

# Evaluating Chicago's Urban Heat Island Policy with Remote Sensing



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# The Heat Island Effect

When a large urban area is a few degrees warmer than its surrounding rural area.

Chicago Urban Heat Island

June 5th 2009

293K

308K



# Two Ways to Combat Heat Island

## The “Green” Method

### Increase Vegetated Surfaces

- Subsidize Green Roofs
- Zone Parks
- Replace Asphalt Lots with Green Fields
- Plant Street Trees
- Minimize Development over Vegetated Areas

## The “White” Method

### Increase Reflective Surfaces

- Subsidize Reflective Roofs
- Change Road Pavement to be more Reflective

# Chicago Heat Wave of 1995



Caused 514 Citizen Deaths

Caused a Series of Policies  
Aimed at Combating the Heat  
Island

# Chicago Heat Island Policies (since 1995)

## GREEN POLICIES

- Over 500 new subsidized green roofs
- 300 acres of schoolyard asphalt replaced with grass
- Over 57 new community parks
- At least 5,000 new street trees each year

## WHITE POLICIES

- Tax incentives for reflective roofs
- New shingle reflectivity zoning codes (for new buildings)
- Brightened pavement on some major roadways.
- 68 Alleyways changed to bright surfaces

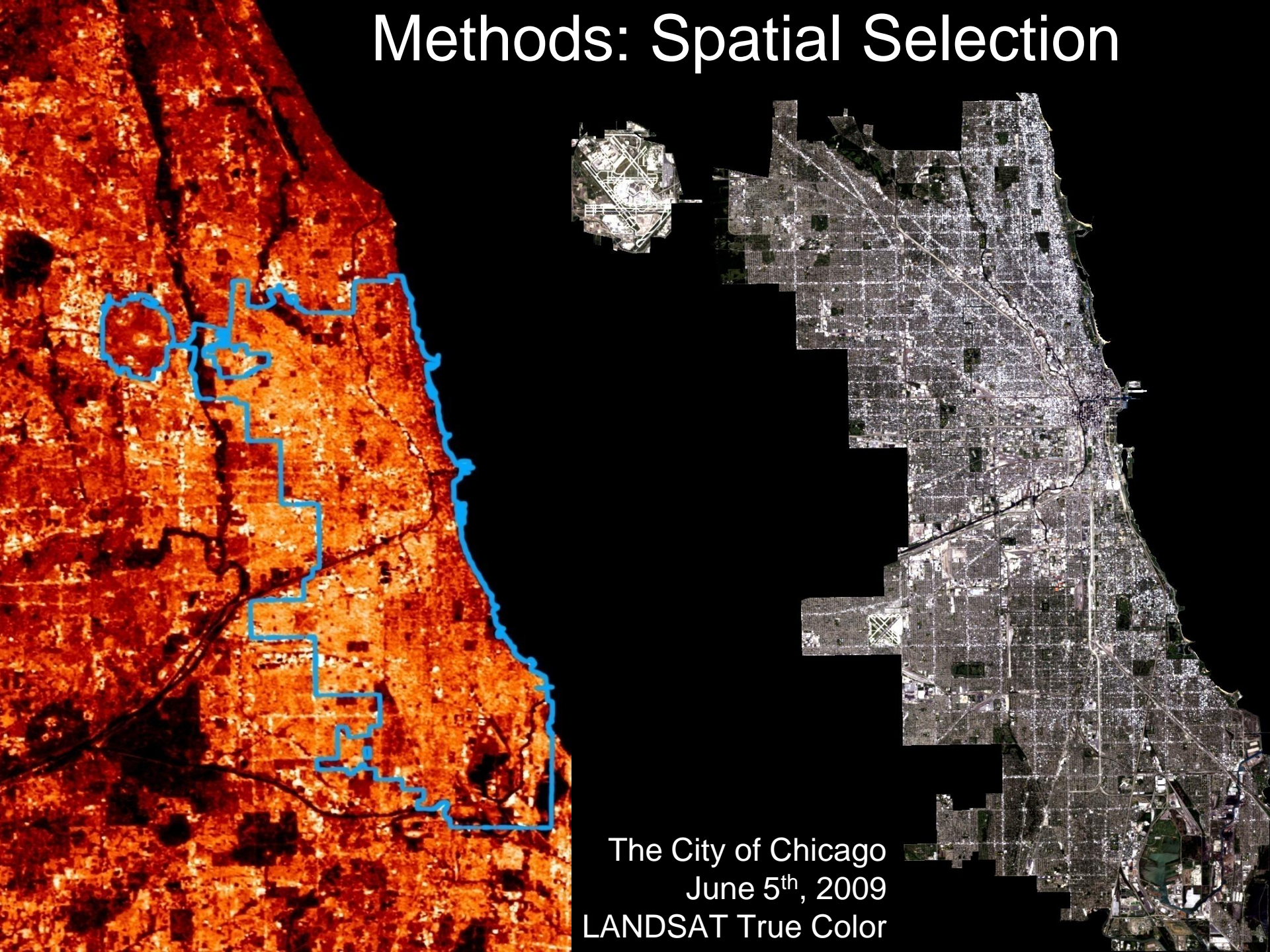
# Project Thesis

Have these policies amounted to a large-scale impact on the heat island?

And, if so,

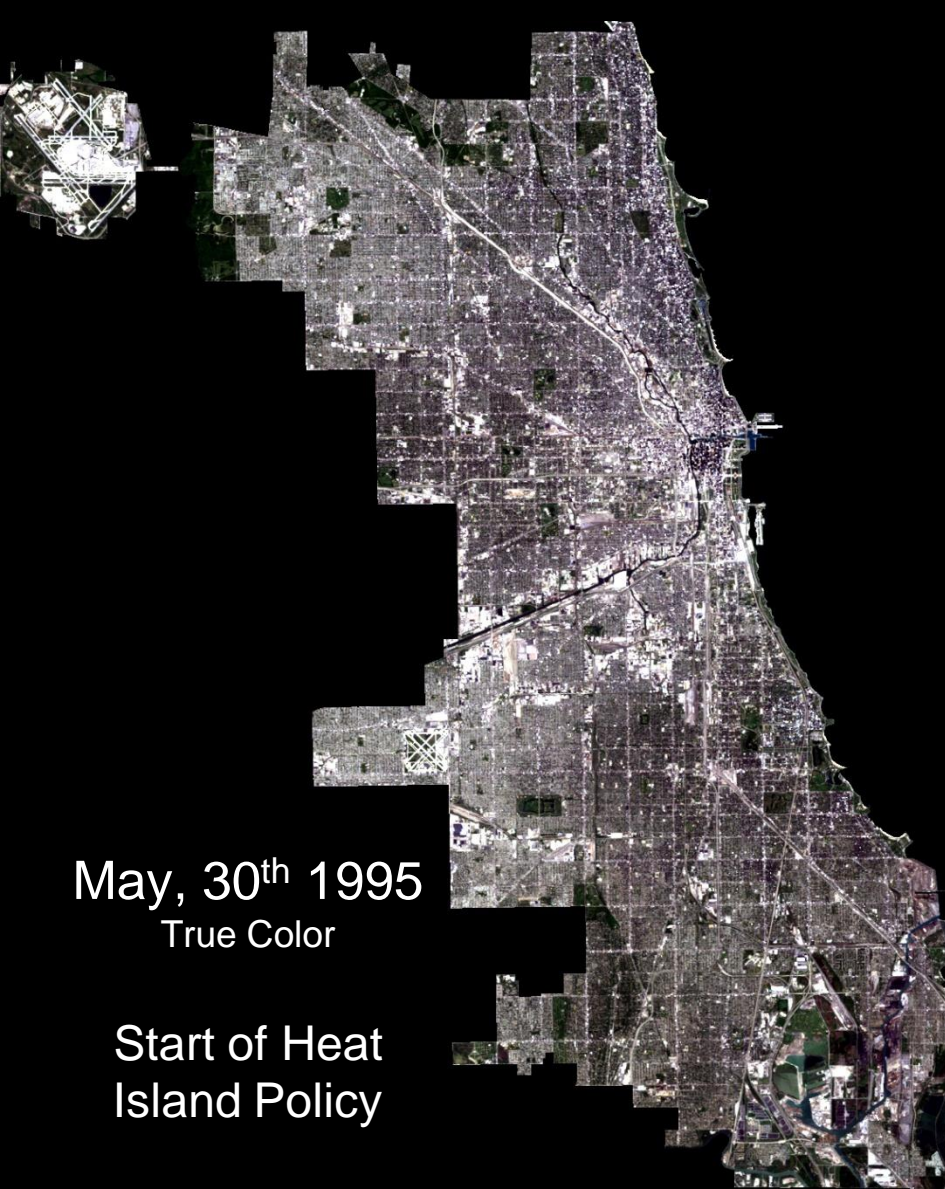
Which policies have been most effective?  
Is a green or a white strategy more effective?

# Methods: Spatial Selection



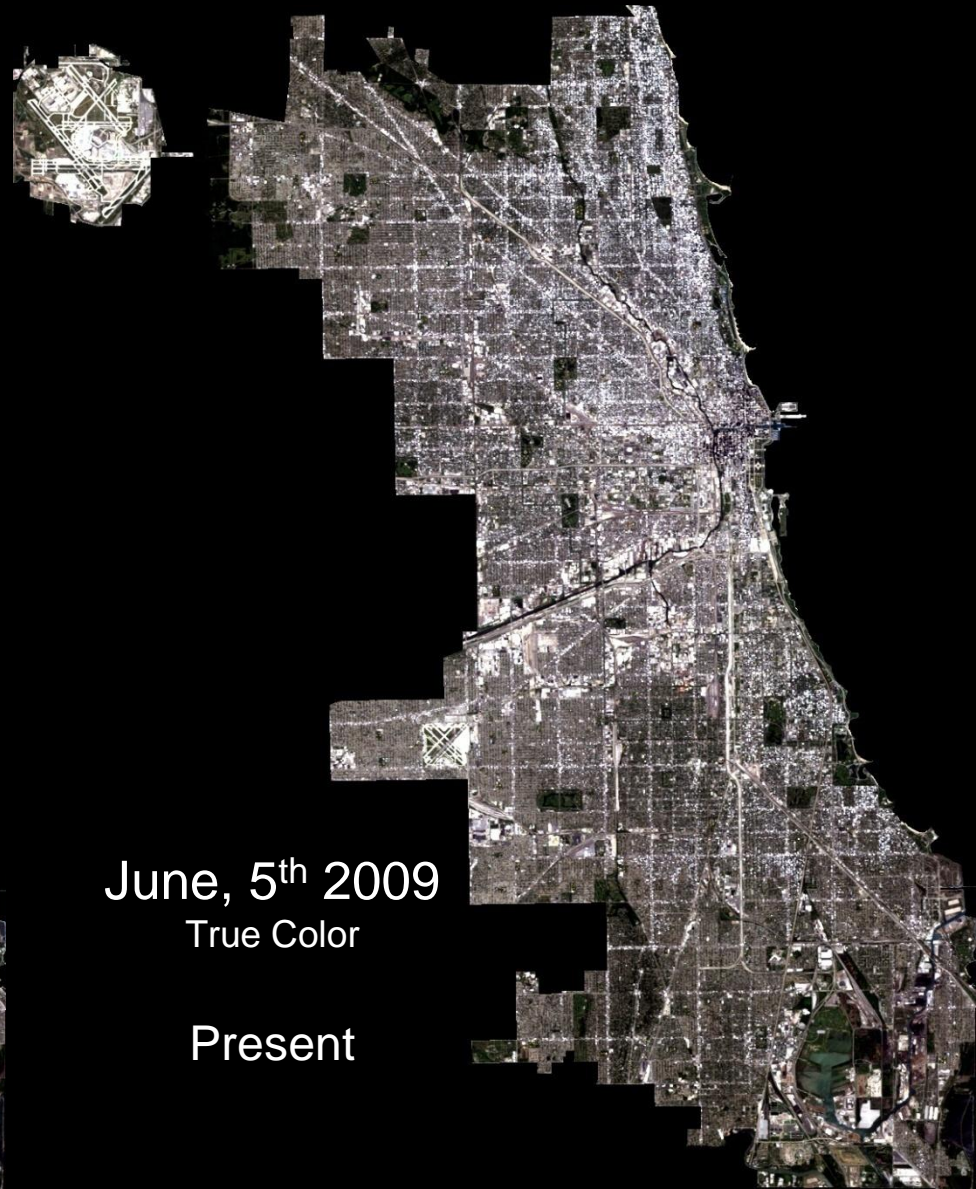
The City of Chicago  
June 5<sup>th</sup>, 2009  
LANDSAT True Color

# Methods: Temporal Selection



May, 30<sup>th</sup> 1995  
True Color

Start of Heat  
Island Policy



June, 5<sup>th</sup> 2009  
True Color

Present



# Methods: NDVI Change

- Calculate NDVI with LANDSAT bands 3 + 4 for both dates.
- Exclude pixels with NDVI less than .3.
- Subtract 1995 pixels from 2009 pixels.



# Methods: NDVI Change

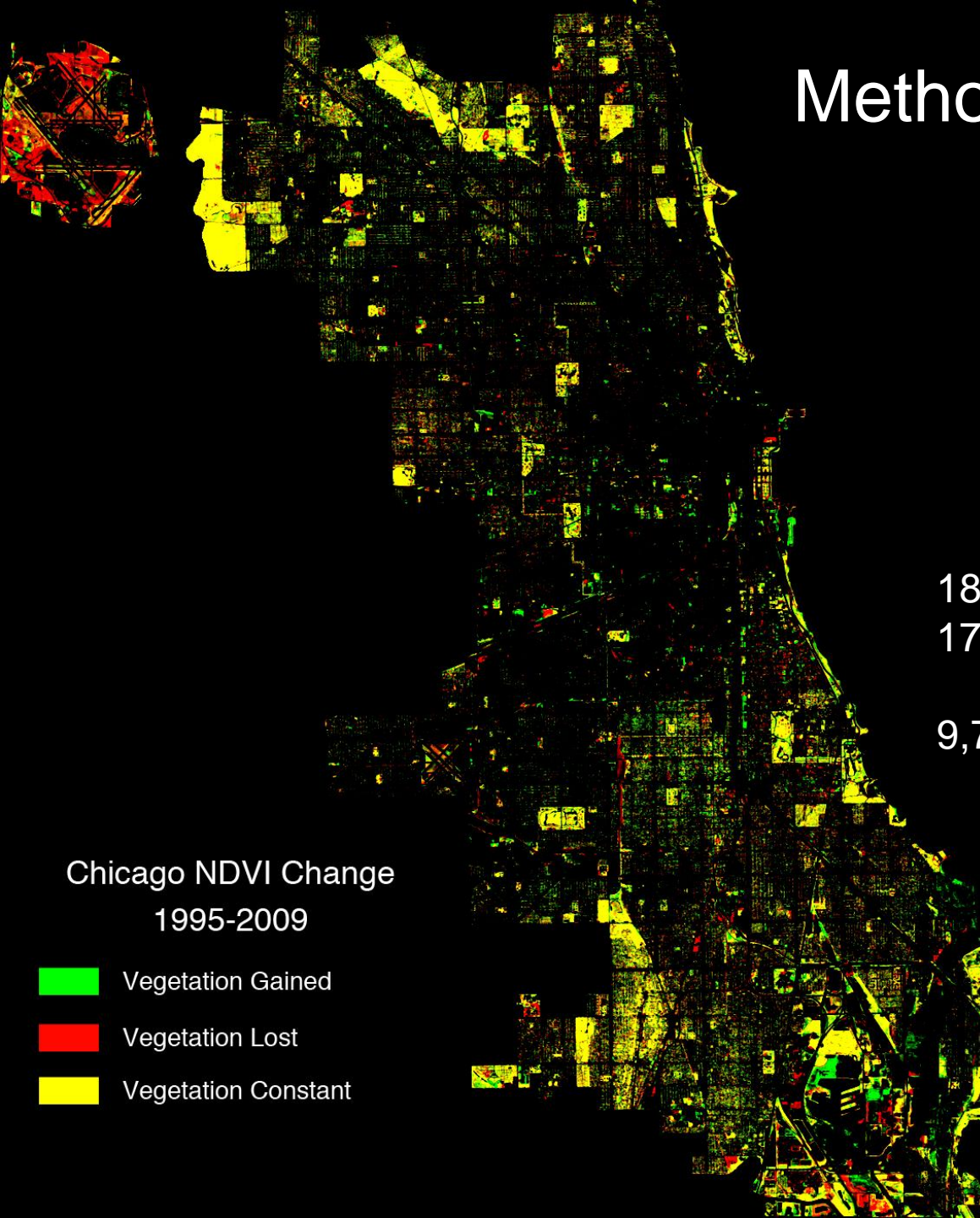
- Set 1995 to red channel, 2009 to green channel.

185,016 vegetated pixels in 1995.  
175,289 vegetated pixels in 2009.

9,727 vegetated pixels lost.

## Chicago NDVI Change 1995-2009

-  Vegetation Gained
-  Vegetation Lost
-  Vegetation Constant



# Methods: Albedo Change



- Convert LANDSAT reflective band DN's to reflectance.
- Use Liang method to weight reflectances and obtain overall albedo.
- Subtract 1995 albedo from 2009 albedo.

# Methods: Albedo Change

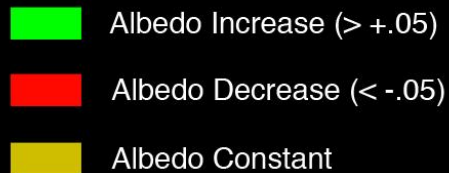
- Set 1995 to red channel and 2009 to green channel.

.149998 average city albedo 1995.

.173263 average city albedo 2009.

.023265 albedo increase.

## Chicago Albedo Change 1995 - 2009



.148293 average non-vegetated albedo 1995.

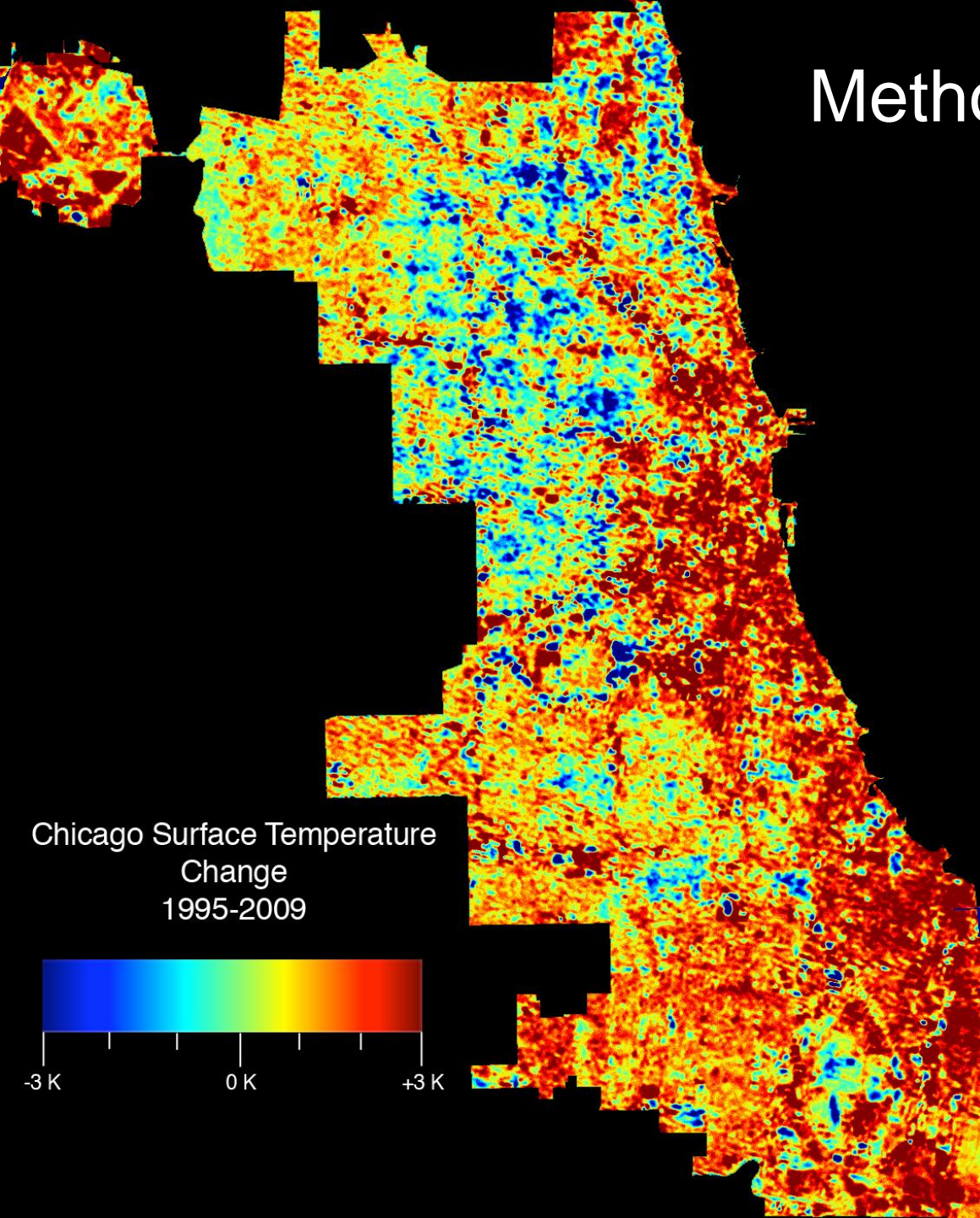
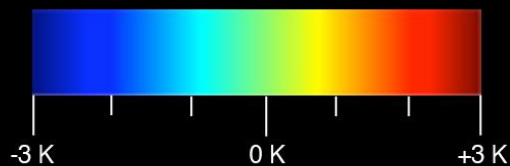
.174788 average non-vegetated albedo 2009.

.026495 albedo increase.

# Methods: Temp Change

- Convert LANDSAT TIR band DN's to radiance.
- Use the inverse of the Planck function to convert radiance to temperature.
- Subtract 1995 temperature from 2009 temperature.
- Color-coded the image

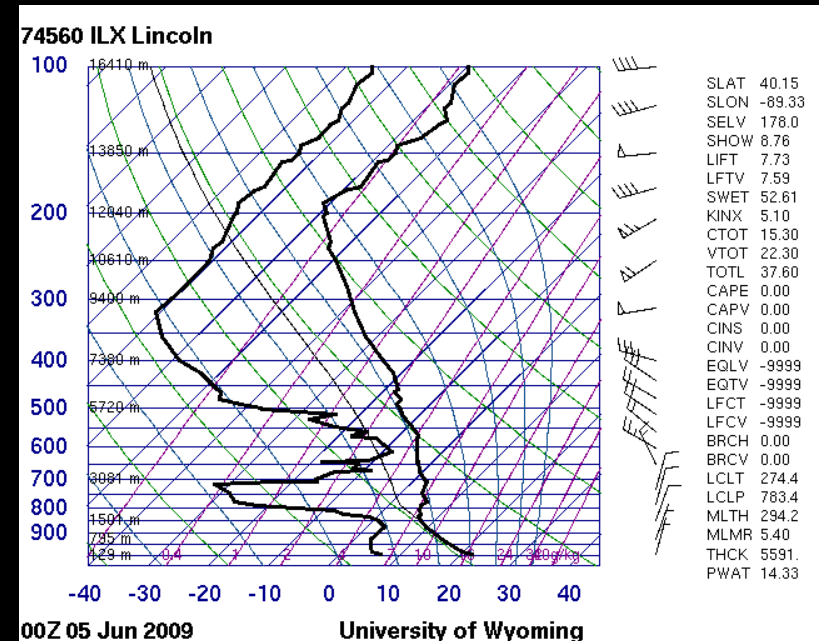
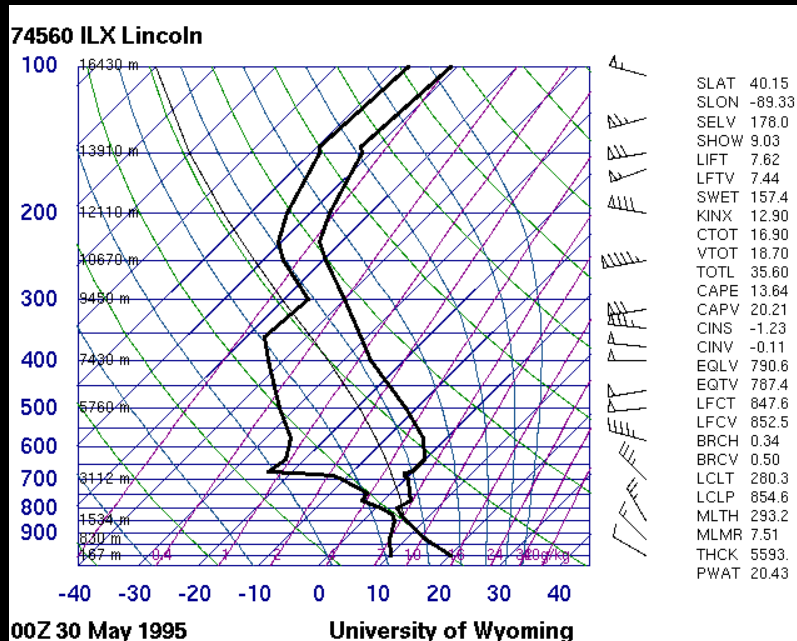
Chicago Surface Temperature  
Change  
1995-2009



# Methods: Temp Change Justification

May 30th, 1995

June 5th, 2009

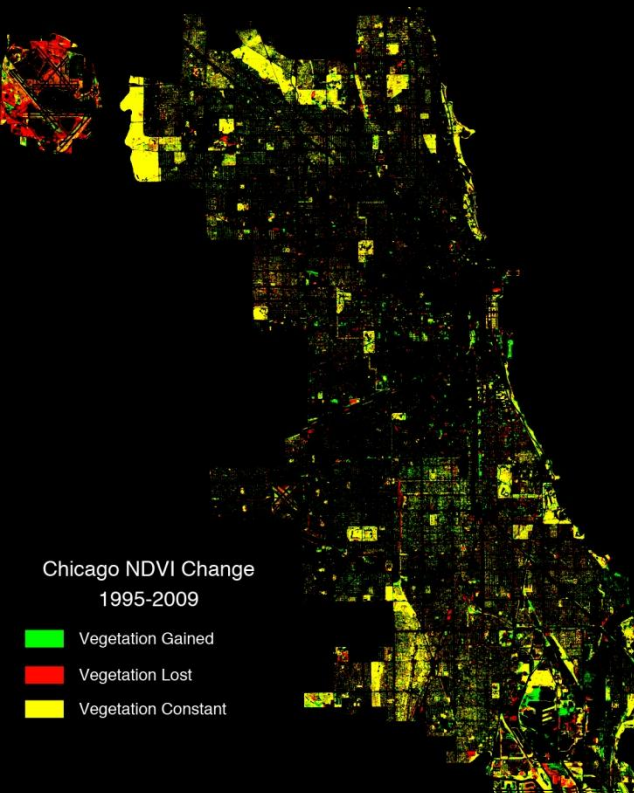


Avg. Temp. at Midway: 67 F  
Avg. Temp. at O'Hare: 68 F

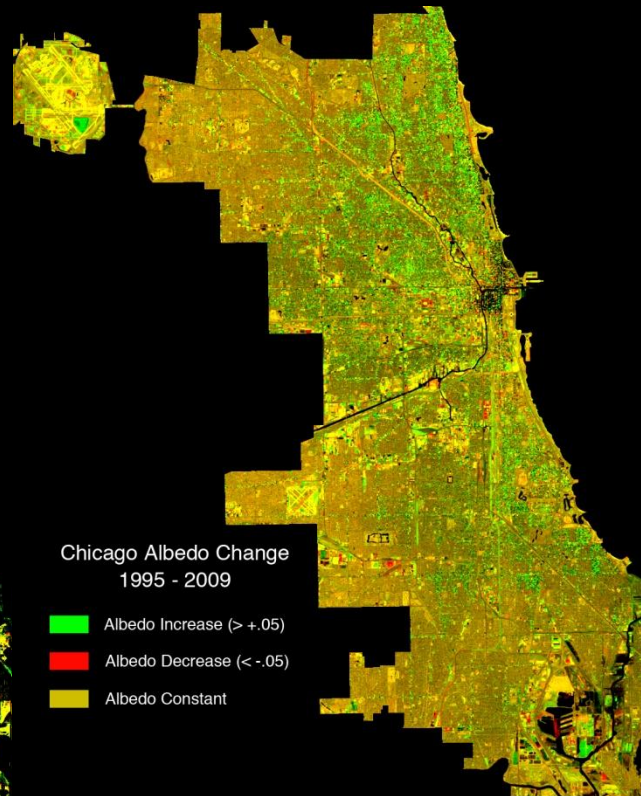
Avg. Temp. at Midway: 65 F  
Avg. Temp. at O'Hare: 62 F

# Results: Compare

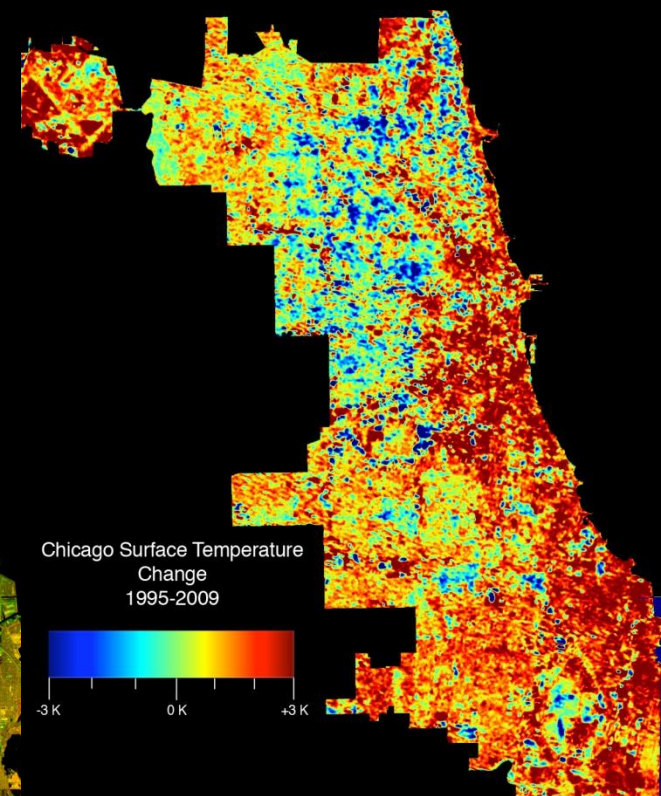
## NDVI Change



## Albedo Change



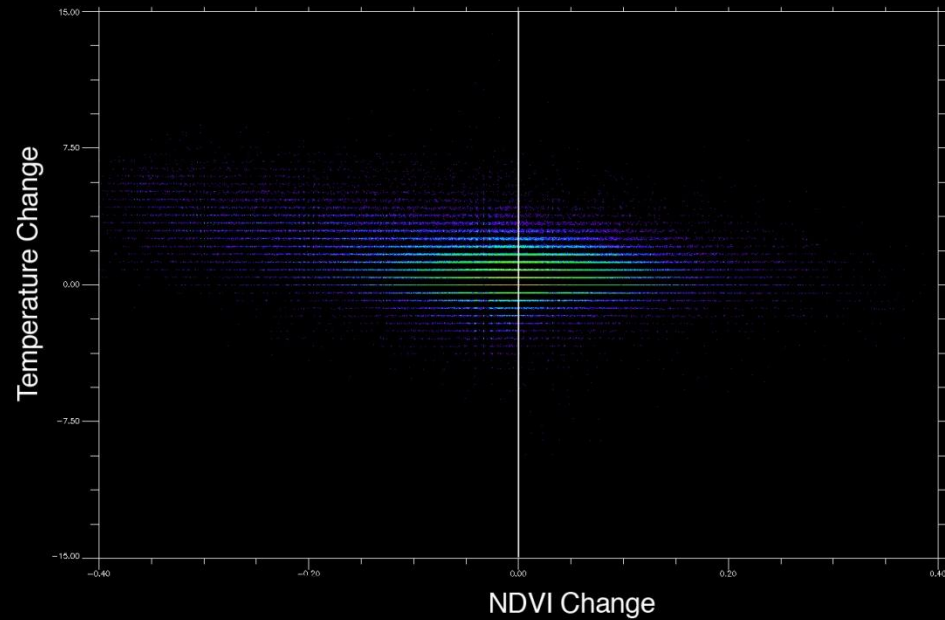
## Temperature Change



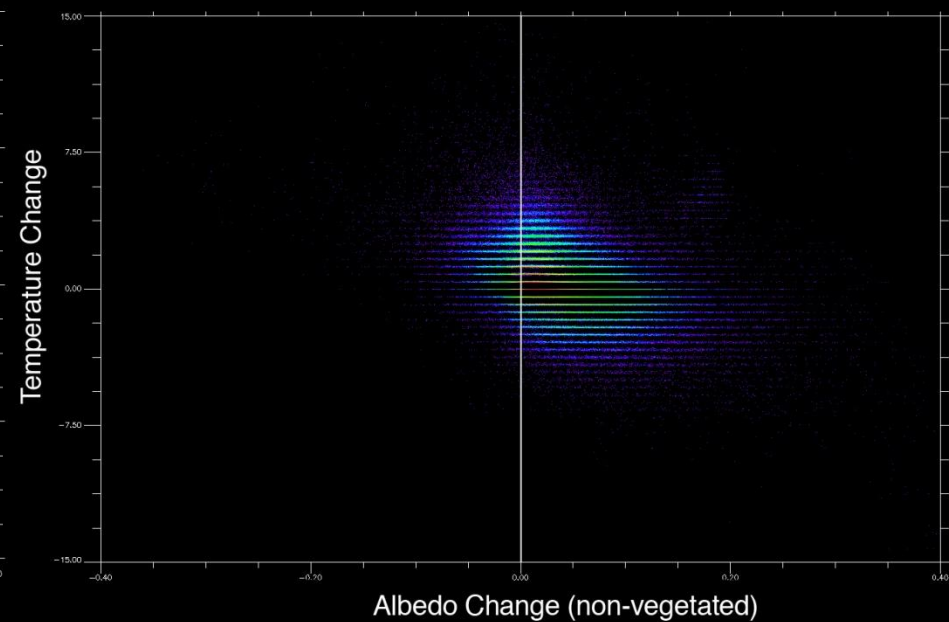
# Correlation of Changes (1995-2009)

NDVI Change to  
Temperature Change

Albedo Change to  
Temperature Change



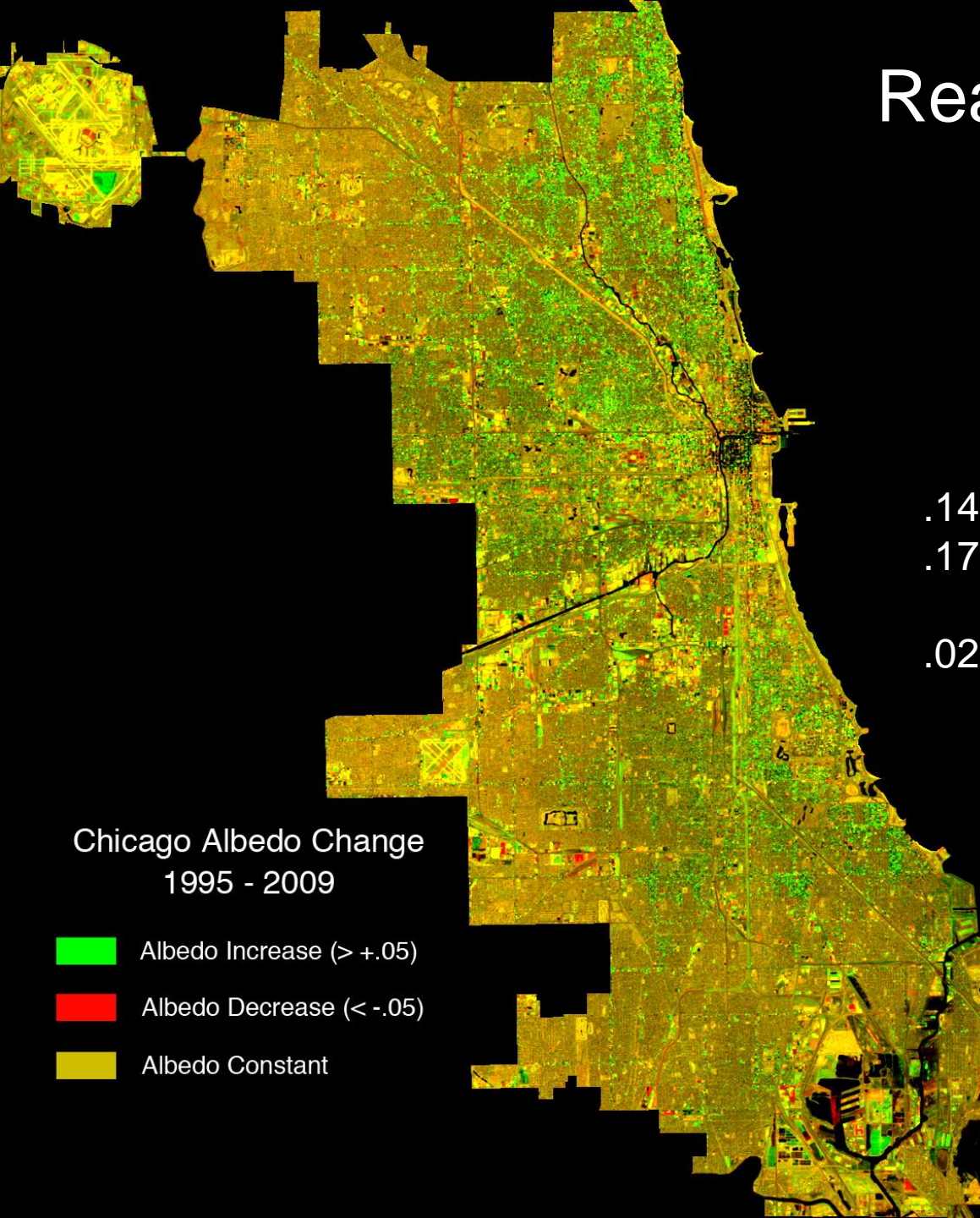
Correlation of  $-.273539$   
Covariance of  $-.030190$



Correlation of  $-.369368$   
Covariance of  $-.025238$



# Real Albedo Change?

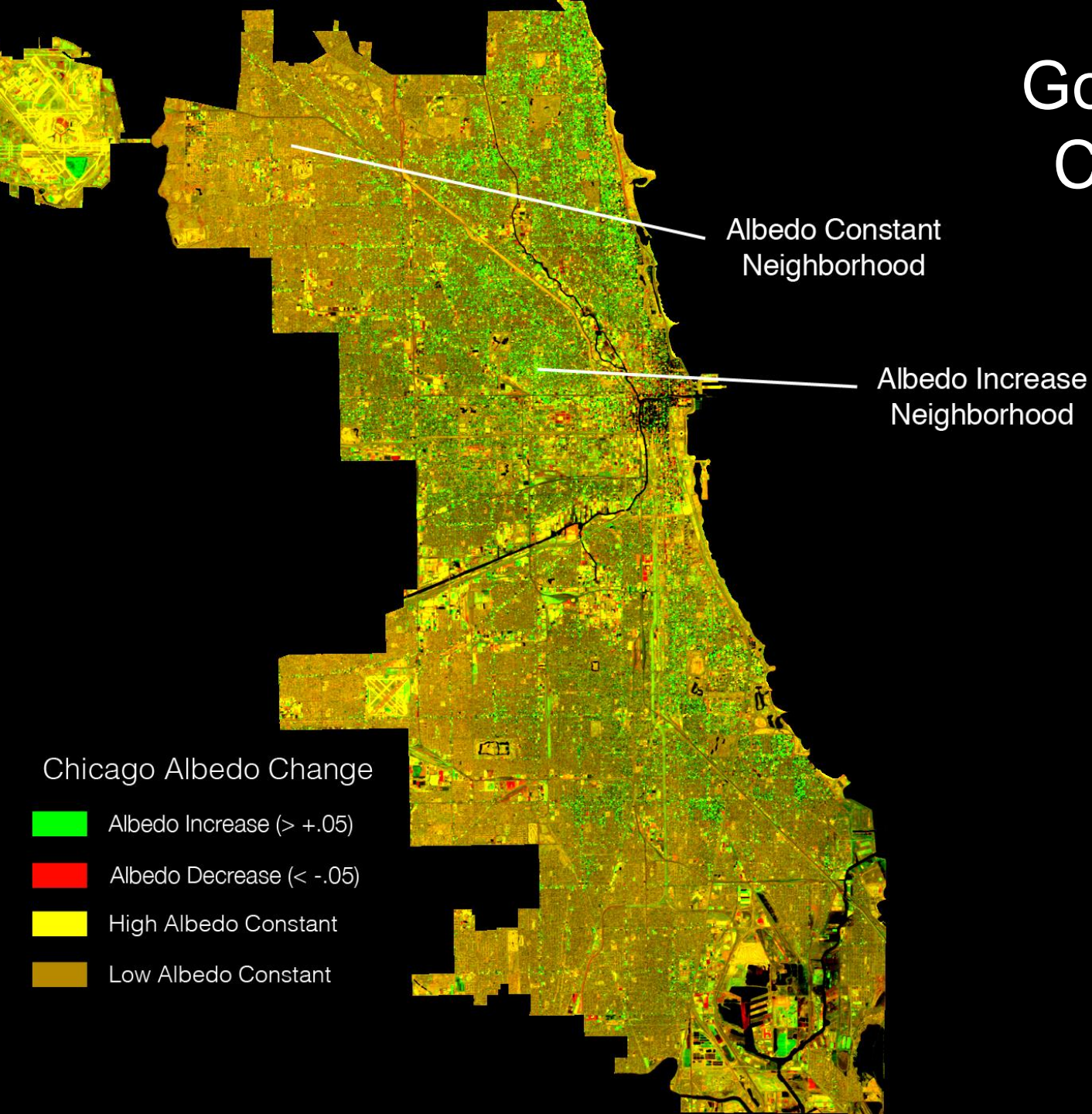


.149998 average city albedo 1995.

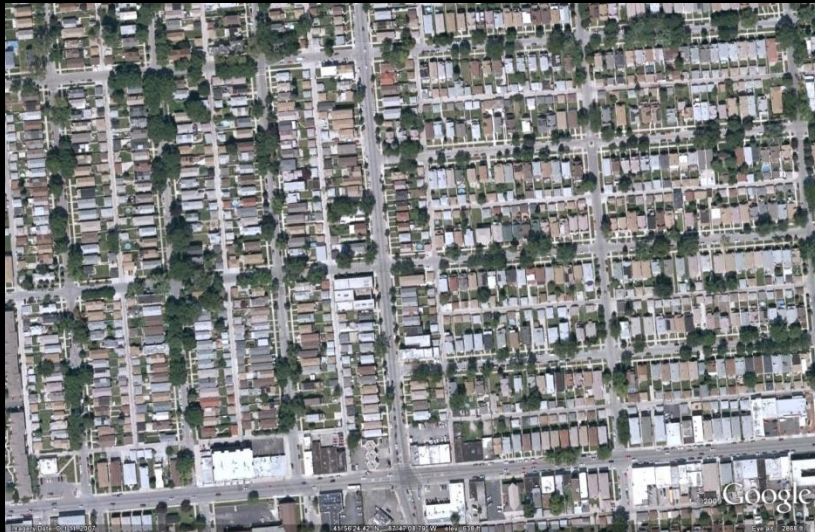
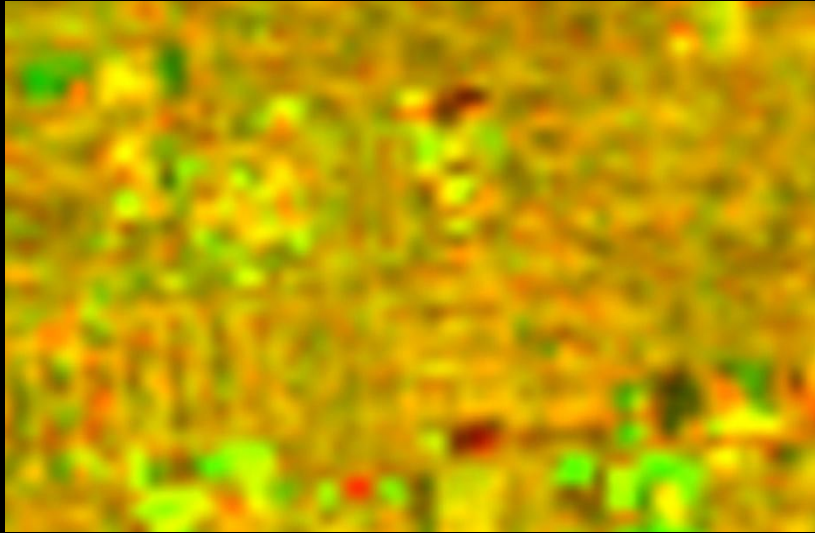
.173263 average city albedo 2009.

.023265 albedo increase.

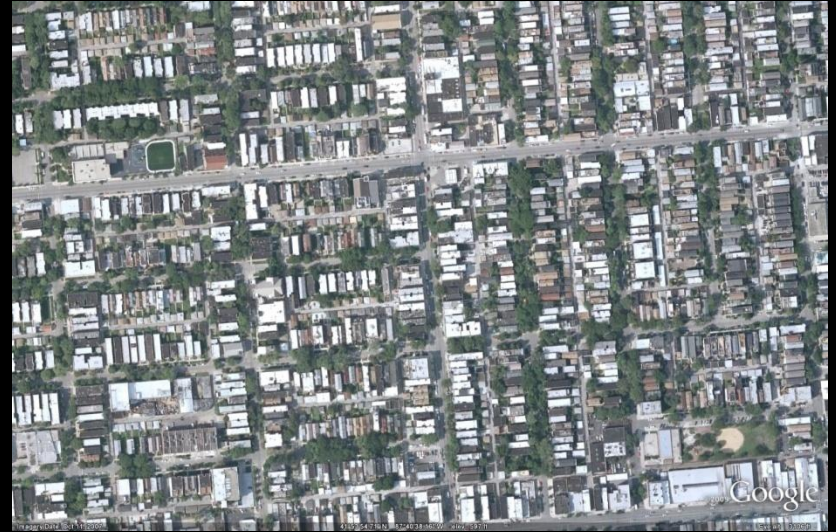
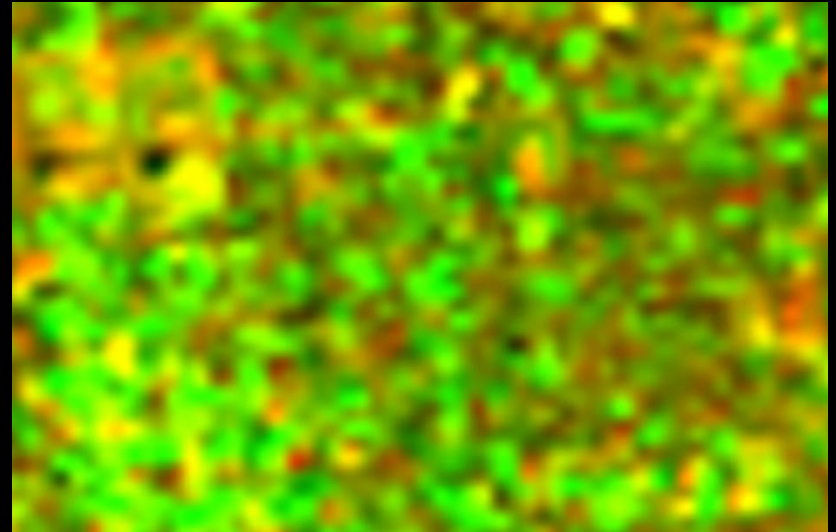
# Google Earth Comparison



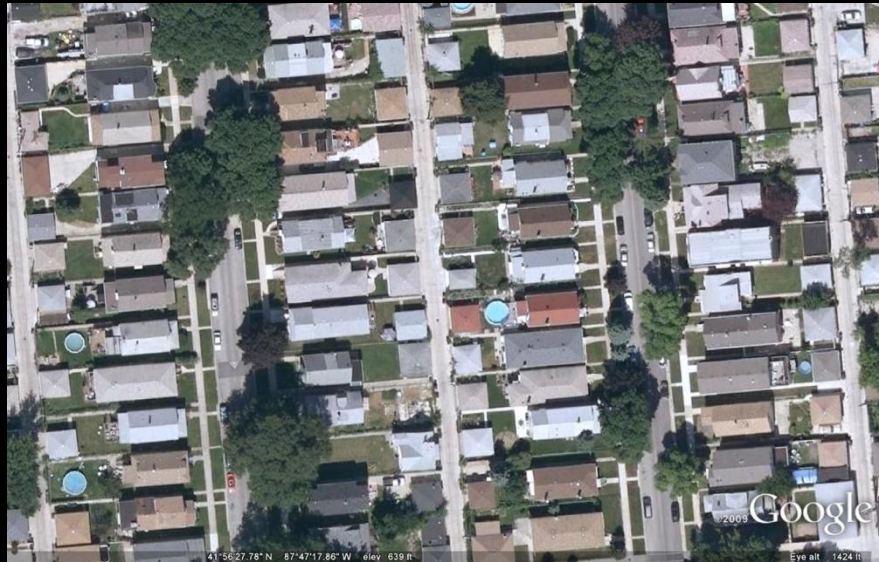
# Albedo Constant Neighborhood



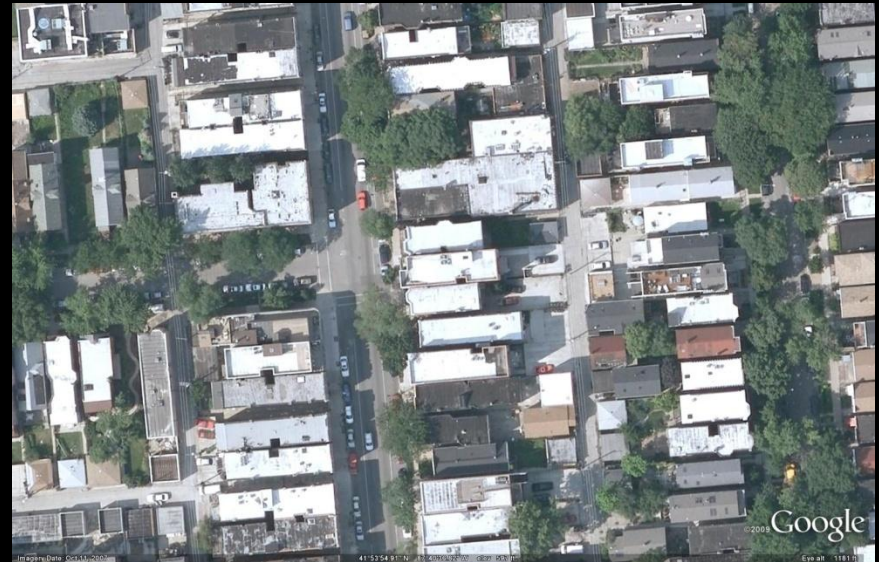
# Albedo Increase Neighborhood



# Albedo Constant Neighborhood



# Albedo Increase Neighborhood

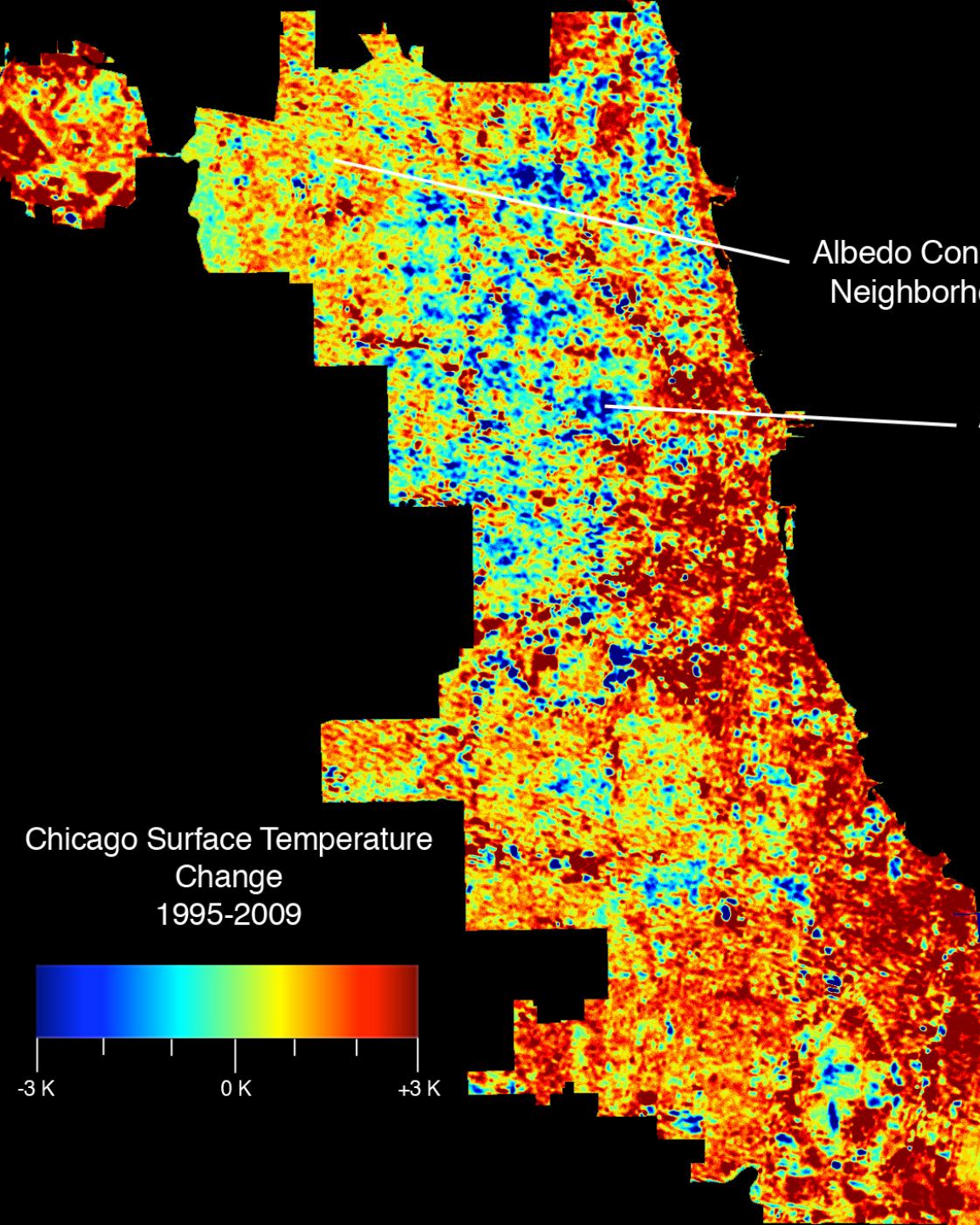
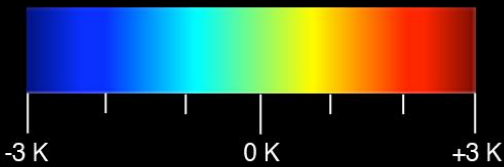


Albedo Increase caused  
a Temperature Decrease

Albedo Constant  
Neighborhood

Albedo Increase  
Neighborhood

Chicago Surface Temperature  
Change  
1995-2009



# Rough Qualitative Analysis of Policies

## Green Policies

Policy	Visually Effective	Effect on Temperature	Area Affected
Green Roofs	No	None	Single Building
Small Parks	Yes	Stabilize	Few Blocks
Large Parks	Yes	Decrease	Neighborhood
Street Trees	Yes	Stabilize	Regional

## White Policies

Policy	Visually Effective	Effect on Temperature	Area Affected
Road Pavement	Yes	None	Regional
Alleyways	No	None	Few Blocks
Residential Reflective Roofs	Yes	Decrease	Regional
Industrial Reflective Roofs	Yes	Decrease	Regional

# Conclusion

Chicago's policies have been working gradually.

In terms of large-scale reduction of the urban heat island over a 15-year period, wide-spread use of reflective roofs seems to be most effective.

Roughly speaking, white policies tend to be more effective than green policies (probably because of cost).

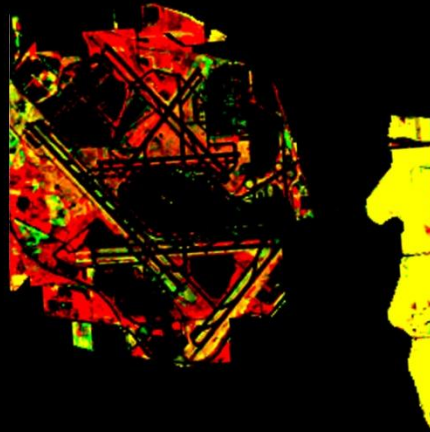
Project Limitation: green policies may be more effective later in summer.

# Conclusion

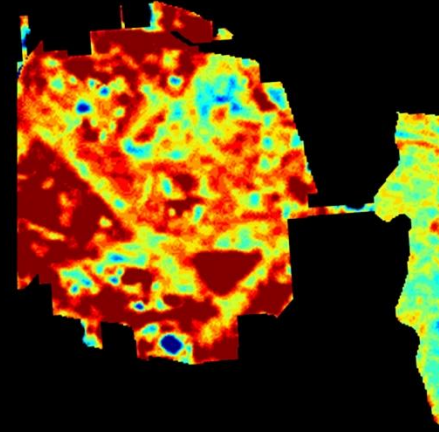
An effective green policy would probably involve limiting development rather than zoning small parks or promoting green roofs.



Present O'Hare Airport  
(Google Earth)



O'Hare NDVI Change  
(1995-2009)



O'Hare Temperature Change  
(1995-2009)



# References

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