A High Spatio-temporal Resolution Land Surface Temperature (LST) Product for Urban Environments

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## MuSLI Type 2 Prototype Product:

<table>
<thead>
<tr>
<th>Data</th>
<th>Spatial</th>
<th>Temporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Land Surface Temperature (LST)</td>
<td>TIR: GOES 16, ECOSTRESS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VSWIR: Landsat 8, Sentinel 2, HLS</td>
<td>30 – 100m</td>
</tr>
</tbody>
</table>

![Map of Los Angeles area with highlighted region](image-url)
Heatwaves are becoming hotter and more humid in 21st century

Hulley and Dousset, 2019
Weather Fatalities 2017

Source: http://www.nws.noaa.gov/om/hazstats.shtml
ECOSTRESS Maps LA's Hot Spots

NASA's ECOSTRESS maps the hot spots in Los Angeles.
Revisit Time vs Spatial Resolution of current TIR sensors

- **ASTER Landsat**
- Local Scale
  - Seasonal Processes
- **ECOSTRESS**
- **Urban sweet spot:**
  - Local, hourly processes
- **VIIRS, MODIS, AVHRR**
  - Regional Scale
  - Seasonal Processes
- **GOES, SEVIRI**
  - Regional Scale
  - Daily Processes

5 days over CONUS

*Not to scale*
GOES-16 ABI:
• 3 thermal bands
• Spatial: 2.5km
• Temporal: 5 minutes
• LST produced at JPL through NASA MEaSUREs
GOES-16 images hotspots at the neighborhood km-scale, but roof-level scale (30m – 100m) are required for more precise and targeted heat mitigation strategies in cities.
Are there physical relationships between LST, NDVI and Albedo over the urban environment?
Vegetation

Confusers:
- Water, soil moisture, shadows

Low Albedo roofs, Roads, Impervious surfaces

High Albedo roofs
High resolution Urban Thermal Sharpener (HUTS) Multivariate Regression Model:

\[ LST_{\text{sharp}} = p_1 \text{NDVI}^4 + p_2 \text{NDVI}^3 \cdot \alpha + p_3 \text{NDVI}^2 \cdot \alpha^2 + p_4 \text{NDVI} \cdot \alpha^3 + p_5 \alpha^4 + p_6 \text{NDVI}^3 + p_7 \text{NDVI}^2 \cdot \alpha + p_8 \text{NDVI} \cdot \alpha^2 + p_9 \alpha^3 + \]
\[ p_{10} \text{NDVI}^2 + p_{11} \text{NDVI} \cdot \alpha + p_{12} \alpha^2 + p_{13} \text{NDVI} + p_{14} \alpha + p_{15} + dLST \]

\[ dLST = \text{Energy balance conservation} \]

LST (09:30) = f1(NDVI, α)
LST (12:30) = f2(NDVI, α)
LST (14:30) = f3(NDVI, α)

....

....

LST (21:00) = f4(NDVI, α)
LST (04:00) = f5(NDVI, α)
GOES-16 Thermal Sharpening

3 km

GOES-16 LST 07:00

100m

GOES-16 LST Sharp 07:00
GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – 9:30 pm
GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – 9:30 pm

Temperatures of green spaces (e.g. parks) overestimated
Heat advisories and public health:
Provide HVI to issue near real-time heat advisories targeted to vulnerable regions in Los Angeles.

Identify optimal locations for cooling centers

But.. Only every ~5 days

Heat Alerts

<table>
<thead>
<tr>
<th>Date of Release</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 01</td>
<td>Air Quality Advisory: Air is unhealthy in Santa Clarita Valley</td>
</tr>
<tr>
<td>July 30</td>
<td>Air Quality Advisory: Air is unhealthy in Antelope Valley and Santa Clarita Valley</td>
</tr>
<tr>
<td>July 30</td>
<td>Heat Alert: High temperatures forecast for Pomona area and San Fernando Valley</td>
</tr>
<tr>
<td>July 29</td>
<td>Air Quality Advisory: Air is unhealthy in parts of LA County</td>
</tr>
<tr>
<td>July 28</td>
<td>Air Quality Advisory: Air Quality is unhealthy in parts of LA County</td>
</tr>
<tr>
<td>July 27</td>
<td>Air Quality Advisory: Air is unhealthy in parts of LA County</td>
</tr>
<tr>
<td>July 26</td>
<td>Air Quality Advisory: Air is unhealthy in parts of LA County</td>
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</table>
Cool Roads

Jordan Av, Gault St to Hart St (1/2 Street)
Beachy Av, Rangoon St to Reliance St
Etiwanda Av, Napa St to Malden St
70th St, 2nd Av to 3rd Av
Woodbine St, Jasmine Av to Vinton Av
Carmona St, Clemson St to Bowsfield St
Orchard Av, 28th St to 29th St
77th St, Cowan Av to Beland Av
Coronado St, Berkeley Av to Mayberry St
Lord St, 90' S/O Marengo St to Pomeroy Av
President Av, 255th St to 255th St
Bonnie Brae St, 12th St to 12th Pl
Selma Av, Laurel Av to Laurel Canyon Bl
Atoll Av, Barbara Ann St to Gault St
Superior St, Noble to Lemona
## Prototype Urban Products - 2020

<table>
<thead>
<tr>
<th>Product</th>
<th>Data sources</th>
<th>Spatial</th>
<th>Temporal</th>
<th>Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban LST</td>
<td>GOES 16/17&lt;br&gt;Landsat 8&lt;br&gt;Sentinel 2&lt;br&gt;HLS&lt;br&gt;ECOSTRESS</td>
<td>30-100m</td>
<td>30 minute</td>
<td>• Los Angeles&lt;br&gt;• Atlanta&lt;br&gt;• Chicago&lt;br&gt;• Phoenix&lt;br&gt;• Minneapolis&lt;br&gt;• Washington DC&lt;br&gt;• Seattle</td>
</tr>
<tr>
<td>Urban Heat Vulnerability</td>
<td>Urban LST + SEDAC demographic</td>
<td>30-100m</td>
<td>30 minute</td>
<td></td>
</tr>
</tbody>
</table>
Questions?
glynn.hulley@jpl.nasa.gov
Future work: 2019-2020

• Sharpening model refinement and validation
  • Fix bias along coastlines
  • Continue validation matchups with ECOSTRESS
  • In situ validation – thermal camera within city

• Test sharpening model in other cities, e.g. Atlanta

• Start producing prototype products
  • Geotiff
  • Quality and error estimates
ECOSTRESS + SEDAC socio-demographic data, but..... Only every 5 days

Require hourly to daily data for near-real time heat advisories and heat mitigation

Hulley and Shivers, 2019
Athens, Greece, 08/21/2018
SEVIRI geostationary thermal (4km, 30minute)
Sentinel-2 + ECOSTRESS sharpening to 100m

Slide courtesy of Pangiotis Sismanidis, NOA
Eggs fry at 66 C (151 F)

Santa Anita Race Track (horseracing)

Hottest spot?

Eggs fry at 66 C (151 F)

63.6 C (147 F)

150 F

34.1360,-118.0460

400 m
ECOSTRESS Urban Diurnal Cycle

Temperature [°C]

Hour of day

Kerry

Glynn

Simon

Josh
Heat Vulnerability Index (HVI) Model

\[ HVI = E_i(x) + S_i(y) - R_i(z) \]

- **Exposure**
  \[ x = \text{Land Surface Temperature (LST)} \]
  \[ E_i(x) \]
  
- **Sensitivity**
  \[ y = \text{Socio-Demographic Data (poverty, elderly etc)} \]
  \[ S_i(y) \]
  
- **Resilience**
  \[ z = \text{Vegetation fraction, Annual Income, Education} \]
  \[ R_i(z) \]

Still to include: Albedo, Building height, ET
Sharpening Methodology

**Training**
- ECOSTRESS LST (70 m)
- L8, S2 A/B, HLS NDVI (30m)
- L8, S2 A/B, HLS Albedo
- Multivariate regression (HUTS)

\[ \text{LST}_{\text{sharp}} = f(\text{NDVI}, \text{Albedo}) \]

**Application**
- Landsat 8 Albedo, NDVI (100m)
- GOES-16 LST (~2.5 km)
- Geolocation and Resampling
- LST_{\text{HUTS}} + Energy Conservation
- GOES LST (30m)
Los Angeles Heat Wave Trends

- **Heat Wave Frequency (number/year)**
  - \( r^2 = 0.75 \)
  - \( p = 0.00 \)
  - 0.4/decade (since 1920)
  - 1.3/decade (since 2000)

- **Heat Wave Season Length (days)**
  - \( r^2 = 0.78 \)
  - \( p = 0.00 \)
  - 9 days/decade (since 1920)
  - 28 days/decade (since 2000)

- **Heat Wave Nighttime Temperature (°F)**
  - \( r^2 = 0.71 \)
  - \( p = 0.00 \)
  - 0.5 °F/decade (since 1920)
  - 1.8 °F/decade (since 2000)

- **Heat Wave Duration (days)**
  - \( r^2 = 0.63 \)
  - \( p = 0.00 \)
  - 0.3 days/decade (since 1920)

**Trend tripled past 20 yrs**

**Increases Fire risk!**

**Human health impacts (Morbidity, Mortality)**
Applications

How do we provide tangible benefits to society and cool cities?
GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – 4:00 am
GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – 4:30 am

Bias = -0.1 K
RMSE = 0.7 K
N = 349139