Applications of Satellite Remote Sensing and Ground -based Observations in Monitoring Lakes and Urban Surface Temperature

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Approximately 2500 satellites are in space!
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(Artist’s concept showing thousands of satellites and other debris orbiting Earth. Photo Credit: ESA)
Urban Heat Islands

Photo courtesy of NASA, depicts temperatures around Providence, RI
Each 2 km² bin has an average temperature $T_i$ and a mix of $k$ surface component fractions $F_{ki}$ with coefficients $C_k$ TBD. Coordinates in 3 dimensions were included to capture weather gradients.

\[ T_i = T_o + \sum_{ik} C_k F_{ik} \]

$C_k$ and $T_o$ found by regression.
2km resolution with 5min temporal resolution

30m resolution with 16 days temporal resolution
GOES-16 provides LSTs at roughly five minute intervals allowing a more accurate representation of the diurnal temperature cycle.

Geostationary satellites only provide partial coverage of the Earth due to viewing geometry and are more expensive to put in orbit ($11b for four satellites).

Infrared sensors, in general, suffer however from cloud interference.

NOAA provides product quality information (PQI) flags with the LST data that includes cloud cover.
MODIS LSTs are generally higher than those from GOES-16. MODIS LSTs are measured four times per day, 0130, 1030, 1330 and 2230.

We calculated the differences in LSTs from July 2017 to March 2018.

Nighttime differences (purple and blue) show a narrower profile across all pixels than the daytime differences (yellow and orange).

The differences in the summer are more scattered than in the winter.

Across CONUS, differences were calculated with respect to land cover type.

Significant differences (6-8 K) can be seen in the valleys of the Great Basin in Nevada, this may be due to the different viewing geometries of MODIS and GOES-16.
Comparison of MODIS and GOES-R Over Urban Regions
Comparison of GOES-R and LandSat Over Urban Regions

Landsat 8 LST: 1540 30 July 2017

Landsat 8 Mean LST: 1540 30 July 2017

GOESR&Landsat-8 max Difference: 30 July 2017

GOESR LST: 1538 30 July 2017
Near-surface air, soil, and skin temperatures are among the key variables for the assessment of global climate change and surface energy budget.

The differences among these three distinct types of temperatures are essential for many applications:
- global climate system
- land-atmosphere trace gas exchange
- hydrological activities
- global energy budget
- study of land surface processes
- numerical land surface model data assimilation

These temperatures are indeed distinct.

They are often-times used interchangeably for some specific applications like in algorithms used to detect high-latitude freeze and thaw (FT) states.

\[-Q^* = Q_H + Q_E - Q_G + \Delta Q_S\]

- $Q^*$ = net upward radiation at surface
- $Q_H$ = upward sensible heat flux
- $Q_E$ = upward latent heat flux
- $Q_G$ = upward molecular heat flux into the bottom
- $\Delta Q_S$ = storage/residual

Surface Energy Balance

Diagram showing the energy balance components.
Ground Observation of Land Surface Energy Balance
Thermal Images of Different Land Surfaces

- Grass
- Asphalt
- Concrete
- City

Ground Observation of Land Surface Energy Balance

![Graph showing land surface temperatures over time for different surfaces]
Lakes are sentinels of climate change
Surface temperatures as an indicator
Using remote sensing to calculate surface temperature
Motivation: large lakes shrinking due to climate and region factors
Question/Hypothesis
Lakes are sentinels of climate change

- Support biodiversity
- Necessary for human resources and recreation
- Sensitive to climate changes
- Present around the globe in diverse geographic locations
- Indicator examples:
  - Water temperature
  - Water level
  - Ice phenology

Remote Sensing of Lakes

LAKE URMIA, Iran

LAKE POOPÓ, Bolivia

LAKE TANGANYIKA, Zambia

GREAT SALT LAKE, Utah

Large lakes shrinking from climate change
Lakes also shrinking from regional mismanagement:
  - Mining
  - Redirecting flow for agriculture
  - Illegal damming
Can we use remote sensing data to distinguish between climate and regional factors?
Lake Urmia

(AghaKouchak et al, 2014)
Studying Endangered Lakes
Land Surface Temperature from MODIS
Land Surface Temperature Trend from MODIS

GREAT SALT LAKE, USA

LAKE CHAD, Chad

LAKE POOPÓ, Bolivia

LAKE URMIA, Iran
What is a Harmful Algal Bloom?

“Harmful algal blooms, or HABs, occur when colonies of algae — simple plants that live in the sea and freshwater — grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal.”, NASA
Chlorophyll-a Detection Using LandSat 8

![Map of chlorophyll-a detection using LandSat 8](image)

### Chlorophyll-a Detection

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Landsat 8 band math</th>
<th>Original use</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Algal Bloom Index</td>
<td>(B5 – B4)/</td>
<td>ocean, designed to minimize</td>
<td>Alawadi</td>
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<tr>
<td>(SABI)</td>
<td>(B2 + B3)</td>
<td>variations in cloud shadow and</td>
<td>(2010)</td>
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<tr>
<td></td>
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<td>atmospheric conditions, using</td>
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<td>MODIS satellite</td>
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<td>3BDA-like</td>
<td>(B2 – B4)/</td>
<td>large freshwater lake, above 3 µg/L,</td>
<td>Brivio et</td>
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<td>(KIVU)</td>
<td>B3</td>
<td>Landsat TM</td>
<td>al. (2001)</td>
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<td>estuarine and coastal waters 1–60 µg/L, using MERIS satellite</td>
<td>Mishra and</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Mishra (2012)</td>
</tr>
<tr>
<td>Normalized Difference</td>
<td>(B5 – B4)/</td>
<td>simulated turbid productive</td>
<td>Dall’Olmo</td>
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<tr>
<td>Vegetation Index (NDVI)</td>
<td>(B5 + B4)</td>
<td>freshwater, using Landsat TM</td>
<td>and Gitelson</td>
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<tr>
<td></td>
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<td>(2006)</td>
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<td>2BDA</td>
<td>B5/B4</td>
<td>coastal, best-fit algorithm, chl a</td>
<td>Kabbara et</td>
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<td>below 4 µg/L, using Landsat 7</td>
<td>al. (2008)</td>
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<tr>
<td>Kab1</td>
<td>1.67 – 3.94 x ln(B2) + 3.78 x ln(B3)</td>
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<td>Kab2</td>
<td>6.92274 – 5.7581 x ln(B1)/ln(B3)</td>
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Boucher et al, 2018