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# Spatiotemporal Distribution of Industrial Regions and Impact on LST in the case of Kocaeli, Turkey


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# Introduction


- Monitoring of urban sprawl especially growth of industrial regions is an important task
  - to maintain the balanced and sustainable development,
  - to understand status of urban air pollution and ecosystems and
  - to support urban planning.
- Additionally, it is also a fact that the increase in industrial areas negatively affects the global warming.

# Introduction


- Global warming occurs when carbon dioxide (CO2) and other air pollutants and greenhouse gasses collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the earth’s surface.
- Normally, this radiation would escape into space—but these pollutants, which can last for years to centuries in the atmosphere, trap the heat and cause the planet to get hotter.
- That's what's known as the greenhouse effect.

# Study Region

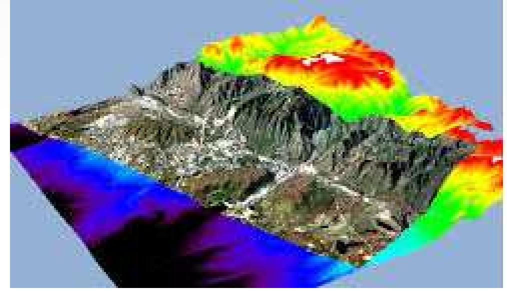
- Due to fast urbanization (traffic, population, building population etc.) and high dense industrialization may cause global warming.
  - Coal-burning power plants
  - the burning of fossil fuels to make electricity
  - the transportation sector
- is the largest source of heat-trapping pollution

# Introduction

- Since 1980's the industrial sector in Turkey has developed with a remarkable rate.
- This can be attributed to three different factors
  - namely a shift from agriculture towards industry,
  - the modernization of the existing industry, and
  - the effect of international trade (KPMG, 2015).

- Industrial region densities may play role on the Land Surface Temperature (LST) distribution.
- Remote sensing technologies use the thermal infrared region of the electromagnetic spectrum in order to observe LST.

# Introduction

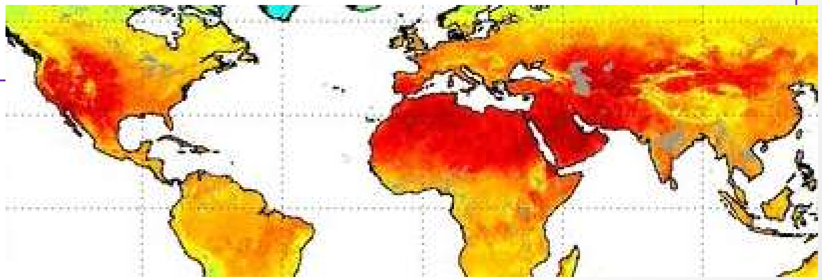



- Remote sensing images provide fast monitoring of multi-temporal spatial data and GIS (Geographic Information Systems) Technologies has become an important tool for handling these spatial data.
- Satellite images are useful for:
    - land use mapping,
    - change analysis,
    - object determination, etc.,
    - as well as thermal bands provide opportunity to determine the **land surface temperatures (LST).**

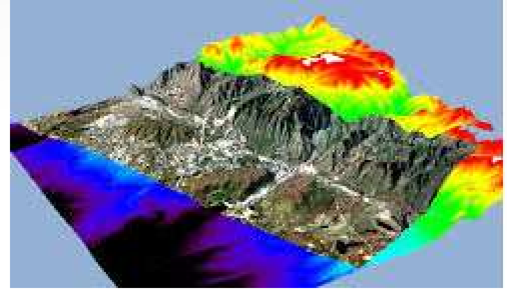
# Introduction

- Land surface temperature (LST) is defined as how hot the "surface" of the Earth would feel to the touch in a specific location.

- LST is a significant parameter to determine the energy exchange between the surfaces of the earth and the radiant temperature that will help to understand the change of the surface temperature



# Aim of the Study

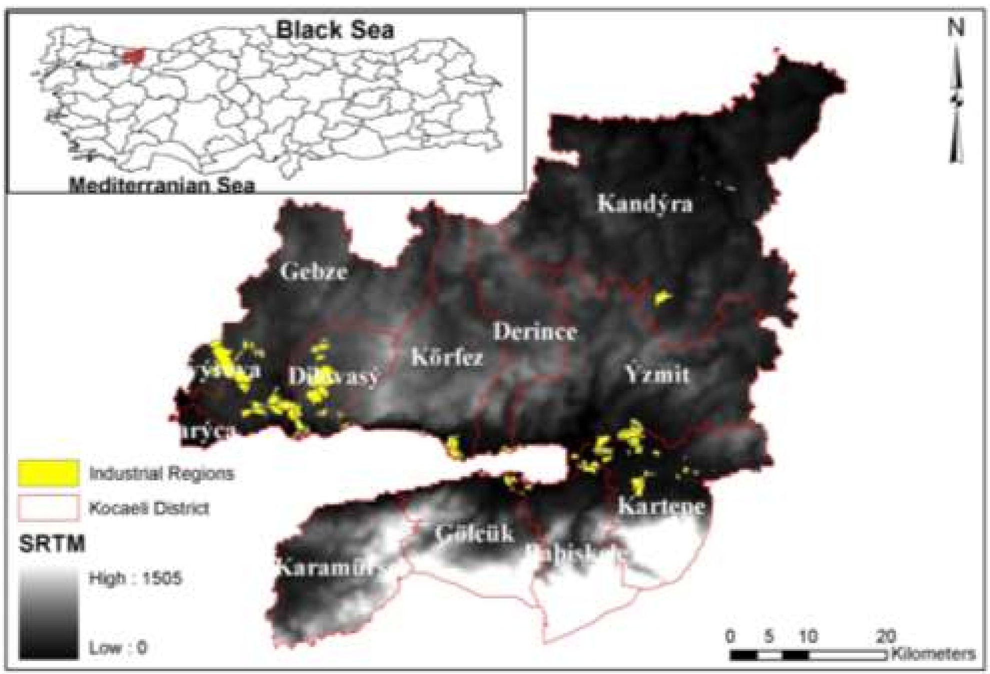



- In this paper :
- spatial and temporal
- distribution of industrial regions and land surface temperature
- investigated and the relationships among these factors are discussed.

- The change in industrial regions was determined with raster-based analysis by handling
  - Landsat 7 ETM+ and Landsat 8 OLI satellite images belong to 2002 and 2016 years respectively.
- LST analysis was determined by handling:
  - Landsat 7 and Landsat 8 OLI satellite images belong to 2000 and 2016 years respectively.

## THE STUDY AREA AND DATA SETS

- Kocaeli is one of the dense industrial provinces of Turkey through where D-100 and TEM highways pass through the city.
- The city lies between the 29°22'-31°22' eastern longitude and 40o31'-42o42' northern latitude and it carries a geopolitical importance as it is located in junction point of roads connecting Asia and Europe.
- It is the Turkey's second largest industrial center after Istanbul.



## THE STUDY AREA AND DATA SETS

- Kocaeli was mainly a production, storage and transfer region for more than 1020 industrial institutions in various sectors as:
  - Petroleum Refineries,
  - automotive,
  - chemistry,
  - textile,
  - machine,
  - food,
  - paper,
  - wood,
  - tanning,
  - coal, etc..

## THE STUDY AREA AND DATA SETS

- The city is divided into 12 urban sub-municipalities.
- The population reached 1.722.795.

# THE STUDY AREA AND DATA SETS

- Landsat7 ETM+ (enhanced thematic mapper plus) and Ladsat 8 OLI images are available for the study area.
- The Landsat7 ETM+ for 2002 and Ladsat 8 OLI for 2016 were used to obtain landuse/landcover map of the region.
- The Landsat7 ETM+ for 2000 and Ladsat 8 OLI for 2016 were used to obtain LST map of the region.

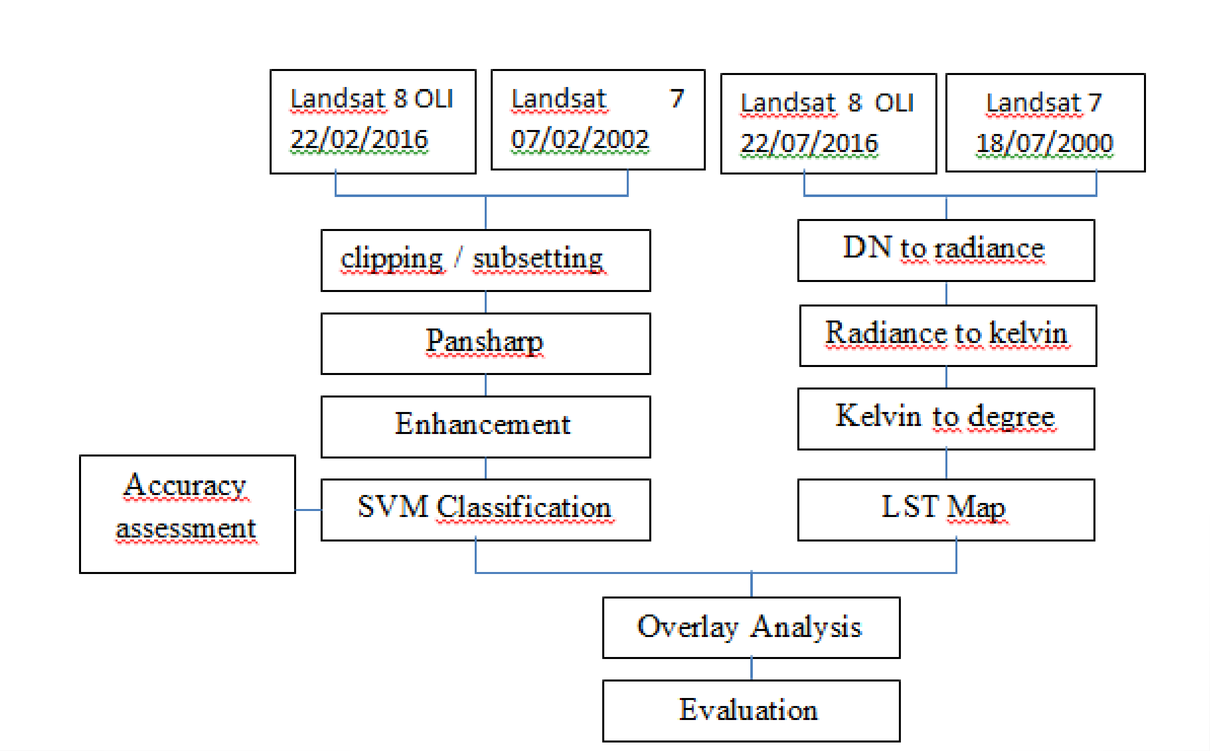
| Satellite | Year | Sensor | Spectral Range | Band #s | Scene Size | Pixel Resolution |
|---|---|---|---|---|---|---|
| L7 ETM+ | 07/02/2002<br>18/07/2000 | multispectral | 0.450-2.35 µm | 1,2,3,4,5,7 | 185x185 km | 30 m |
| L7 ETM+ | | thermal | 10.40-12.50 µm | 6.1, 6.2 | | 60 m |
| L7 ETM+ | | panchromatic | 0.52-0.90 µm | 8 | | 15 m |
| L8 OLI | 22/02/2016<br>22/07/2016 | multispectral | 0.433-1.39 | 1,2,3,4,5,6,7,9 | 180x185 | 30 m |
| L8 OLI | | thermal | 10.6-12.5 | 10,11 | | 100 m |
| L8 OLI | | panchromatic | 0.50-0.68 | 8 | | 15 m |

# THE STUDY AREA AND DATA SETS

- Atmospheric changes affect the radiometric resolution of the satellite image, at the same time
- substances such as clouds, snow, rainy weather can lead to errors when classifying and trying to distinguish objects, and a separate class may be required for these substances.
- For this reason, it was noted the satellite images that were belonging to the same month were chosen.
- The images were obtained from the http://earthexplorer.usgs.gov/ internet adress freely.

# Method and Analysis

- The method of the study contains of the processing of the image data to
- obtain spatiotemporal change of industrial regions and
- obtain LST values on these regions
- within 14 years period in the case of Kocaeli, Turkey.

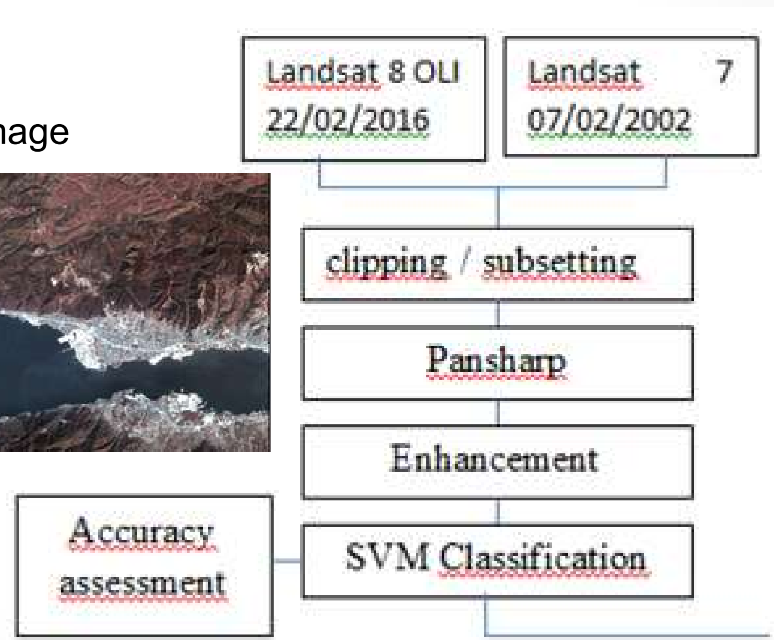


# Method and Analysis

- The clipping/subsetting process was carried out initially in the Kocaeli province in order to cover the industrial areas of Izmit Gulf.
- Then the 30 m resolution Landsat images were pansharpaned with pan band to obtain 15 m. spatial resolution images.
- The images were then enhanced to increase the determination of the features. After obtaining the landuse/landcover map by using SVM methos the accuracy was tested by using an error matrix.

a. 2002 Landsat image

b. 2016 Landsat image



# Method and Analysis

- **Spatiotemporal Industrial Region Analysis**
- Support vector machine classification method was used to classify the images.
- A hyperplane that can best distinguish the training data is obtained by using the decision function.

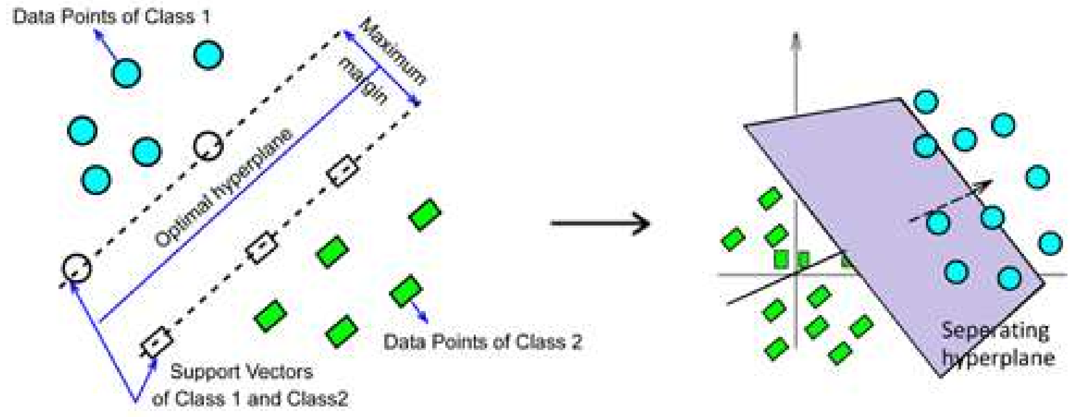



**Fig. 2.** Linear support vector machine example (modified from Burges (1998)).

# Method and Analysis

- **Spatiotemporal Industrial Region Analysis**
- For SVM classification training areas were created by choosing polygons that contain training pixels representing the land covers.
- 8 land cover classes including water, industry, green regions, bare soil, urban and road were selected for training regions.
- The sigmoid kernel was used. The gamma in kernel function and penalty parameter was selected as 0.143 and 100 respectively.

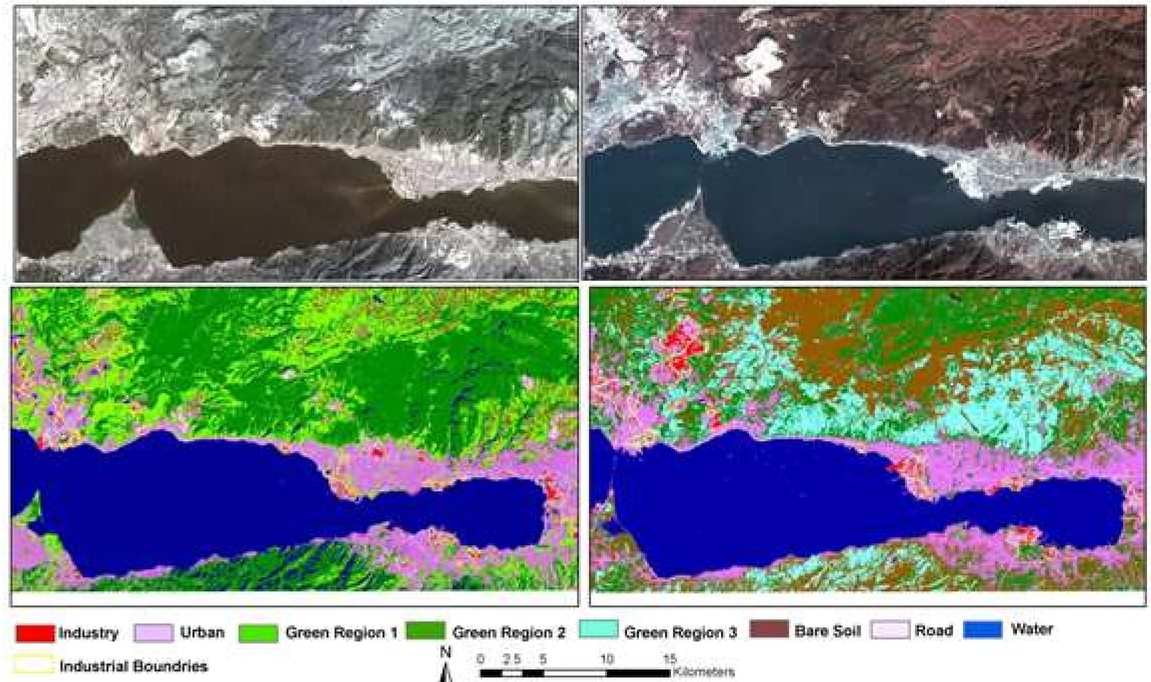


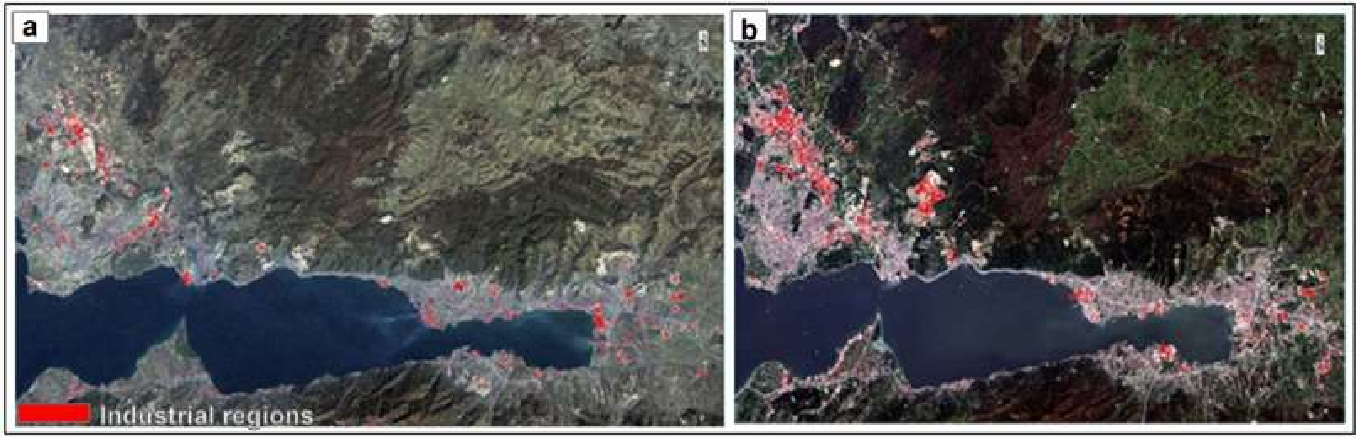

Figure 3. a. 2002 Landsat image b. 2016 Landsat image c. 2002 SVM classification map d.

# Method and Analysis

- **Spatiotemporal Industrial Region Analysis**
- For accuracy assessment purposes, selection of ground truth pixels was done by random sampling.
- Accuracy analysis was carried by comparing the classified pixels with ground truth pixels using a confusion matrix.
- The results were presented in terms of Kappa Coefficient and overall accuracy.
- According to the results
  - kappa coefficients 2002: 0.9883
  - kappa coefficients 2016: 0.9856
  - and
  - overall accuracy 2002: 99.87%
  - overall accuracy 2016: 99.86 %

# Method and Analysis

- The classes other than the industry in 2002 and 2016 were combined into one class, reducing the number of classes to two (Figure 4).
- These images containing two classes were differentiated by change detection difference analysis.
- As a result of this process 35.15% differences and increases in the field of industry have been observed for 14 years

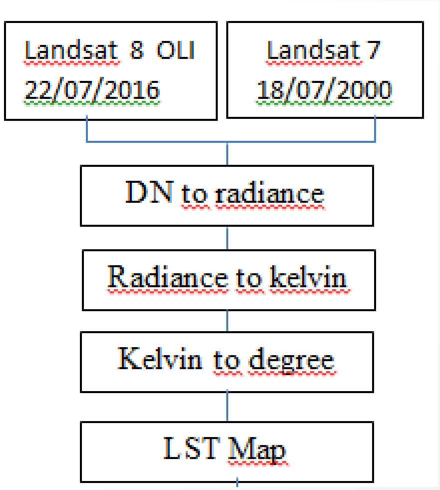



The industrial regions obtained by classification was overlaid with Landsat images a. 2002 industrial regions b. 2016 industrial regions

# Method and Analysis

- **Land surface temperature (LST) estimation**
- The spectral radiance and quantized calibrated values in DNs from the relevant header file was obtained before calculating the radiance.
- The following formula was used to convert DNs to spectral radiance
- 

$$L_{\gamma} = \frac{LMax_{\lambda} - LMin_{\lambda}}{QCalMax - QCalMin} \times (DN - QCalMin) + LMin_{\lambda}$$

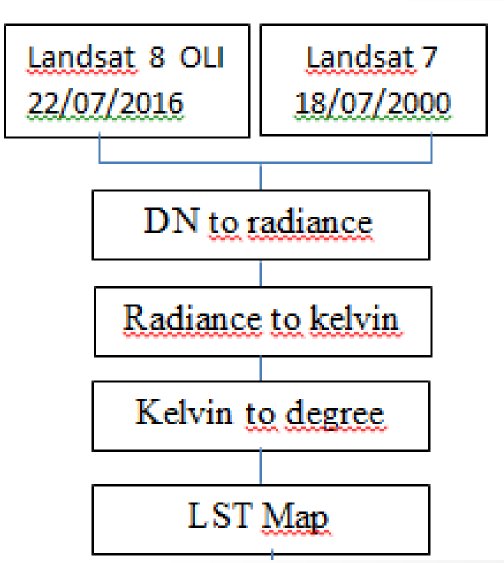



Where; Lʎ is the spectral radiance at the sensors aperture in W/(m2* sr* µm);
DN is the quantized calibrated pixel value,
Lminʎ and Lmaxʎ are the minimum and maximum spectral radiance of thermal band respectively,
QCalMin and QCalMax are the minimum and maximum quantized calibrated pixel value in DNs, respectively

# Method and Analysis

- **Land surface temperature (LST) estimation**
- The spectral radiance (Lʎ) obtained by equation (7) is converted to satellite brightness temperature (Landsat project science office, 2002; USGS, 2013) by using the following conversion formula

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}\right) + 1}$$

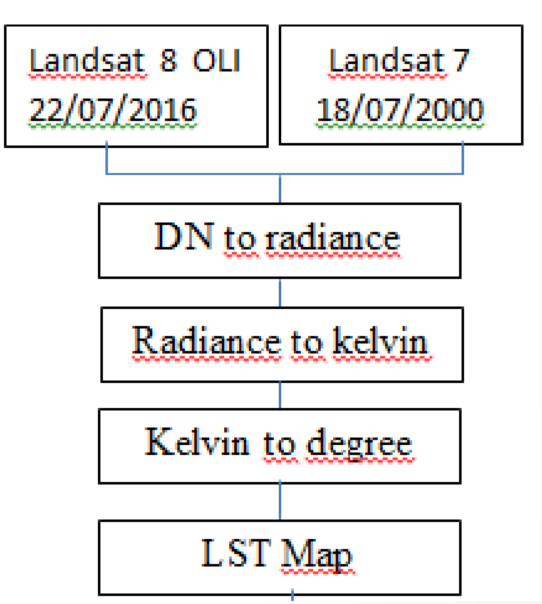



Where T is the effective at-satellite temperature in Kelvin (K),
$L_\lambda$ is the spectral radiance;
K2 and K1 are the thermal band pre-launch calibration constants.
For Landsat7 ETM+ band 6.1 image, K2 = 1282.71, and K1 = 666.09.
For Landsat8 OLI band 10 images, K2 = 1321.08 and K1 = 774.89.

# Method and Analysis

- **Land surface temperature (LST) estimation**
- The satellite temperature in Kelvin are then transformed to Celsius by using the equation

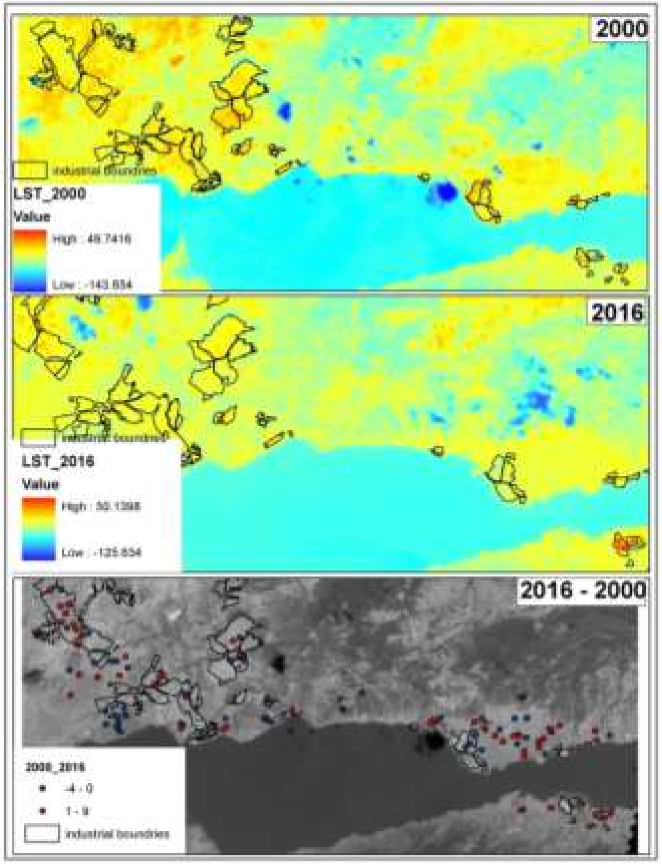
$$T(C) = T - 273.15$$



# Results and Discussion

## 3.Relationship analysis between LST and industrial region

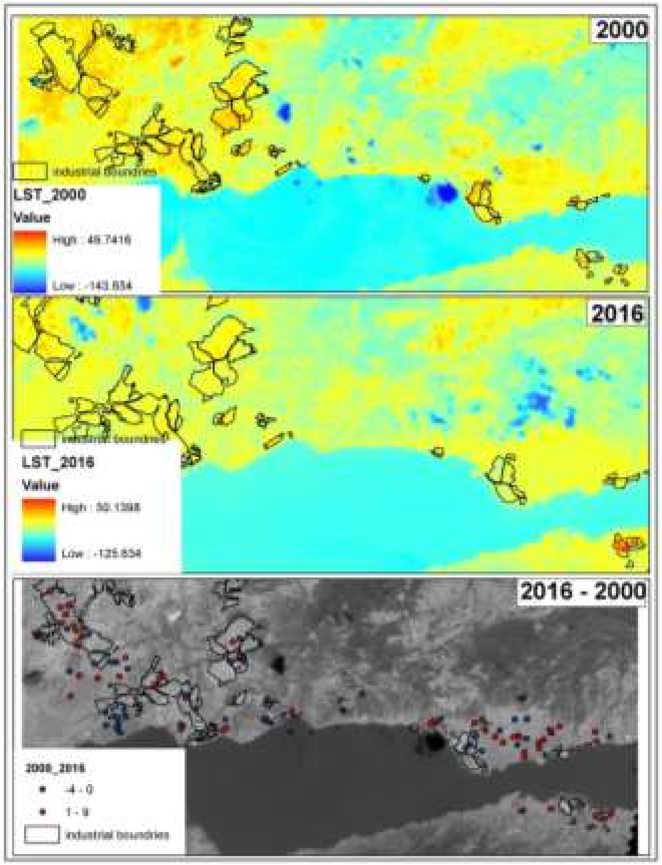
- In order to investigate the relationship between the industrial regions and land surface temperature, the LST for 2000 and 2016 was overlaid with industrial region boundaries.
- 100 random points is employed in and around the industrial regions to produce a radiant temperature difference after the surface radiant temperature of each year has been normalized.



# Results and Discussion

## 3.Relationship analysis between LST and industrial region

- The temperatures were resampled to database of generated random points from the 2000 and 2016 LSM maps.
- Then the temperature values were compared by calculation of the difference.



# Results and Discussion

- The temperature difference of %70 of the distributed random points were higher than 0 which indicated 1 to 9 degrees of increase in the temperature.
- On the other hand %30 indicates negative difference means decrease in temperature between -1 to -4.

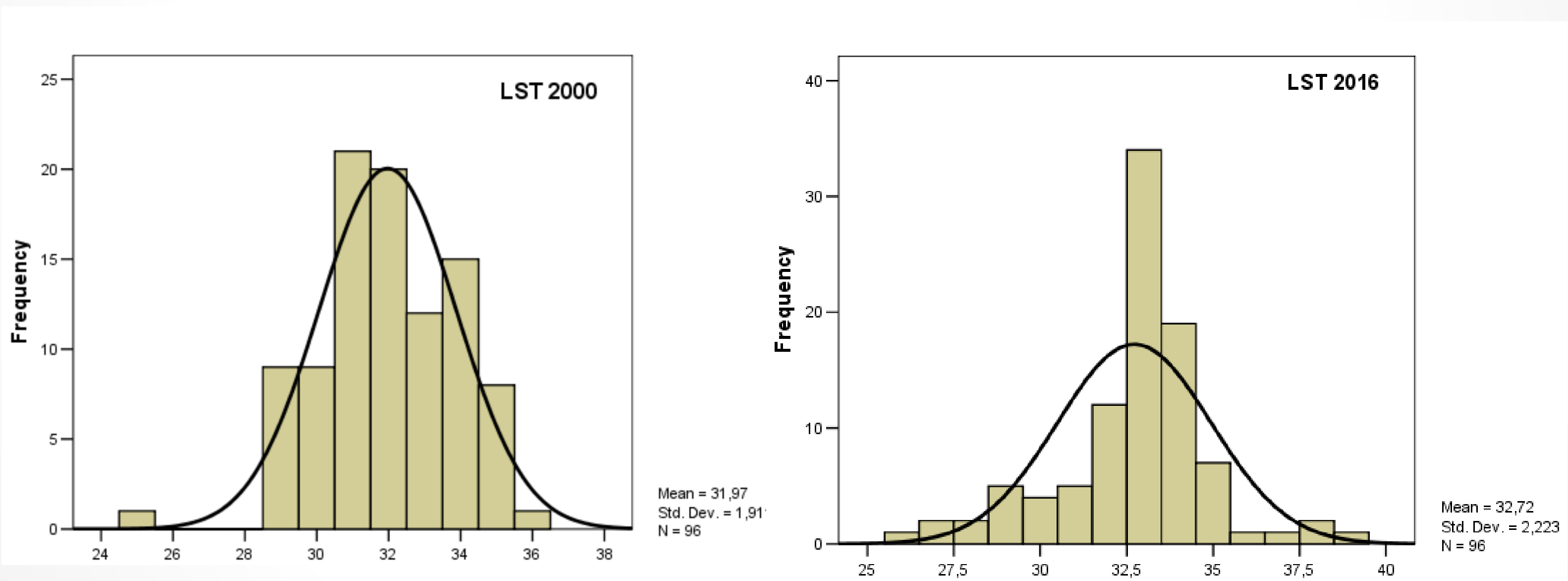



**Figure 7.** The frequency distribution for LST 2000 nd LST 2016

# Results and Discussion

| Descriptive Statistics | | | | |
|---|---|---|---|---|
| | Min. | Max. | Mean | Std. Dev. |
| LST 2000 | 25 | 36 | 31,97 | 1,911 |
| LST 2016 | 26 | 39 | 32,72 | 2,223 |

**Table 2.** The statistics for sample points

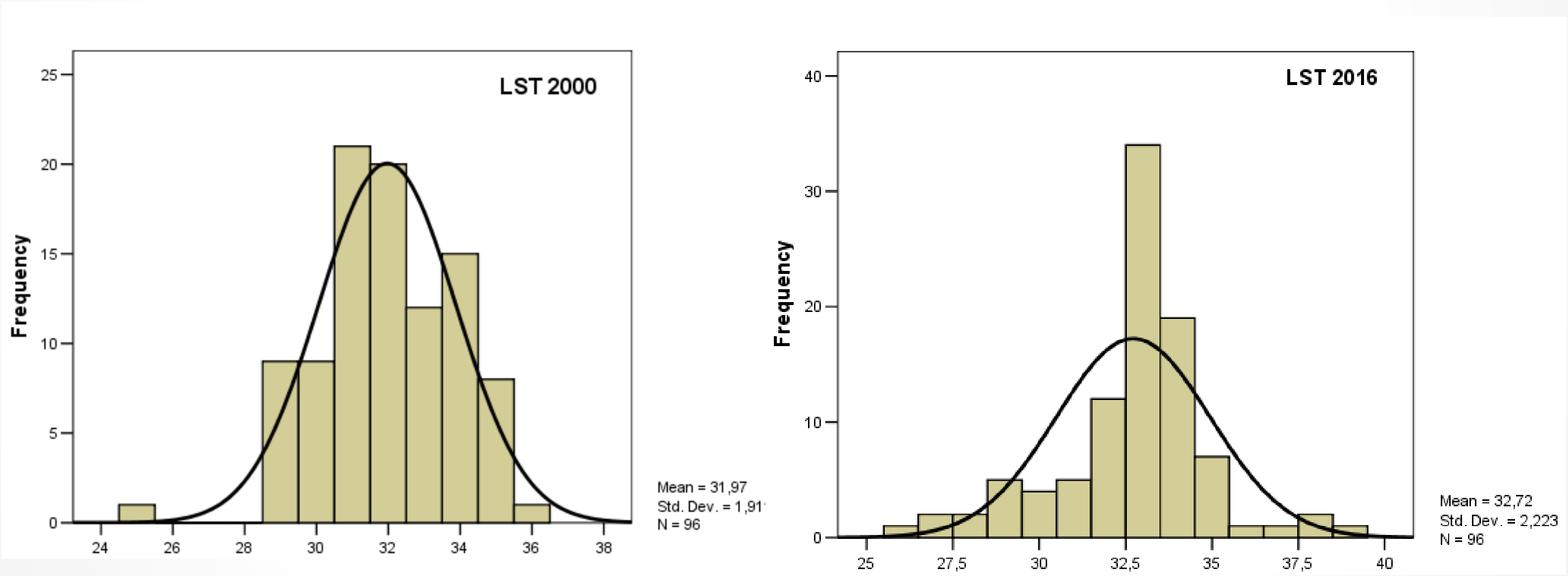



**Figure 7.** The frequency distribution for LST 2000 nd LST 2016

# Conclusion

- The combined use of remote sensing and GIS allows for an examination of the impact of industrial region expansion on surface temperature.
- In this study, an integrated approach of remote sensing and GIS was developed for evaluation of spatiotemporal distribution of industrial region and its impact on surface temperature in Kocaeli city, Turkey.
- The results indicate that 35.15% increase in the field of industry has been observed for 14 years.

# Conclusion

- The LST values were compared in and around industrial regions. Spatiotemporal difference of LST values were compared by employing 100 sample points.
- The results showed that industrial development raised surface radiant temperature by 1 to 9 degrees for 70% of random sampled points of the study region.
- The min, mean and maximum temperature increased 1, 0.5 and 3 degrees respectively.
- As a result the integration of remote sensing and GIS provides an efficient way to detect industrial region expansion and to evaluate its impact on surface temperature.

- Thank you so much for your concern….