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

Hamid Norouzi, PhD, PE

New York City College of Technology, CUNY

The Graduate Center, Earth & Environmental Sciences, CUNY

REU

5/11/2018

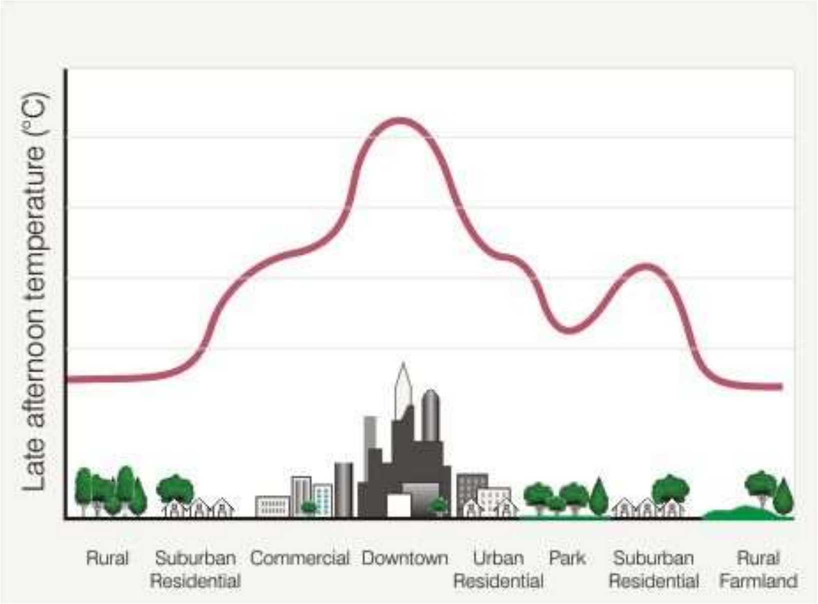
Approximately 2500 satellites are in space!

(Artist’s concept showing thousands of satellites and other debris orbiting Earth. Photo Credit: ESA)

Approximately 2500 satellites are in space!

(Artist's concept showing thousands of satellites and other debris orbiting Earth. Photo Credit: ESA)

Urban Heat Islands



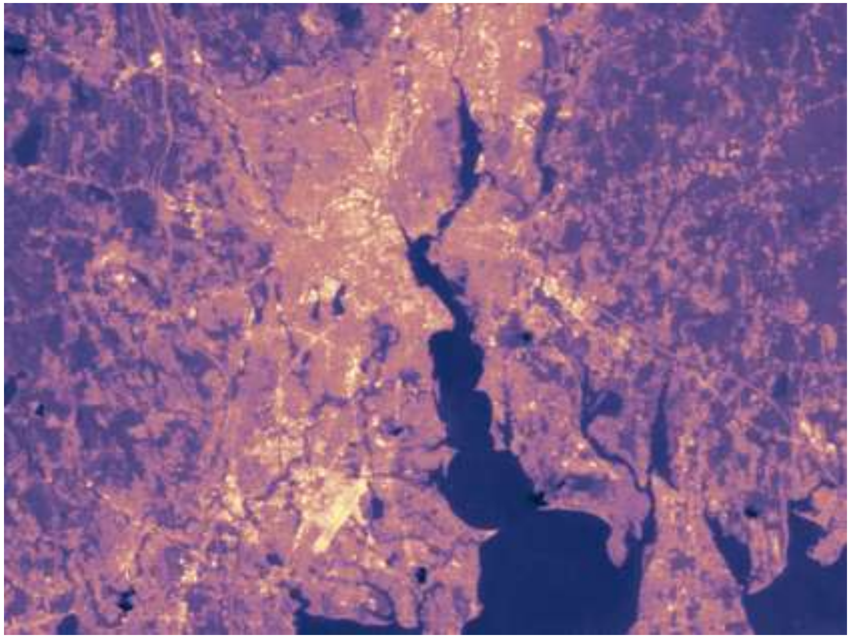
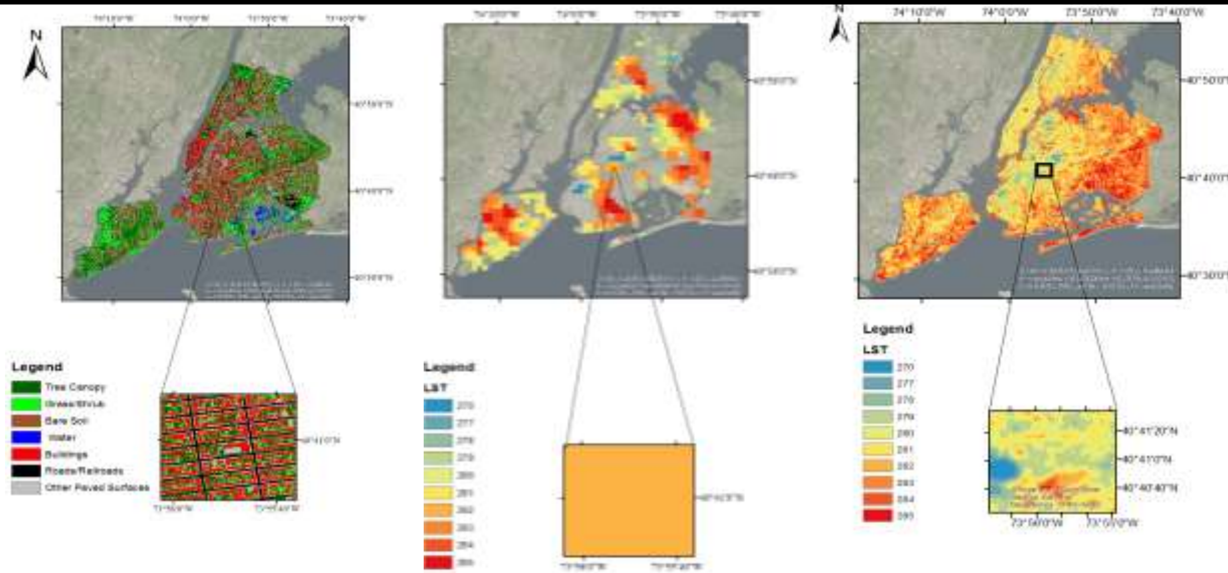
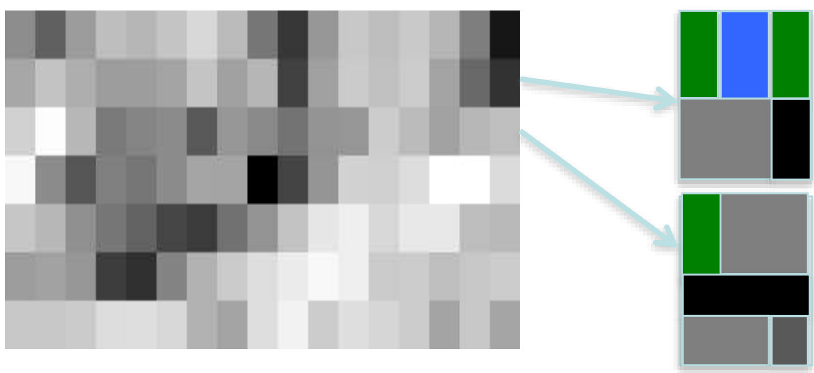


Photo courtesy of NASA, depicts temperatures around Providence, RI

Downscaling of Land Surface Temperature





30% Veg
20% water
40% building
10% road

15% Veg
0% water
65% building
20% road

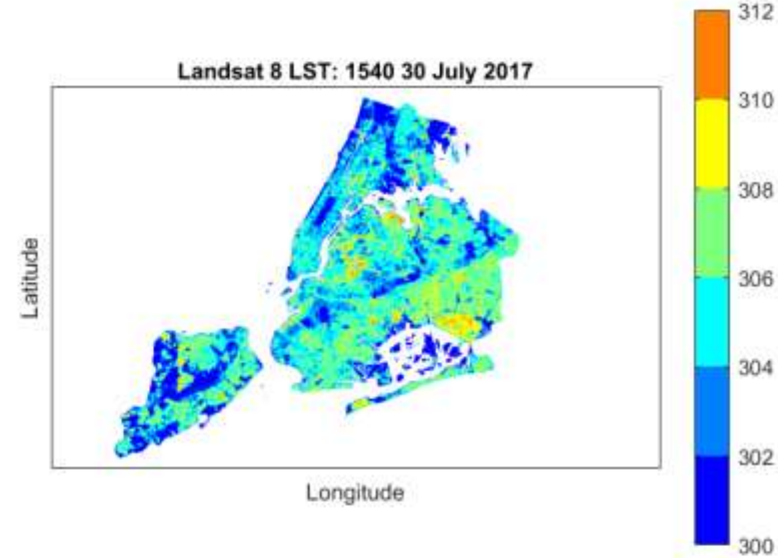
Each 2 km^2 bin has an average temperature T_i and a mix of k surface component fractions F_{ki} with coefficients C_k TBD. Coordinates in 3 dimensions were included to capture weather gradients.

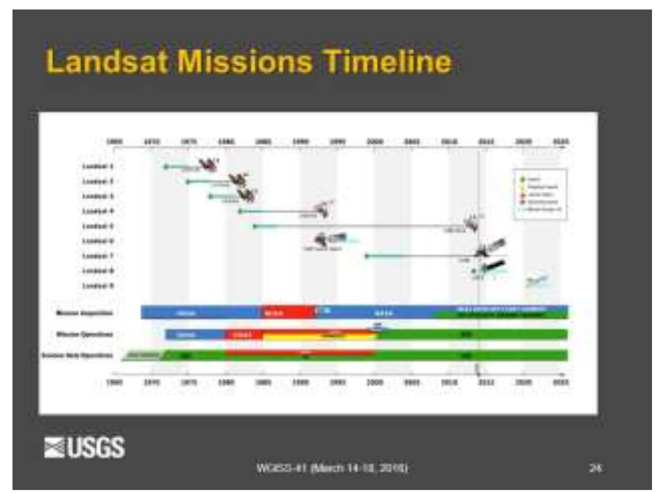
$$T_i = T_o + \sum_{ik} C_k F_{ik}$$

C_k and T_o found by regression.

GOES-R & LandSat 8

2km resolution with 5min temporal resolution





30m resolution with 16 days temporal resolution

Comparison of GOES-16 and MODIS LSTs

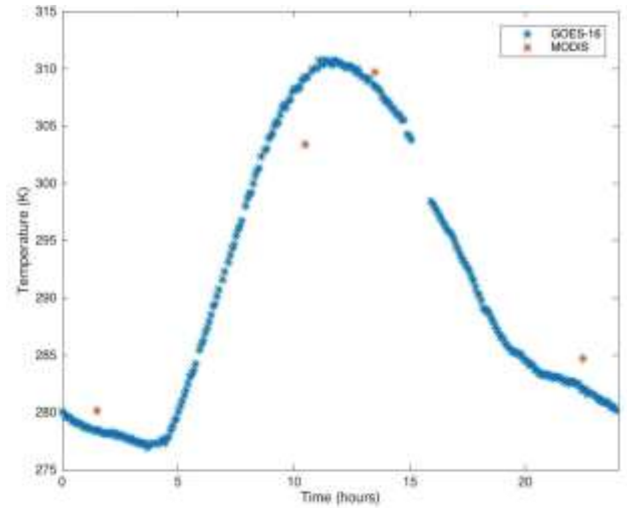
GOES-16 provides LSTs at roughly five minute intervals allowing a more accurate representation of the diurnal temperature cycle.

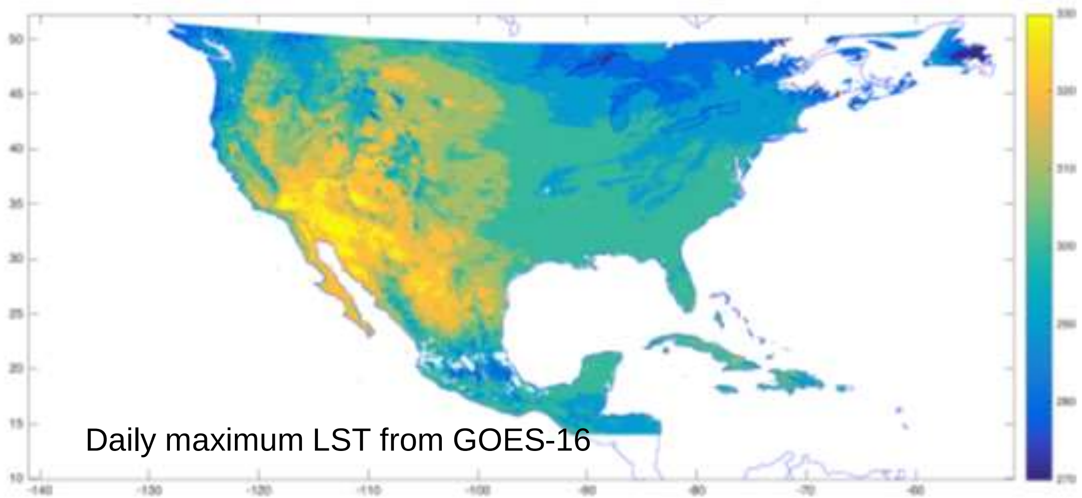
Geostationary satellites only provide partial coverage of the Earth due to viewing geometry and are more expensive to put in orbit ($11b for four satellites).

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

NOAA provides product quality information (PQI) flags with the LST data that includes cloud cover.

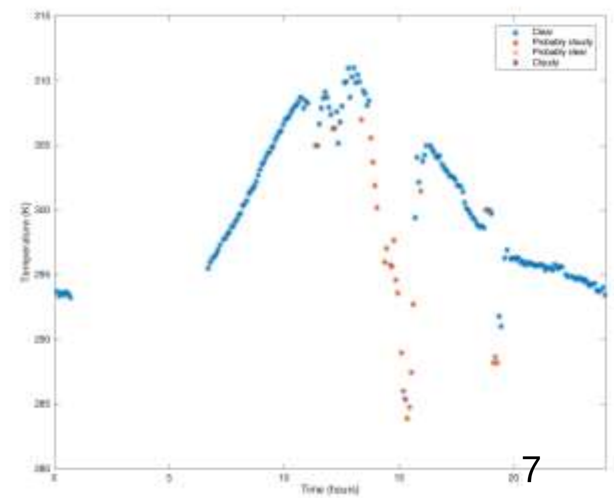
GOES-16 v MODIS DTC, July 2017 NYC





Daily maximum LST from GOES-16

GOES-16 LSTs by PQI



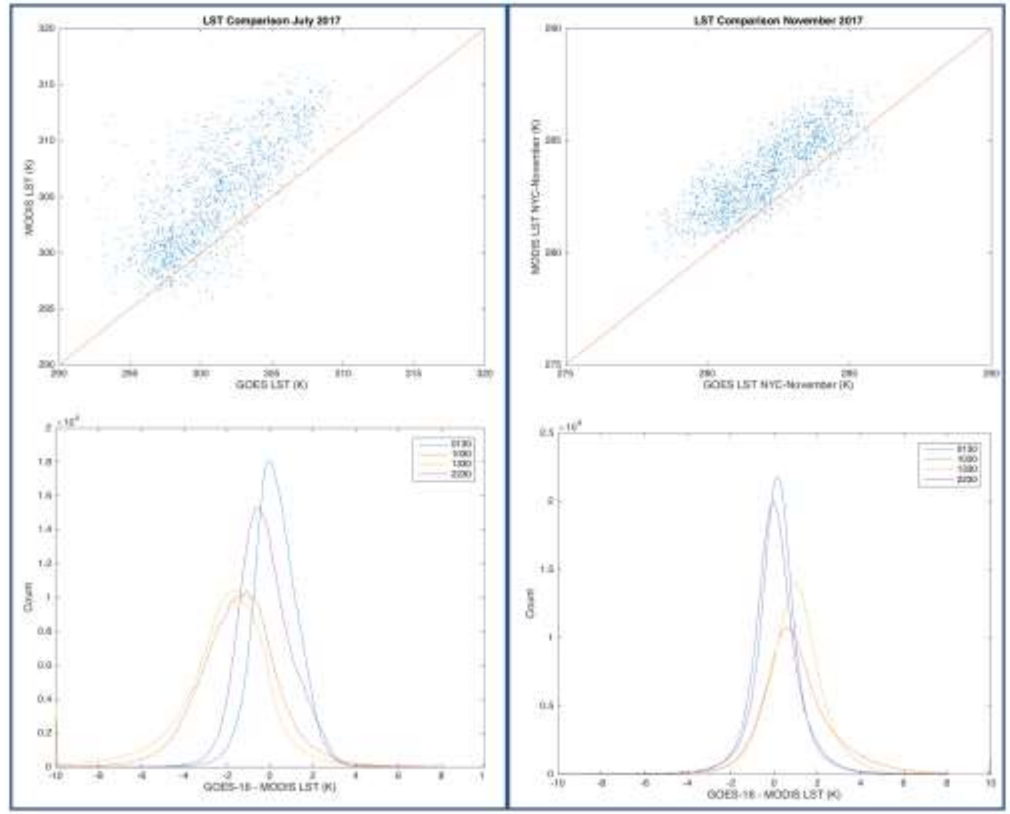
Effect of Temperature on GOES-16 and MODIS differences

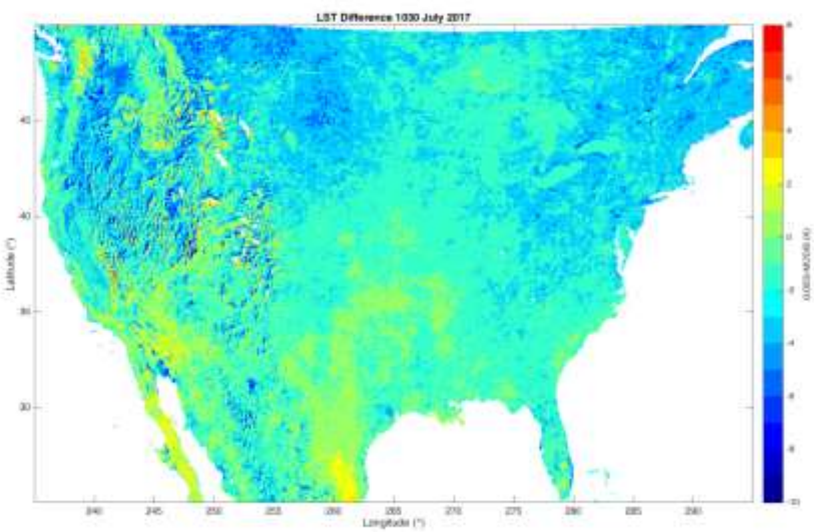
MODIS LSTs are generally higher than those from GOES-16.
MODIS LSTs are measured four times per day, 0130, 1030, 1330 and 2230.

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.

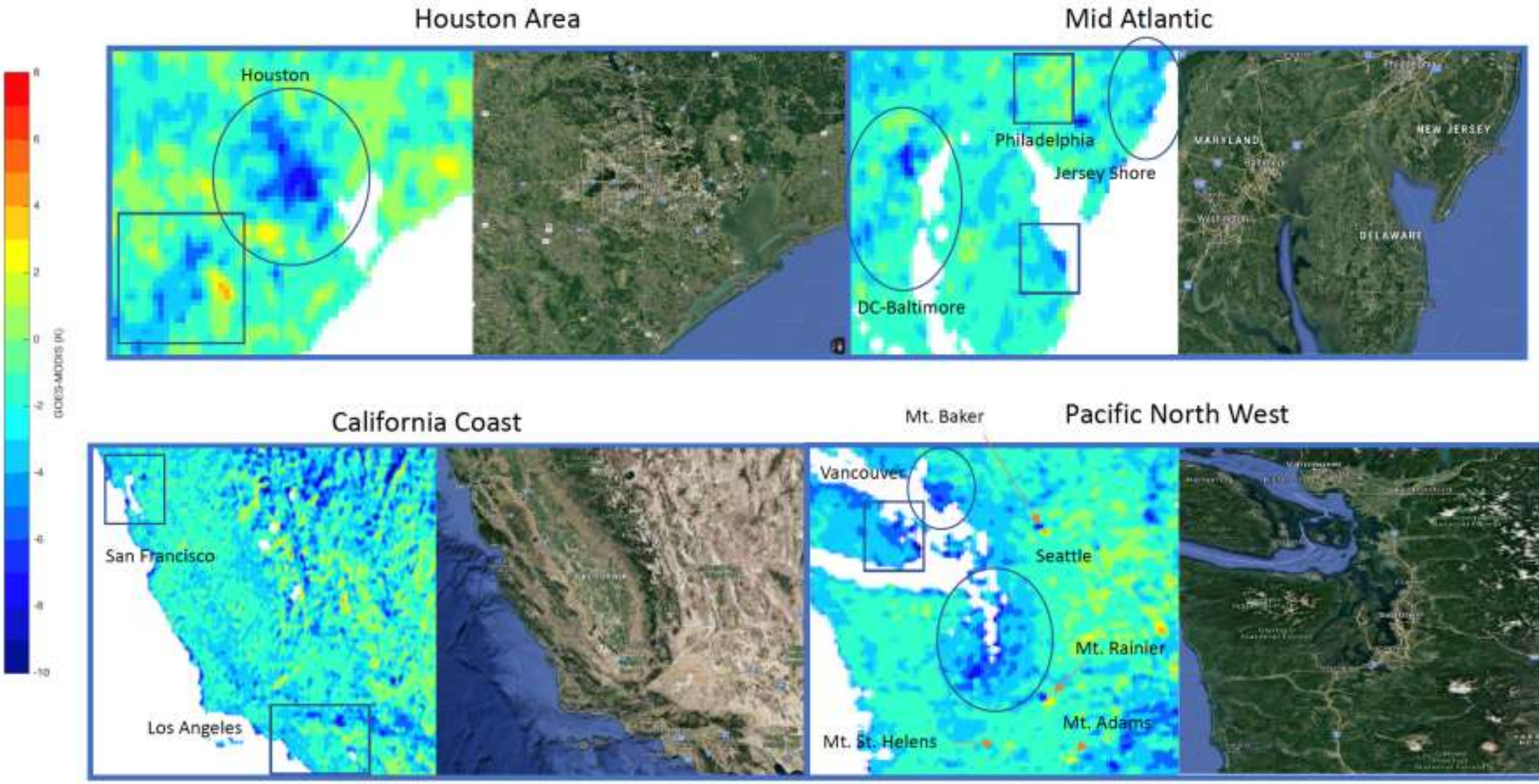




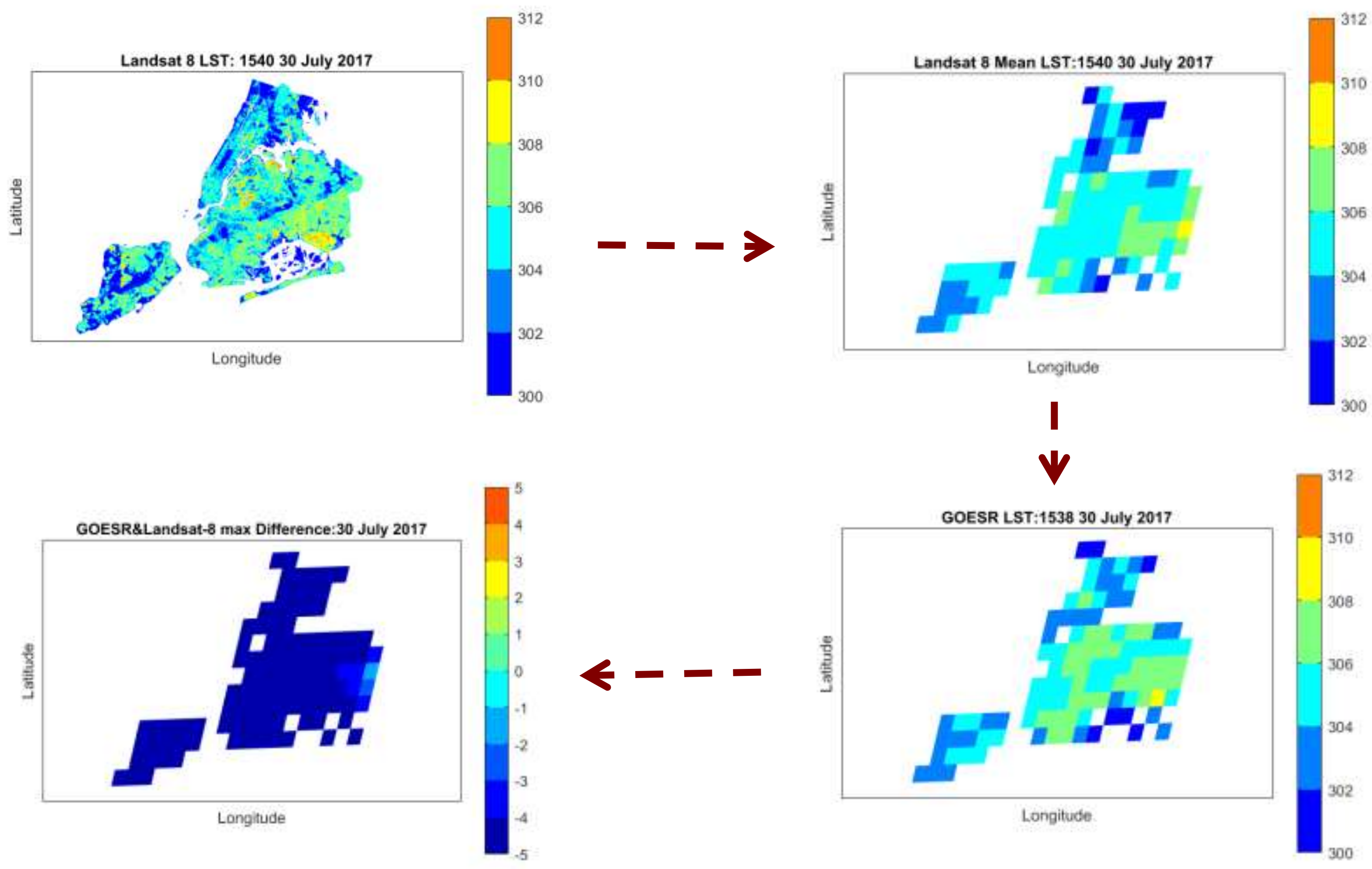
Across CONUS, differences were calculated with respect to land cover type.

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



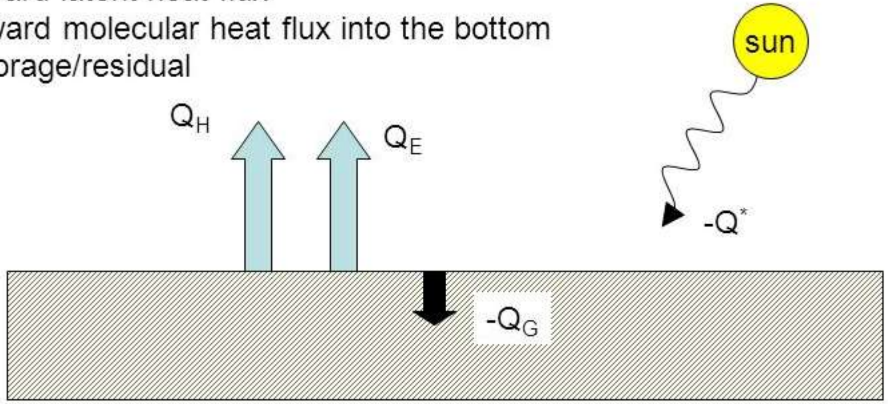
Surface Energy Balance

- ❑ 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

$$-Q^* = Q_H + Q_E - Q_G + \Delta Q_s$$

$-Q^*$ = 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
ΔQ_S = storage/residual

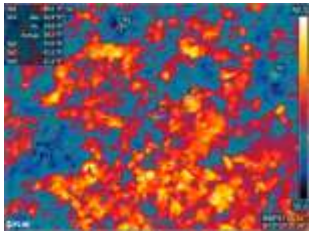


- ❑ These temperatures are indeed distinct

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

Ground Observation of Land Surface Energy Balance

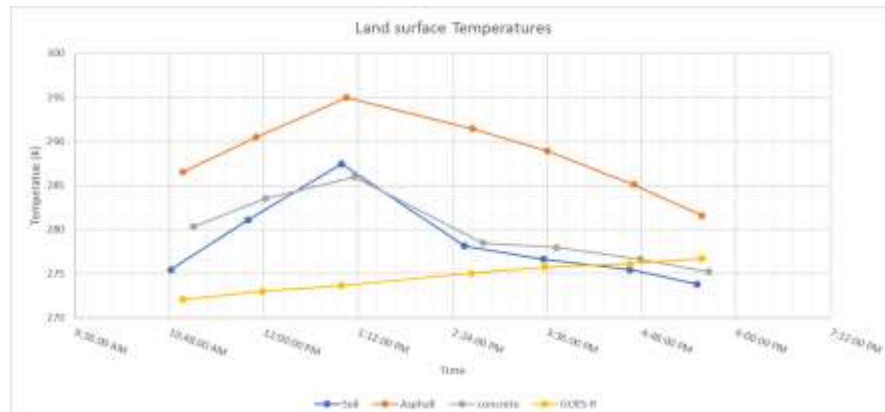
Ground Observation of Land Surface Energy Balance

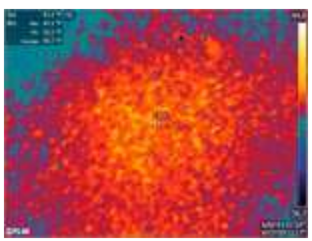


Grass

Thermal Images of Different Land Surfaces

Asphalt





Concrete

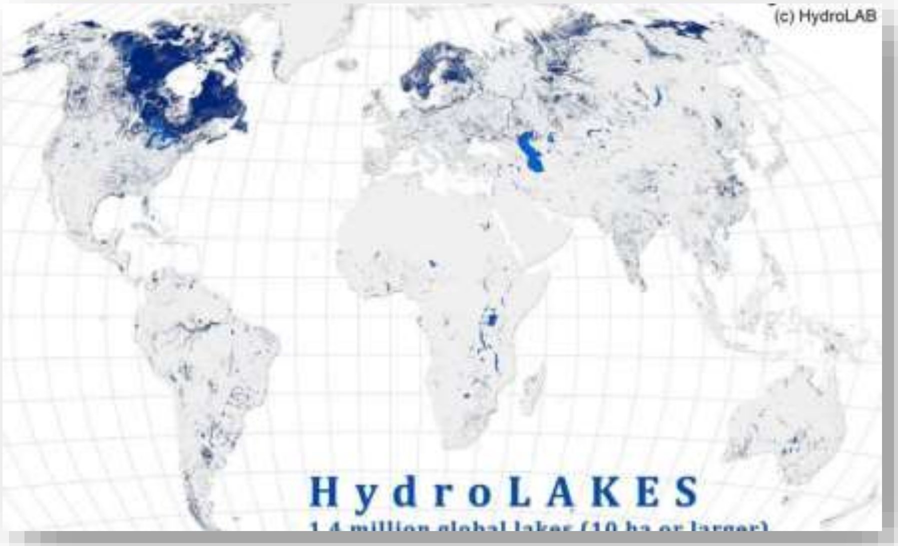
City

Lakes

- 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

https://www.iisd.org/ela/

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

https://phys.org/news/2016-12-global-database-scientists-track-role.html

Remote Sensing of Lakes

LAKE URMIA, Iran

LAKE POOPÓ, Bolivia

LAKE TANGANYIKA, Zambia

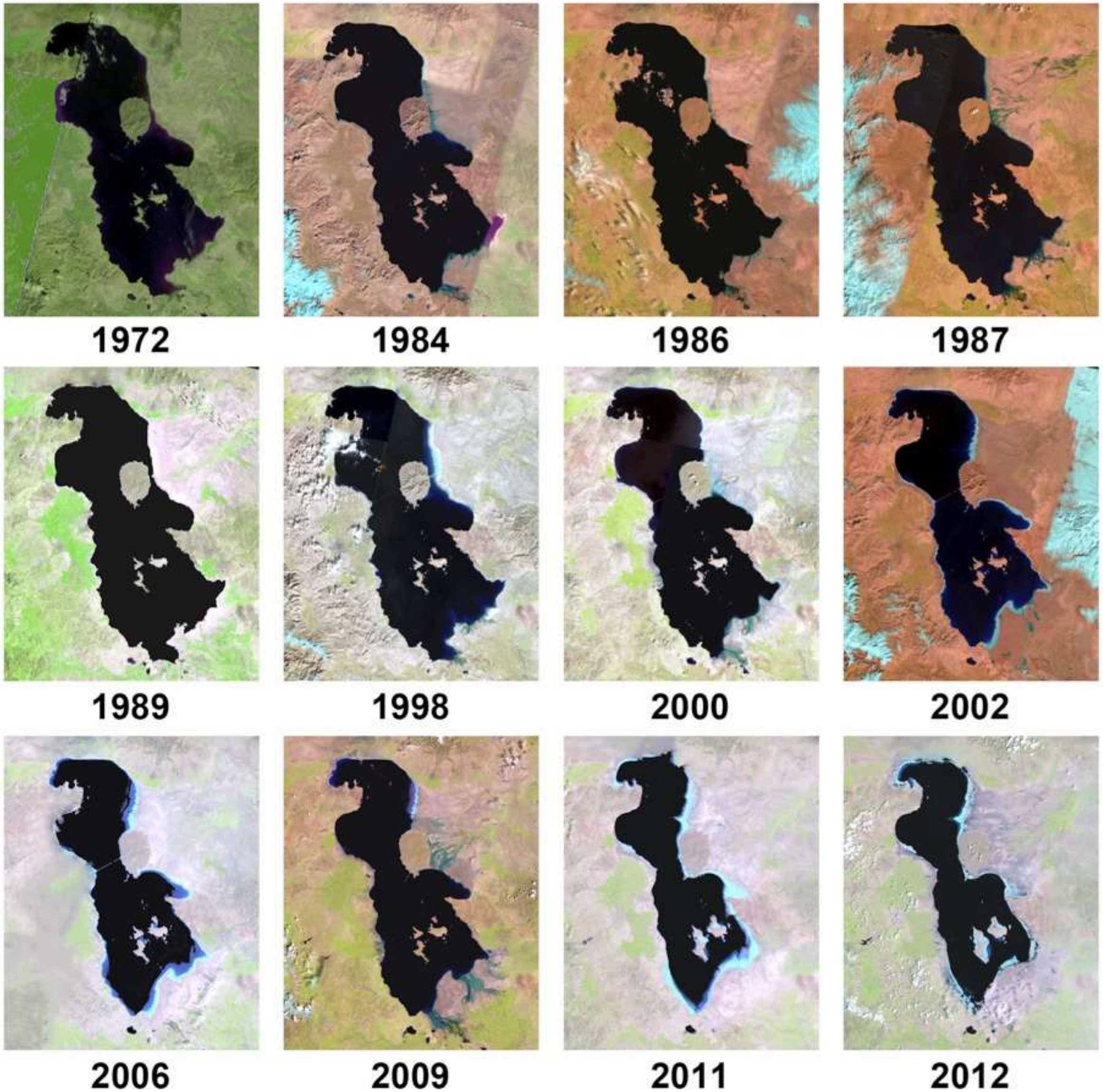
GREAT SALT LAKE, Utah

Source: https://www.nationalgeographic.com/magazine/2018/03/drying-lakes-climate-change-global-warming-drought/

Question Motivation: Lakes shrinking due to climate and regional factors

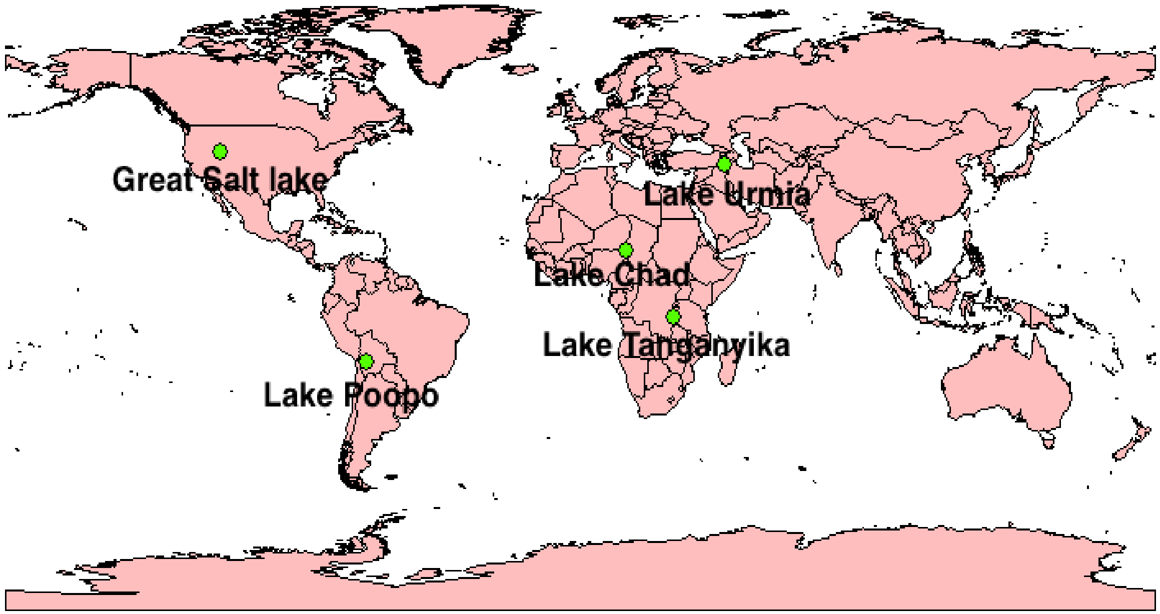
- Large lakes shrinking from climate change
- Lakes also shrinking from regional mismanagement:
  - Mining
  - Redirecting flow for agriculture
  - Illegal damming
- Can we use remote sensing data to distinguish between climate and regional factors?

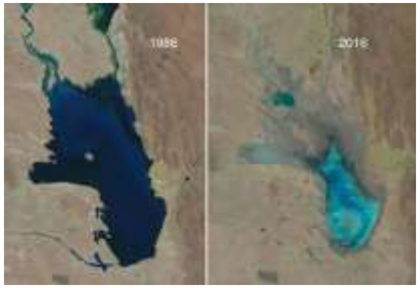
Lake Urmia

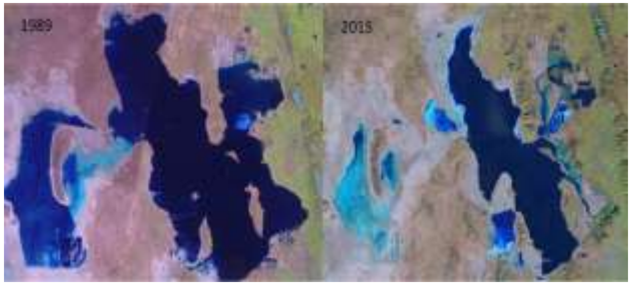


(AghaKouchak et al, 2014)

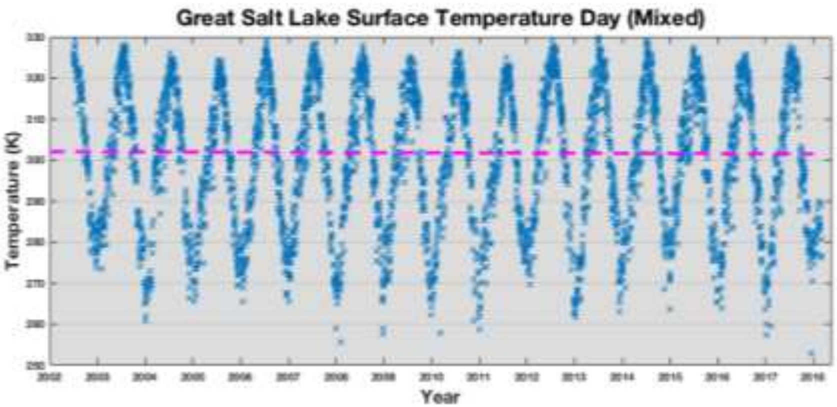
Studying Endangered Lakes

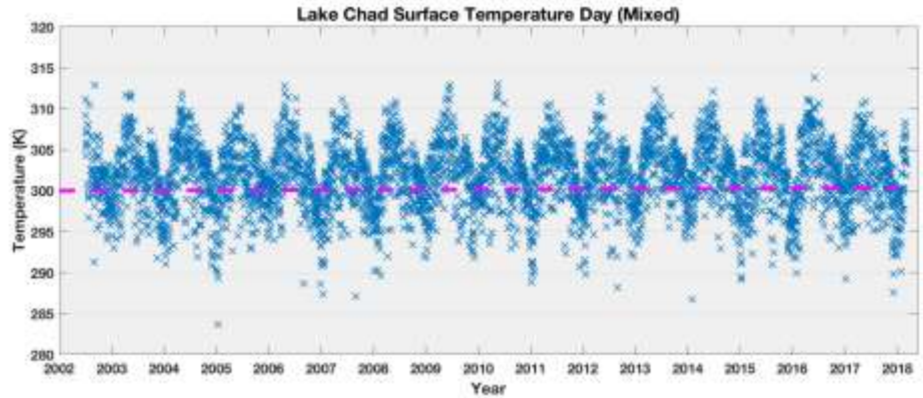


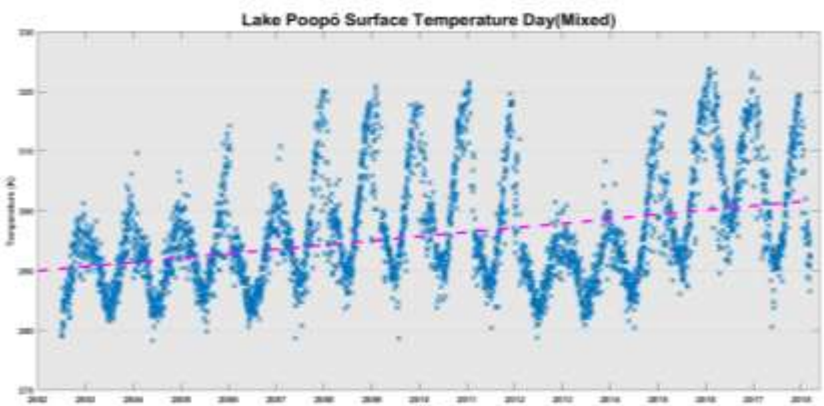


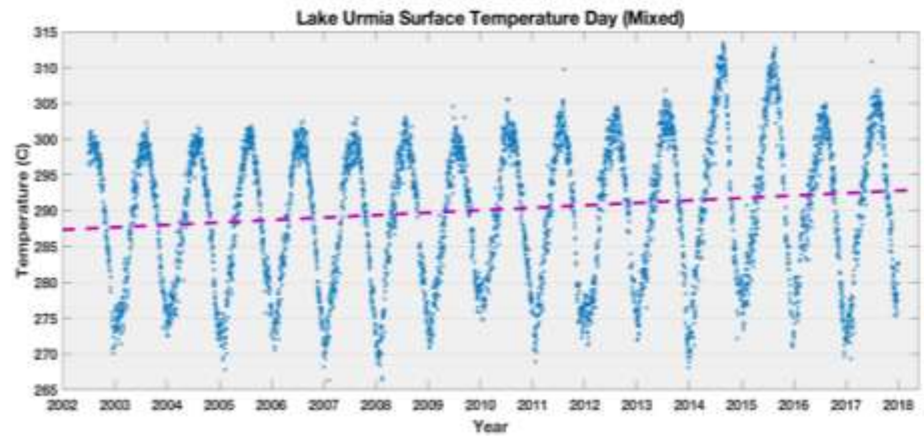


Land Surface Temperature from MODIS

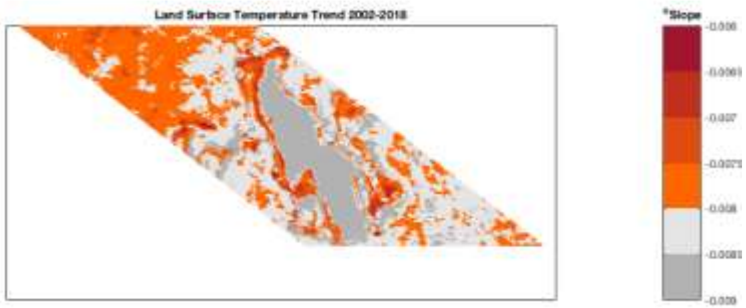




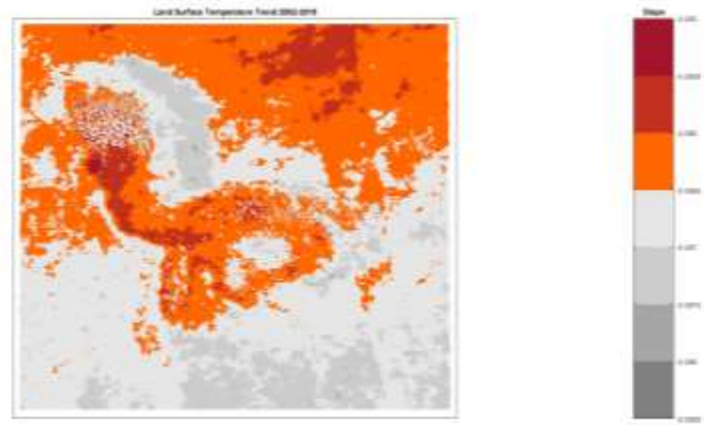




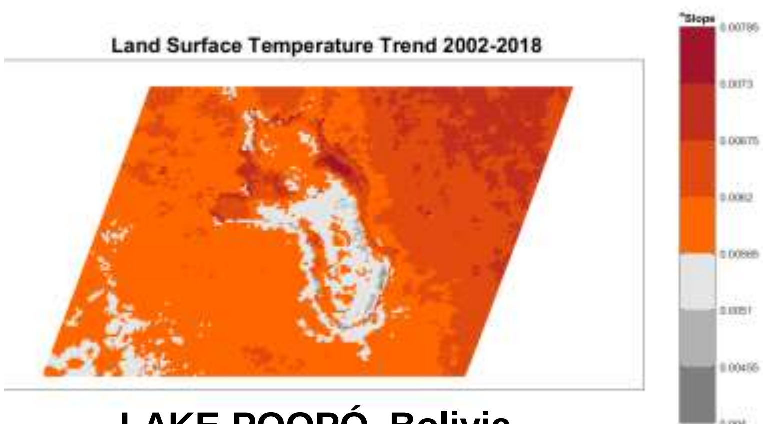
Land Surface Temperature Trend from MODIS



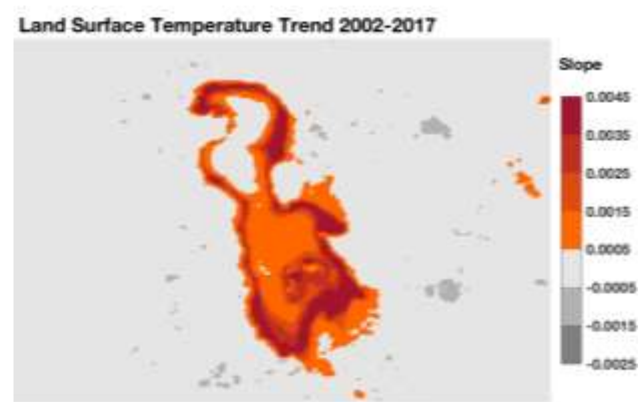
GREAT SALT LAKE, USA



LAKE CHAD, Chad



LAKE POOPÓ, Bolivia



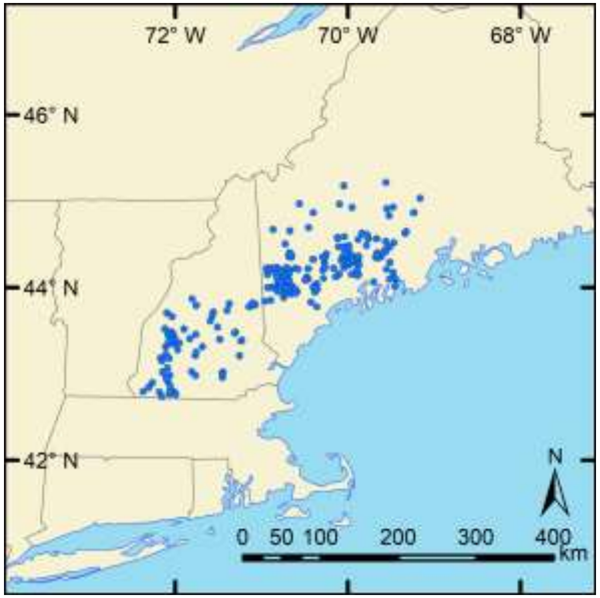
LAKE URMIA, Iran

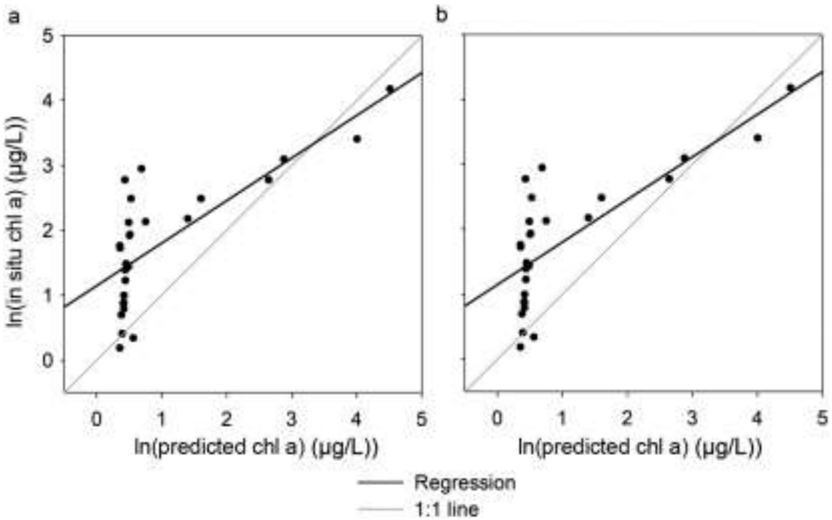
Harmful Algal Bloom

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





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

Boucher et al, 2018