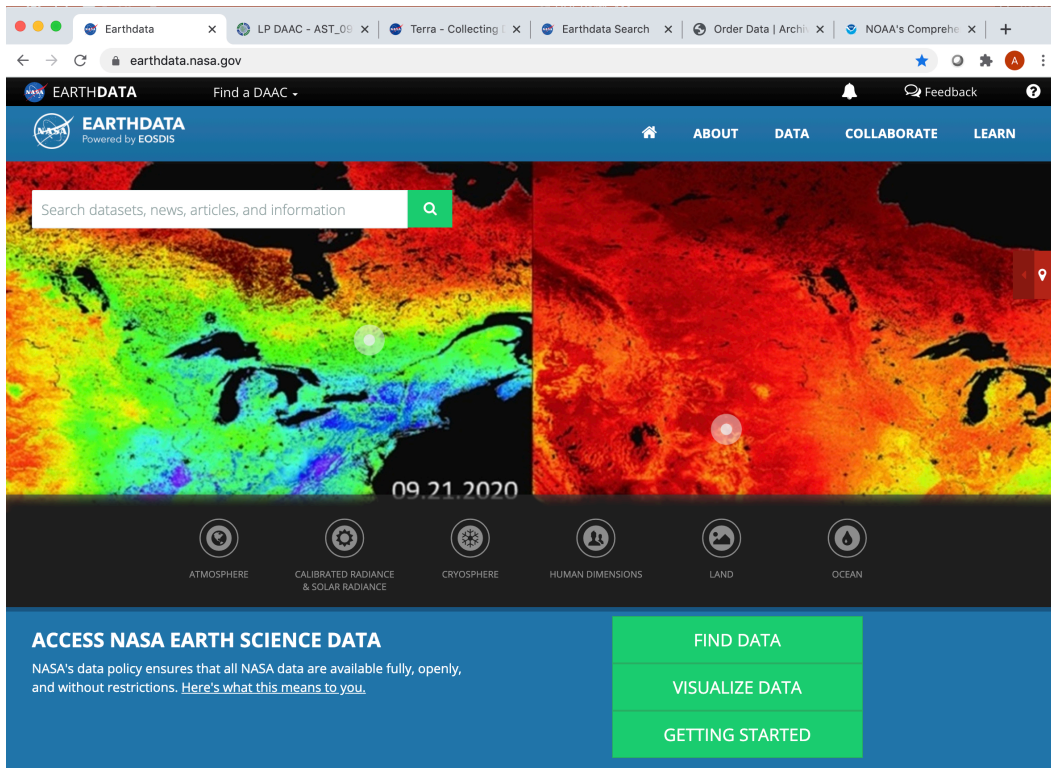


Satellite Radiance and Derived Products Data Search

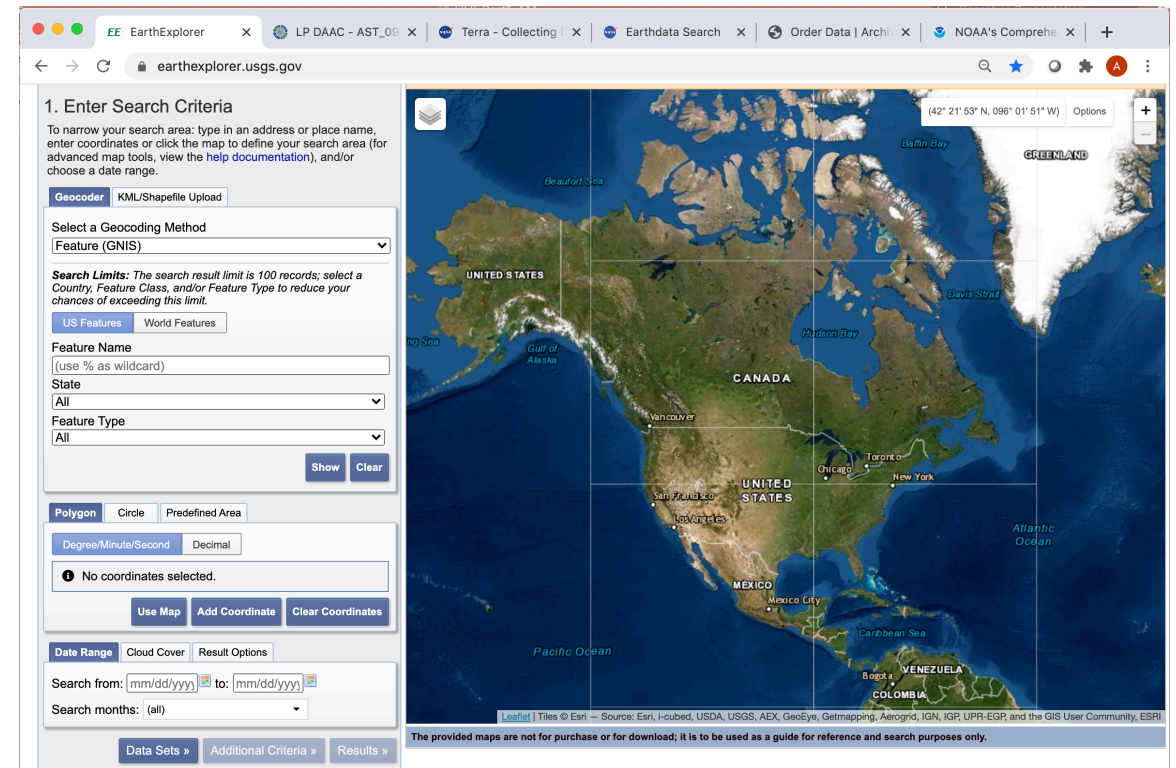
All NASA satellite data can be searched through the following sites

<https://earthdata.nasa.gov/>

<https://earthexplorer.usgs.gov/>



NASA EarthData



USGS EarthExplorer

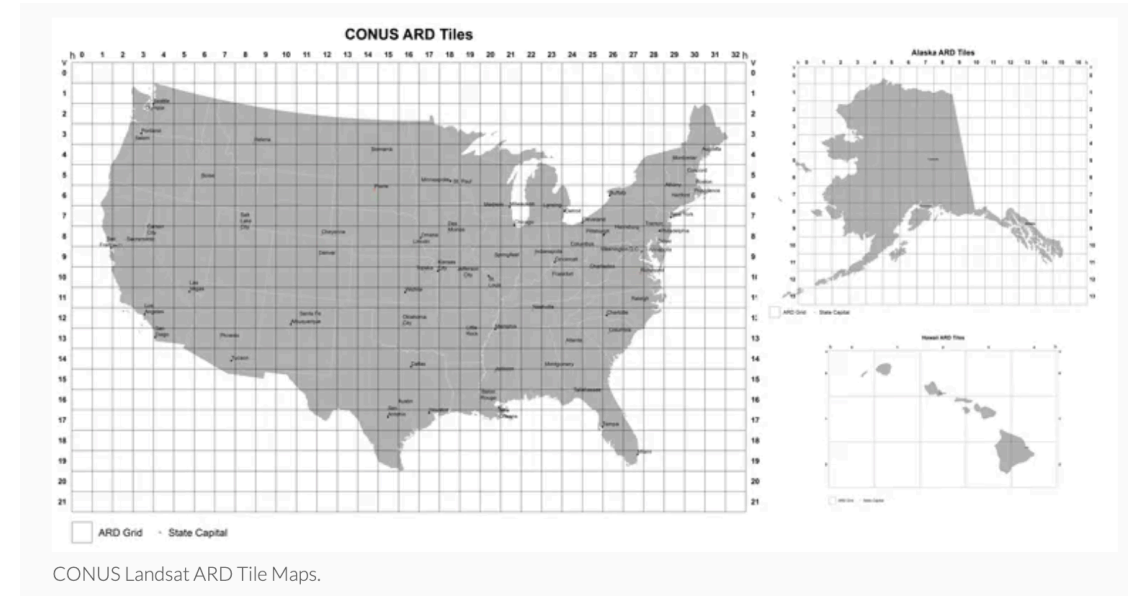




Land Surface Temperature Data Products

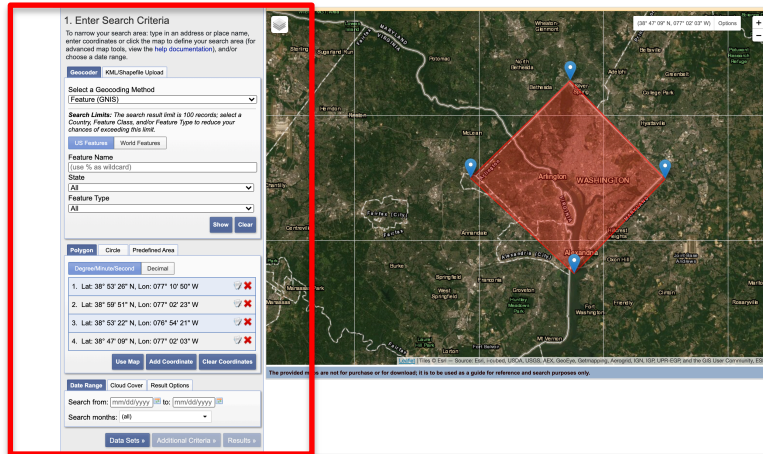
Landsat LST Data

- <https://www.usgs.gov/media/files/landsat-provisional-surface-temperature-product-guide>
- Provisional Land Surface Temperature based on Landsat 4-8 missions' TIR
- Part of U.S. Landsat Analysis Ready Data (ARD) products (1982 to present)
- ASTER Global Emissivity Database (GED) and NDVI data are used
- Atmospheric profiles of geopotential height, specific humidity, and air temperature extracted from reanalysis data
- Data available **for the U.S.** at 30 m resolution



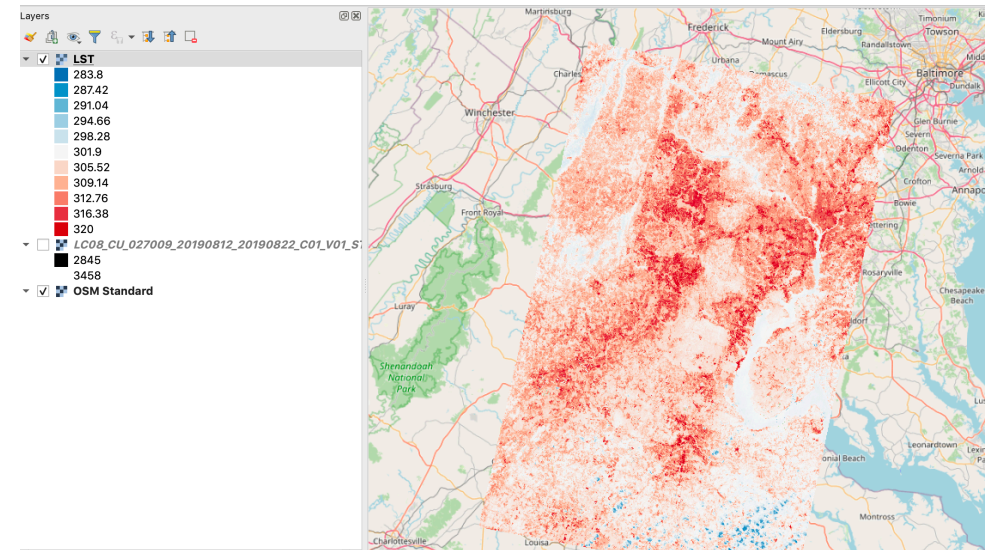
Landsat LST Data Access

<https://earthexplorer.usgs.gov/>



Spatial and Temporal Sub-setting

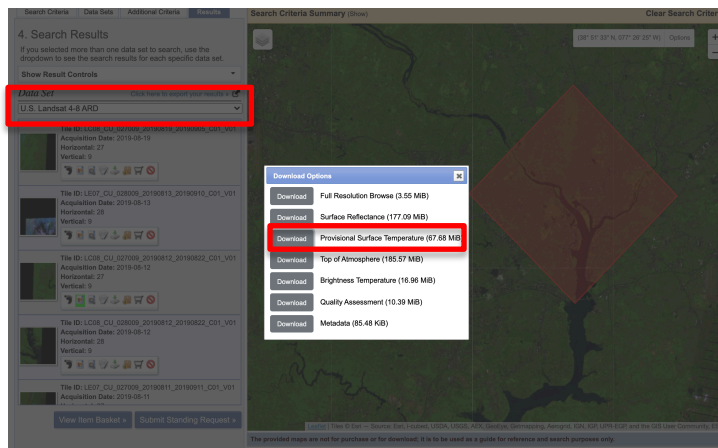
LST for Washington DC on 22 August 2019



Search Landsat ARD data.

Select 'surface temperature', select tiles, and download tiff images.

LST Viewed in QGIS:
There is a scale factor of 0.1



MODIS LST Data

<https://modis.gsfc.nasa.gov/data/dataproduct/mod21.php>

- A physics-based algorithm to retrieve the LST and Emissivity simultaneously
- Based on TIR bands at a spatial resolution of 1 km
- Based on the ASTER Temperature Emissivity Separation (TES) algorithm
- An improved Water Vapor atmospheric correction scheme
- Global data available since 2000

Product Name

Terra Product ID

Aqua Product ID

LST & Emissivity (E) Daily 5-Min L2 Swath 1km

[MOD21_L2](#)

[MYD21_L2](#)

LST & E Daily L3 Global 1km Day

[MOD21A1D](#)

[MYD21A1D](#)

LST & E Daily L3 Global 1km Night

[MOD21A1N](#)

[MYD21A1N](#)

LST & E 8-Day L3 Global 1km

[MOD21A2](#)

[MYD21A2](#)



VIIRS LST Data

<https://viirsland.gsfc.nasa.gov/Products/NASA/LSTESDR.html>

- The VIIRS Land Surface Temperature (LST) & Emissivity (E) are developed synergistically with the MODIS product.
- The same algorithmic approach is used in order to ensure data product continuity from MODIS to VIIRS.

Product Name	Product ID
LST & E Twice-Daily 6-min L2 Swath 750 m	VPN21_L2
LST & E Day L3 Global 1 km	VNP21A1D
LST & E Night L3 Global 1 km	VNP21A1N
LST & E 8-day L3 Global 1 km	VNP21A2



ECOSTRESS LST Data

<https://lpdaac.usgs.gov/products/eco2lstev001/>

- The ECOSTRESS collects data over the conterminous U.S. as well as key biomes and agricultural zones around the world, and at selected FLUXNET sites.
- Available in swaths with 70 m resolution.
- Atmospherically corrected LST&E values derived from five TIRS bands.
- A physics-based Temperature/Emissivity Separation (TES) algorithm is used.
- Available since 7/2018-07-09 to present at variable temporal resolution.

Product Name	Product ID
LST & E	ECO2LSTE



MODIS, VIIRS, ECOSTRESS Data Access

<https://lpdaacsvc.cr.usgs.gov/appeears/>

USGS AppEEARS

Welcome to *AppEEARS*!

Application for **E**xtracting and **E**xploring **A**nalysis **R**eady **S**amples
(*AppEEARS*)

The Application for Extracting and Exploring Analysis Ready Samples (*AppEEARS*) offers a simple and efficient way to access and transform geospatial data from a variety of federal data archives. *AppEEARS* enables users to subset **geospatial datasets** using spatial, temporal, and band/layer parameters. Two types of sample requests are available: **point samples** for geographic coordinates and **area samples** for spatial areas via vector polygons. Sample requests submitted to *AppEEARS* provide **more not only with** data values, but also associated quality data values. Interactive visualizations with summary statistics are provided for each sample within the application, which allow users to preview and interact with their samples before downloading their data. Get started with a sample request using the Extract option above, or visit the [Help page](#) to learn more.

For more information on details of using AppEEARS review this ARSET webinar:

<https://www.youtube.com/watch?v=KJTyMDyvBik>

Temporal
Sub-setting

Product
Search

Format and
Projection

Spatial Sub-
setting

Extract Area Sample

Enter a name to identify your sample

LST

Upload a file or draw a polygon using the or icon

Drop a vector polygon file containing the area feature(s) to extract or [click here](#) to select the file.

Supported file formats:

- ESRI Shapefile (zip including .shp, .dbf, .prj, and .shx files)
- GeoJSON (.json or .geojson)

Start Date

End Date

Is Date Recurring?

Select the layers to include in the sample

Land Surface Temperature

Terra MODIS Land Surface Temperature & Emissivity (LST&E) MOD11A1.006, 1000m, Daily, (2000-02-24 to Present)

Terra MODIS Land Surface Temperature & Emissivity (LST&E) MOD11A2.006, 1000m, 8 day, (2000-02-18 to Present)

Aqua MODIS Land Surface Temperature & Emissivity (LST&E) MYD11A1.006, 1000m, Daily, (2002-07-04 to Present)

Aqua MODIS Land Surface Temperature & Emissivity (LST&E) MYD11A2.006, 1000m, 8 day, (2002-07-04 to Present)

Aqua MODIS Land Surface Temperature & Emissivity (LST&E)

Output Options

File Format:

Projection:

NOTE: Be aware that any reprojection of data from its source projection to a different projection will inherently change the data from its original format. All reprojections use GDAL's [gdalwarp](#) function in combination with the PROJ.4 string listed above. For additional information, see the [AppEEARS help documentation](#).



ASTER LST Data

https://lpdaac.usgs.gov/products/ast_08v003/

- The ASTER Surface Kinetic Temperature is generated from five TIR bands. (Global LST are available at 90 m spatial resolution.)
- Available since 03/2000 with variable temporal resolution
- Using the TIR, emissivity and LST are derived iteratively.
- Temperature/Emissivity Separation (TES) algorithm along with atmospheric correction is used

Product Name	Product ID
LST	AST_08
Emissivity	AST_03



Access ASTER LST

- [https://search.earthdata.nasa.gov/search/granules?p=C1299783630-LPDAAC_ECS&pg\[0\]\[gsk\]=-start_date&q=C1299783630-LPDAAC_ES&tl=1588271332!4!!](https://search.earthdata.nasa.gov/search/granules?p=C1299783630-LPDAAC_ECS&pg[0][gsk]=-start_date&q=C1299783630-LPDAAC_ES&tl=1588271332!4!!)

Product Search

The screenshot displays the NASA Earthdata Search interface for the product 'ASTER L2 Surface Temperature V003'. The page shows 569 granules. A red box highlights the 'Download All 569 Granules' button. The interface includes a sidebar with spatial filters (SW: 38.68831, -77.17676; NE: 39.03969, -76.81201) and a temporal selection bar at the bottom showing the years 2013 through 2020. The main content area displays a grid of granule thumbnails with their respective start and end dates.

Spatial Sub-setting

Temporal Selection

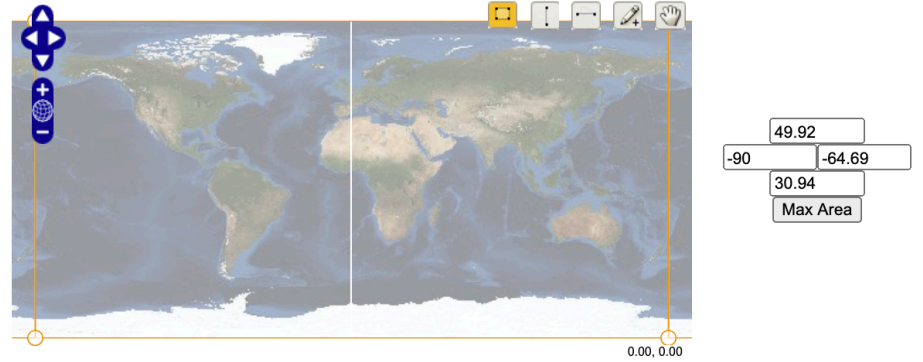


GOES LST Data

https://www.avl.class.noaa.gov/saa/products/search?datatype_family=GRABIPRD

- The GOES-16 & 17 LST contains images with instantaneous pixel values.
- Available at 10 km resolution for Full Disk and 2 km resolution for CONUS.
- Available from NOAA CLASS site starting in 5/2017 with time interval of 60-minute.

Spatial



49.92
-90 -64.69
30.94
Max Area

0.00, 0.00

Temporal
(maximum range is 366 days)

Start Date (format: YYYY-MM-DD) 2020-08-01 [calendar icon]
Start Time (UTC) (format: HH:MM:SS) 16:00:00

End Date (format: YYYY-MM-DD) 2020-08-10 [calendar icon]
End Time (UTC) (format: HH:MM:SS) 16:00:00

Specify the range of the times for: Each Day Or The Entire Range Of Days

Advanced Search

Datatype

- ABI L1b Radiances Data
- ABI L2+ Cloud & Moisture Imagery Data
- ABI L2+ Product Data (Select Product Type)

ABI Channel

- C01
- C02
- C03
- C04

Product Type

- Hurricane Intensity
- Land Surface (Skin) Temperature
- Legacy Vertical Moisture Profile
- Rainfall Rate/QPE

ABI Scan Sector

- Full Disk
- CONUS
- Mesoscale scene 1
- Mesoscale scene 2

Satellite

- G16
- G17

→





Ancillary Data Products for Urban Heat Island Vulnerability and Impact Analysis

Population Data

<http://sedac.ciesin.columbia.edu>

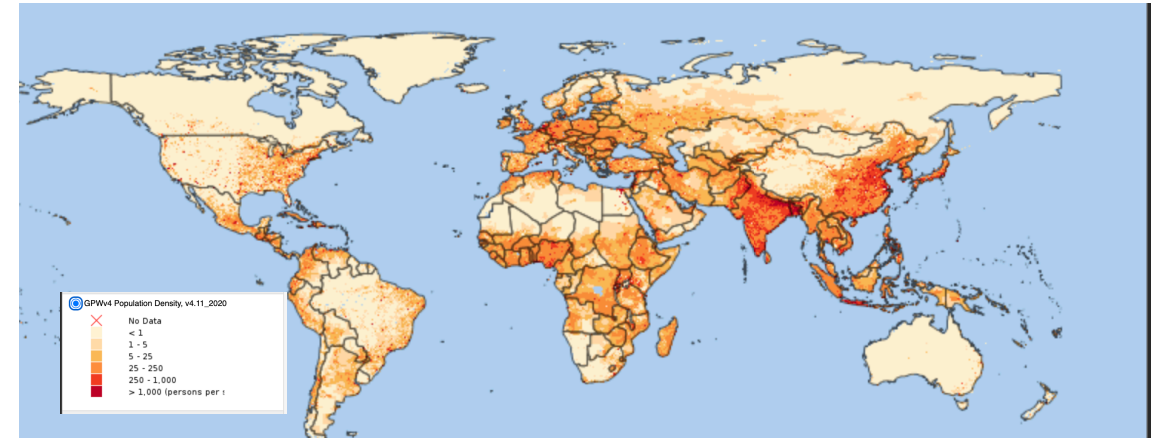
SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)
A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIESIN at Columbia University

DATA | MAPS | THEMES | RESOURCES | SOCIAL MEDIA | ABOUT | HELP

Data Collections (41)

1 of 2
Prev | Next

- Anthropogenic Biomes**
Describes 21 global anthropogenic biomes based on population density, land use, and vegetation cover, grouped into six categories—dense settlements, villages, croplands, rangeland, forested, and wildlands.
- Archive of Census Related Products (ACRP)**
A collection of value-added georeferenced data files derived from the 1990 U.S. Census, spanning the United States and its territories.
- China Dimensions**
A wide range of data from circa 1990, including administrative boundaries, population and agricultural census data, and other statistics, covering the administrative regions of China.
- Climate Effects on Food Supply**
Assessments of potential climate change impacts of temperature and precipitation on global staple crop production (wheat, rice, and maize), with a focus on quantitative estimates of yield changes based on multiple climate scenarios.
- Compendium of Environmental Sustainability Indicators**
A compilation of sustainability indicators from multiple sources incorporating multiple country codes. Methodological summaries are contained in an accompanying metadata database.
- Energy Infrastructure**
Data on the locations and status of nuclear power facilities along with estimates of the population residing near locations with at least one operating reactor.
- Environmental Performance Index (EPI)**
Released every two years since 2006, the EPI groups performance indicators into two policy categories, environmental health and ecosystem vitality, in order to gauge how close countries are to reaching established environmental policy goals.
- Environmental Sustainability Index (ESI)**
Released four times between 2000 and 2005, and based on a compilation of indicators derived from underlying data sets, the ESI measures overall progress towards environmental sustainability for 146 countries.
- Environmental Treaties and Resource Indicators (ENTRI)**
Information on treaty participation by country, environmental treaty texts, and a Conference of Party (COP) decision search tool for major multilateral environmental agreements.
- Georeferenced Population Data sets of Mexico**
Administrative boundaries, settlement locations and populations, and gridded population data for Mexico circa 1990. Includes place names, geographic coordinates of more than 30,000 urban and metropolitan places, and elevation data for
- Global Agricultural Lands**
Combines satellite data with agricultural inventory data to estimate the proportion of land area in cropland and pasture for the year 2000.
- Global Fertilizer and Manure, v1**
Global gridded data sets of fertilizer application rates and manure production of nitrogen and phosphorus for circa 2000.



Other Useful Datasets:

- Global Human Built-up And Settlement Extent (HBASE) Dataset From Landsat
- Global Grid of Probabilities of Urban Expansion to 2030, v1 (2000–2030)



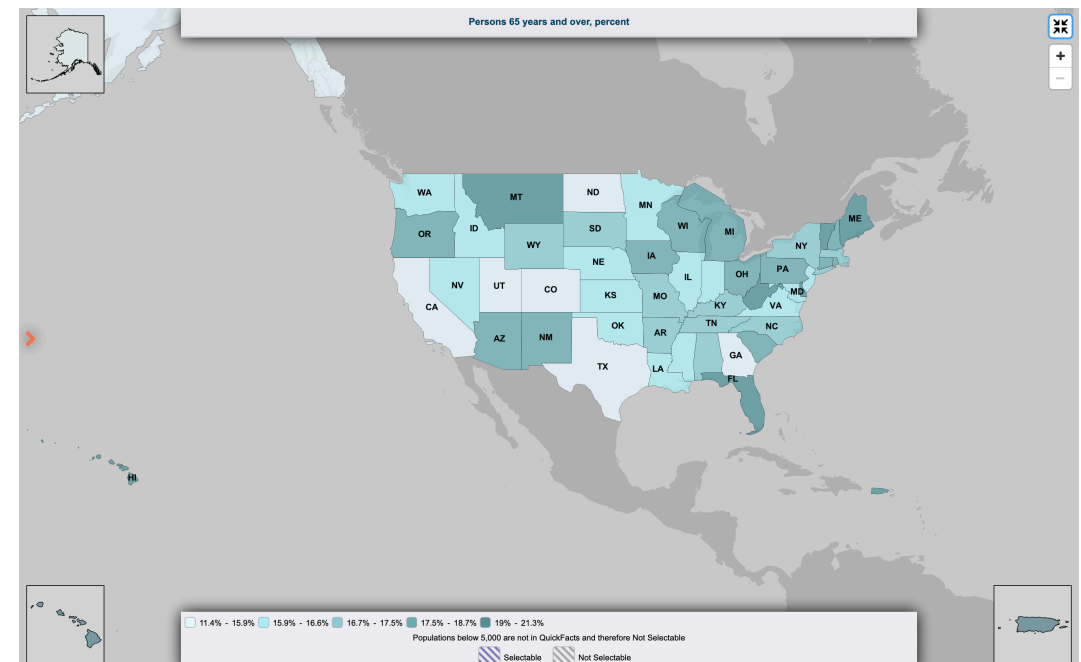
United States Census Bureau Data

<https://www.census.gov/data.html>

A variety of socioeconomic data available by state, county, and city.

The screenshot shows the 'QuickFacts' interface for the United States. A search bar is at the top left. A dropdown menu is open, listing various data categories such as 'Population', 'Age and Sex', 'Race and Hispanic Origin', 'Population Characteristics', and 'Housing'. The 'Population' category is selected, and a list of specific facts is shown, including 'Population estimates, July 1, 2019, (V2019)'. A table on the right shows data for the 'United States'.

Fact	Value
Population estimates, July 1, 2019, (V2019)	328,239,523
Population estimates base, April 1, 2010, (V2019)	308,758,105
Population, percent change - April 1, 2010 (estimates base) to July 1, 2019, (V2019)	6.3%
Population, Census, April 1, 2010	308,745,538



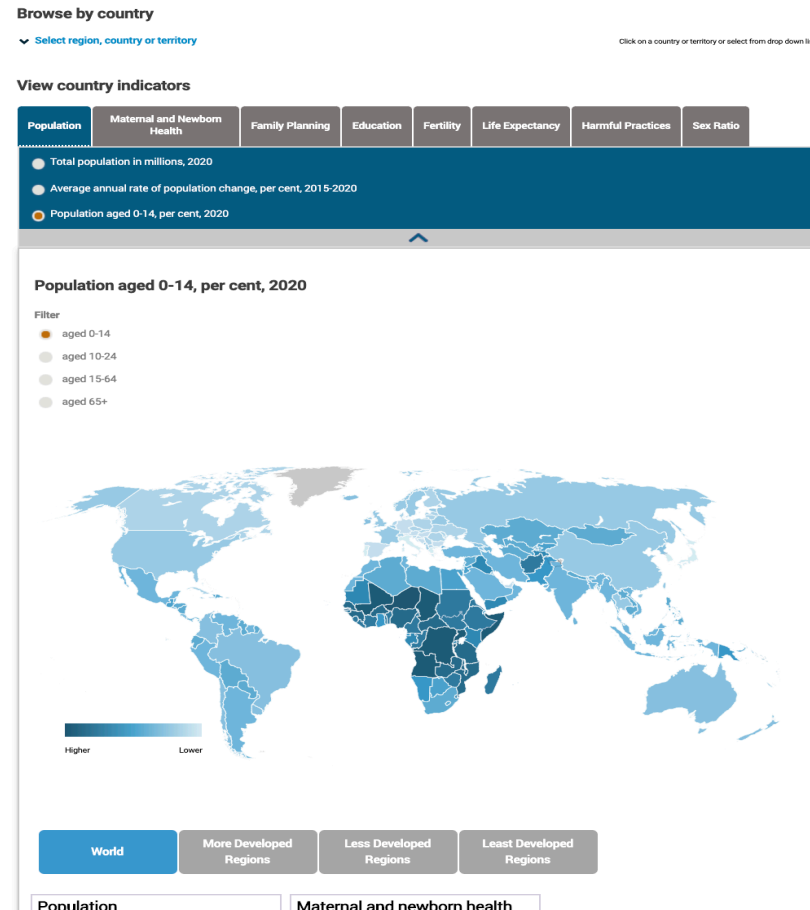
Population (%) above the age of 65 years



United Nations World Population Dashboard

<https://www.unfpa.org/data/world-population-dashboard>

Population data and development indicators



Limitations of Satellite Remote Sensing for Urban Heat Islands

- Data acquisition times of sun-synchronous satellites usually do not coincide with the time of day where the SUHI is at a minimum or maximum.
- The most widely used satellite for SUHI detection (i.e. Landsat) only has daytime data.
- Optical sensors cannot penetrate clouds or vegetative cover, which can lead to data gaps or a decrease in data utility.
- The accuracy of land surface temperature (LST) estimates depends strongly on corrections for atmospheric effects and an accurate estimate of surface emissivity.
- Radiances received by sensors are influenced by the sensor-viewing angle.
- It is difficult to obtain high spectral, spatial, and temporal resolution with the same instrument.
- A large amount of data exists in various spatial and temporal resolutions, file formats, sizes, and from multiple sources.



Benefits of Satellite Remote Sensing for Urban Heat Islands

- Continuous spatial coverage compared to in situ data
- Provides data where no systematic in situ measurements are available and augments where they are
- Simultaneous observations of LST, surface emissivity, and land cover from various satellites (e.g. Landsat/TM, ETM+, OLI & TIRS, MODIS, VIIRS, AVHRR)
- Global, consistent, data coverage from many satellites
- Availability of open-source data





Demo: Converting Thermal Infrared Data from the Landsat Series of Satellites to Land Surface Temperature Estimates Using Google Earth Engine

Google Earth Engine (GEE)

- Cloud based geospatial processing platform
- Available to scientists, researchers, and developers for analysis of the Earth
- Google's computational power
- Application Programming Interface (API)
- JavaScript code editor (Python available)
- Contains a catalog of satellite imagery and geospatial datasets:
 - <https://developers.google.com/earth-engine/datasets/catalog/>
- Sign up for a free account:
 - <https://earthengine.google.com/>

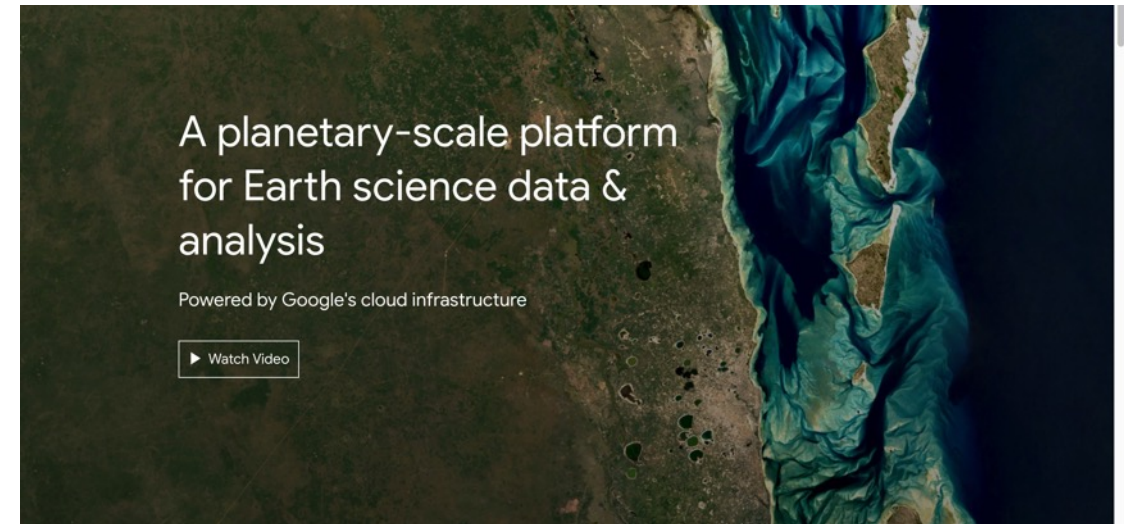


Image Credit: [Google](#)



Google Earth Engine (GEE)

The image shows a screenshot of the Google Earth Engine (GEE) web interface. The interface is divided into several sections:

- Search bar:** At the top, with the text "Search for datasets or places" pointing to it.
- Script manager:** On the left, with arrows pointing to "API documentation" and "Asset manager".
- Code Editor:** In the center, containing a JavaScript script for cloud masking. The text "Code Editor" is overlaid on it.
- Inspector/Console/Task manager:** On the right, with arrows pointing to "Help button", "Feedback button", "Task manager", "Console output", and "Inspect locations, pixel values, objects on the map".
- Map:** At the bottom, showing a satellite view of a coastal area. Labels include "Geometry Tools", "Zoom", and "Layer manager".

```
1 // This example uses the Sentinel-2 QA band to cloud mask
2 // the collection. The Sentinel-2 cloud flags are less
3 // selective, so the collection is also pre-filtered by a
4 // CLOUDY_PIXEL_PERCENTAGE flag, to use only relatively
5 // cloud-free imagery.
6
7 // Function to mask the Sentinel-2 QA band.
8 function maskQA(img) {
9   // Sentinel-2 QA band.
10  var qa = img.select('QA60');
11
12  // Bits 10 and 11 are clouds and cirrus, respectively.
13  var cloudMask = qa.select(10, 11).eq(0);
14
15  // Both flags are 1 if the pixel is cloudy or cirrus, indicating clear c
16  var mask = qa.bitwiseAnd(cloudMask).eq(0).and(
17    qa.bitwiseAnd(cirrusMask).eq(0));
18
19  // Return the masked and scaled data, without the QA ba
20  return img.updateMask(mask).divide(10000)
21    .select(['B.*']);
22}
```

Image Credit: [Google](https://www.google.com)



Google Earth Engine (GEE)

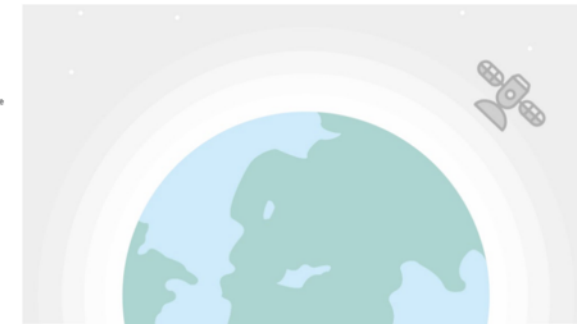
- Resources to learn more about Google Earth Engine:
 - [Developer's Guide](#)
 - [Google Earth Engine Developers Group](#)

Welcome to Google Earth Engine

Google Earth Engine is a geospatial processing service. With Earth Engine, you can perform geospatial processing at scale, powered by Google Cloud Platform. The purpose of Earth Engine is to:





- Provide an interactive platform for geospatial algorithm development at scale
- Enable high-impact, data-driven science
- Make substantive progress on global challenges that involve large geospatial datasets

[Get Started!](#)



About Google Earth Engine

Earth Engine is a public data catalog, compute infrastructure, geospatial APIs and an interactive app server.

 <p>Datasets</p> <p>Petabyte scale catalog of public and free-to-use geospatial datasets.</p> <p>Explore the Data Catalog</p>	 <p>Compute</p> <p>Leverage Google's cloud platform for planetary-scale analysis of Earth science data.</p> <p>Read the publication</p>	 <p>APIs</p> <p>Full-featured JavaScript, Python and REST APIs.</p> <p>Developer guides</p>	 <p>Apps</p> <p>Dynamic, publicly accessible user interfaces for Earth Engine analyses.</p> <p>Apps gallery</p>
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How to use Google Earth Engine

[Developer Guides](#)

Connect to the Earth Engine service through one of the APIs. Client libraries for JavaScript and Python translate complex geospatial analyses to Earth Engine requests. Or connect directly to Earth Engine servers using the REST API.




 <p>JavaScript</p> <p>Interactive JavaScript using the Code Editor, the open source JavaScript library in Node.js (learn more about Earth Engine in Node.js), or Earth Engine Apps.</p>	 <p>Python</p> <p>The open source Python library running in Colab, your Python environment, or App Engine (learn more about Earth Engine powered App Engine apps).</p>	 <p>REST</p> <p>Authenticated HTTP requests (learn more about the Earth Engine REST API). The REST API contains new and advanced features that may not be suitable for all users. If you are new to Earth Engine, please get started with the JavaScript guide.</p>
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Image Credit: [Google](#)



Computing Land Surface Temperature in GEE

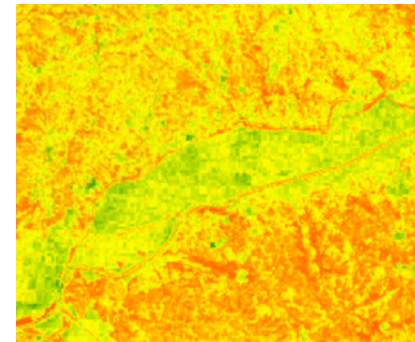
- The production chain was fully coded in JavaScript by Ermida et al. (2020) using the Code Editor Platform.
- Repository is freely available from the following GEE or Git repositories:
- GEE:
https://code.earthengine.google.com/?accept_repo=users/sofiaermida/landsat_smw_lst
- Git:
https://earthengine.google.com/users/sofiaermida/landsat_smw_lst

Ermida, S.L., Soares, P., Mantas, V., Götsche, F.-M., Trigo, I.F., 2020. Google Earth Engine open-source code for Land Surface Temperature estimation from the Landsat series. *Remote Sensing*, 12 (9), 1471; <https://doi.org/10.3390/rs12091471>



Computing Land Surface Temperature in GEE

- Land Surface Temperature is computed from Landsat 4-8 (TM, ETM+, OLI, TIRS) data using the Statistical Mono-Window (SMW) algorithm developed by CM-SAF.
- The approach is based on an empirical relationship between TOA brightness temperatures in a single TIR channel and LST utilizing simple linear regression (Freitas et al., 2013).
- All inputs to the LST algorithm are obtained from the [GEE Data Catalog](#).
 - Landsat Data (USGS)
 - Atmospheric Data (NCEP & NCAR)
 - Surface Emissivity from ASTER GED (NASA JPL)



Landsat Data Used for Estimating Land Surface Temperature

- Landsat satellite with instrument(s)
- Used bands from the instrument(s)
- Wavelength in micrometers (μm)
- GEE Dataset
- Spatial Resolution
- Equatorial Crossing Time
- Date Range

Satellite	Used Bands	Wavelength (μm)	Dataset	Spatial Resolution	E.C.T.	Date Range
Landsat 4 (TM)	Red: B3	0.63–0.69	C01/T1_SR	30 m	9:45 am (16-day)	22 August 1982 to 14 December 1993
	NIR: B4	0.76–0.90	C01/T1_SR	30 m		
	TIR: B6	10.4–12.5	C01/T1_TOA	120 ² m		
Landsat 5 (TM)	Red: B3	0.63–0.69	C01/T1_SR	30 m	9:45 am (16-day)	1 January 1984 to 5 May 2012
	NIR: B4	0.76–0.90	C01/T1_SR	30 m		
	TIR: B6	10.4–12.5	C01/T1_TOA	120 ² m		
Landsat 7 (ETM+)	Red: B3	0.63–0.69	C01/T1_SR	30 m	10:00 am (16-day)	1 January 1999 to present
	NIR: B4	0.77–0.90	C01/T1_SR	30 m		
	TIR: B6 ¹	10.4–12.5	C01/T1_TOA	60 ² m		
Landsat 8 (OLI; TIRS)	Red: B4	0.64–0.67	C01/T1_SR	30 m	10:00 am (16-day)	11 April 2013 to present
	NIR: B5	0.85–0.88	C01/T1_SR	30 m		
	TIR: B10	10.6–11.19	C01/T1_TOA	100 ² m		

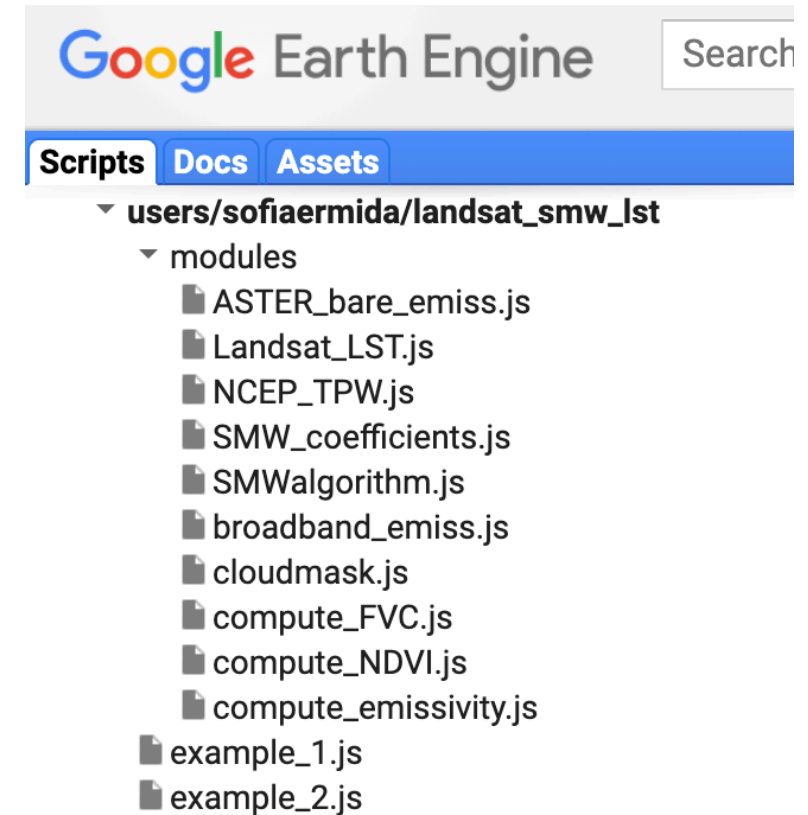
Note: ¹ low gain band (B6_VCID_1); ² resampled to 30 m.

Source: Ermida et al., 2020



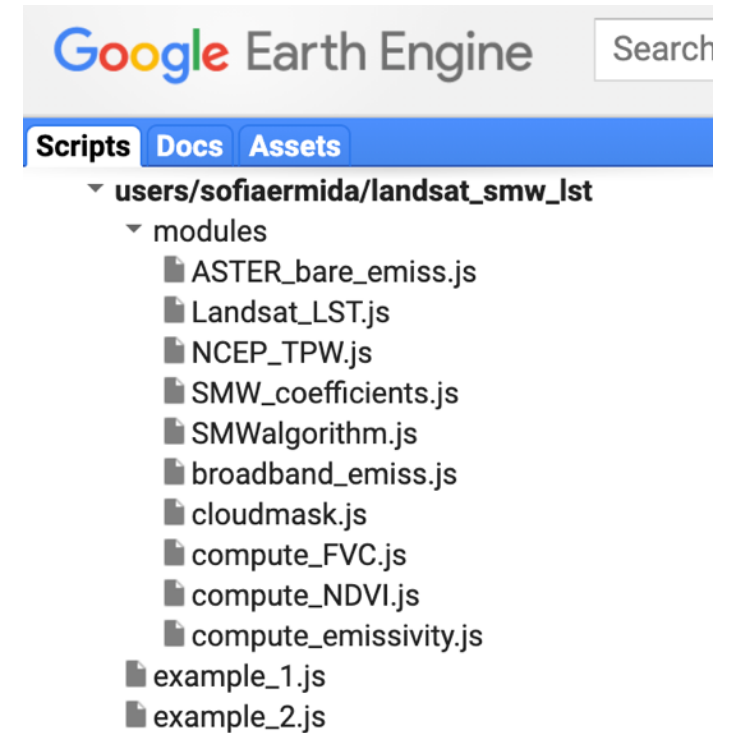
Computing Land Surface Temperature in GEE

- Launch the Google Earth Engine application.
- Add the repository from Ermida et al. (2020).
 - https://code.earthengine.google.com/?accept_repo=users/sofiaermida/landsat_smw_lst
- Confirm the repository and all associated modules have been added to your Scripts manager.



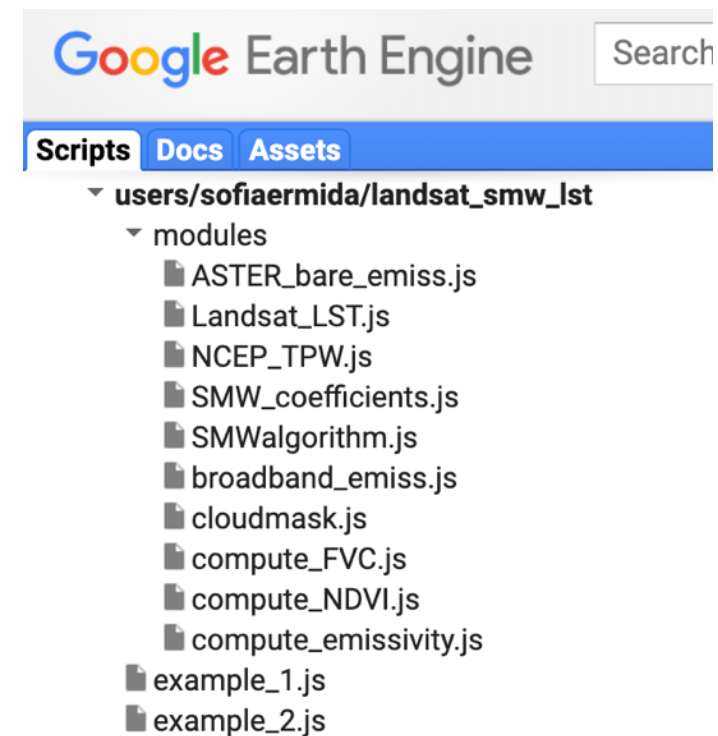
Computing Land Surface Temperature in GEE

- Each module contains reusable code (i.e. functions) that are shared between scripts to calculate LST.
- **ASTER_bare_emiss.js** – Applies a vegetation cover correction to ASTER emissivity in order to obtain a bare ground emissivity component at each pixel
- **Landsat_LST.js** – Selects the Landsat data based on user inputs and performs the LST computation
- **NCEP_TPW.js** – Matches the atmospheric water vapor data from NCEP reanalysis to each Landsat image
- **SMW_coefficients.js** – Coefficients for the Statistical Mono-Window Algorithm
- **SMWalgorithm.js** – Applies the Statistical Mono-Window algorithm to compute the LST



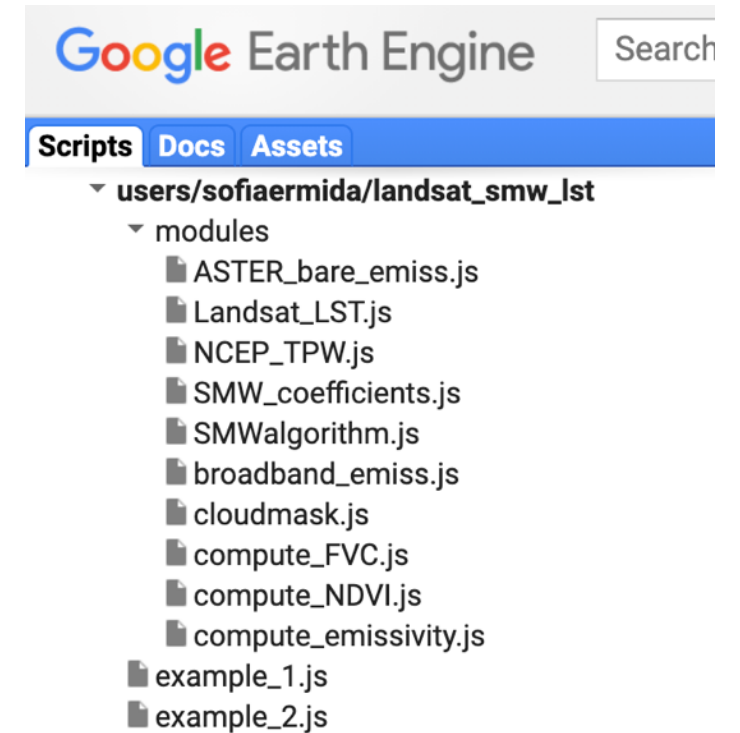
Computing Land Surface Temperature in GEE

- Each module contains reusable code (i.e. functions) that are shared between scripts to calculate LST.
- **Broadband_emiss.js** – Computes broad-band emissivity from ASTER GED
- **cloudmask.js** – Masks clouds and cloud shadow using the Quality band
- **compute_FVC.js** – Computes the Fraction of Vegetation Cover from NDVI
- **compute_NDVI.js** – Computes NDVI values for Landsat
- **compute_emissivity.js** – Computes surface emissivity for Landsat. Requires values from “compute_FVC.js”



Computing Land Surface Temperature in GEE

- **example_1.js**
 - Shows how to compute Landsat LST from Landsat-8 over Coimbra, Portugal
 - Corresponds to the example images shown in Ermida et al. (2020)
- **example_2.js**
 - Shows how to get LST time series at the SURFRAD DRA site
 - Corresponds to the method used to extract time series for comparison with station LST used in Ermida et al. (2020)



Computing Land Surface Temperature in GEE

- To modify the code for your study area, users need to specify the following inputs in `example_1.js`
 - geometry: <ee.Geometry>
 - Region of interest
 - landsat: <string>
 - The Landsat satellite id
 - Valid Inputs: 'L4', 'L5', 'L7' and 'L8'
 - date_start: <string>
 - Start date of the Landsat collection
 - Format: YYYY-MM-DD
 - date_end: <string>
 - End date of the Landsat collection
 - Format: YYYY-MM-DD
 - use_ndvi: <boolean>
 - If true, NDVI values are used to obtain a dynamic emissivity; if false, emissivity is obtained directly from ASTER.

```
// select region of interest, date range, and landsat satellite
var geometry = ee.Geometry.Rectangle([-8.91, 40.0, -8.3, 40.4]);
var satellite = 'L8';
var date_start = '2018-05-15';
var date_end = '2018-05-31';
var use_ndvi = true;
```



Get Involved – GLOBE Citizen Science

- The Global Learning and Observations to Benefit the Environment (GLOBE) Program is an international science and education program that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process.
- GLOBE UHI Data Collection Campaign: <https://www.globe.gov/web/surface-temperature-field-campaign>
- GLOBE Surface Temperature Protocol eTraining: <https://www.globe.gov/get-trained/protocol-ettraining/etraining-modules/16867642/12267>



THE GLOBE PROGRAM

Credit: [GLOBE](#)



Student Activities – My NASA Data

- My NASA Data provides grade 3-12 teachers access to NASA mission data through unique tools that help students learn about Earth system science. The project's value is providing Earth science data resources that are teacher- and student-friendly.
- My NASA Data UHI Phenomena Resources: <https://mynasadata.larc.nasa.gov/phenomenon/creation-of-urban-heat-islands>
- My NASA Data UHI Story Map: <https://mynasadata.larc.nasa.gov/lesson-plans/creation-urban-heat-islands-story-map>



Credit: [My NASA Data](#)



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- Zhou, Decheng, et al. "Satellite Remote Sensing of Surface Urban Heat Islands: Progress, Challenges, and Perspectives." *Remote Sensing*, vol. 11, no. 1, 2018, p. 48., doi:10.3390/rs11010048.
- Zhou S., and J. Cheng, 2020, An Improved Temperature and Emissivity Separation Algorithm for the Advanced Himawari Imager, in *IEEE Transactions on Geoscience and Remote Sensing*, 58, 7105-7124, doi: 10.1109/TGRS.2020.2979846.



Questions

- Please enter your questions into the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the course.



Credit: [NASA](#)



Contacts

- Trainers
 - Sean McCartney: sean.mccartney@nasa.gov
 - Amita Mehta: amita.v.mehta@nasa.gov
- Training Webpage:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/satellite-remote-sensing-urban-heat-islands>
- ARSET Website:
 - <https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>

