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# RPPR Final Report

## as of 29-Apr-2020

Agency Code:

Proposal Number: 72593EV

**Agreement Number: W911NF-18-1-0371**

### INVESTIGATOR(S):

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**Report Date:** 31-Aug-2019

Date Received: 28-Apr-2020

**Final Report** for Period Beginning 01-Sep-2018 and Ending 31-May-2019

**Title:** Towards understanding the urban surface energy budget

**Begin Performance Period:** 01-Sep-2018

**End Performance Period:** 31-May-2019

**Report Term:** 0-Other

Submitted By: Prathap Ramamurthy

Email: pramamurthy@ccny.cuny.edu

Phone: (801) 652-1675

**Distribution Statement:** 1-Approved for public release; distribution is unlimited.

**STEM Degrees:** 0

**STEM Participants:** 0

**Major Goals:** The primary goal of the project was to use satellite derived remote sensing data to advance our understanding of urban surface energy budget. The urban surface energy balance, key to understanding the surface-atmosphere interactions in urban areas is yet unknown. Surface heterogeneity is the central limiting factor-urban environments are made up of bricks, steel, asphalt, vegetation which all have different thermal and physical properties resulting in complex exchanges of heat and momentum. Traditional tower based techniques commonly used to study the urban surface energy balance have many inconsistencies. Here in we have used satellite data to overcome the issues related to surface heterogeneity and advance our knowledge on surface energy balance. We coupled data from a geostationary satellite with high temporal resolution with data from a polar orbiting satellite that has low temporal but high spatial resolution to downscale the data. This data was then used to understand the thermal characteristics of urban environments. Additionally algorithms were developed to use multi-spectral bands of the geostationary satellite to compute urban storage heat flux.

**Accomplishments:** Overall the project helped to use satellite derived dataset to study urban climate at relevant spatial and temporal scales. The project: 1) Developed an air temperature model to study urban air temperatures. 2) Developed the tools required to downscale coarse resolution satellite products for urban areas. 3) Developed tools to compute and validate urban storage heat flux. 4) Advanced our fundamental knowledge of urban surface energy budget

**Training Opportunities:** Nothing to Report

**Results Dissemination:** Results from the project were presented in the American Geophysical Union Conferences and also published in high impact scientific journals. Results were also used to enhance courses that the PI is teaching. Additionally, the PI, who was one of the Chair's of the 9th International Conference on Urban Climate held in New York City in August 2018 and attended by more than 600 scientists from more than 50 countries, organized a special session on urban remote sensing.

**Honors and Awards:** Nothing to Report

**Protocol Activity Status:**

**Technology Transfer:** Nothing to Report

**RPPR Final Report**  
as of 29-Apr-2020

**PARTICIPANTS:**

**Participant Type:** PD/PI

**Participant:** Prathap Ramamurthy

**Person Months Worked:** 9.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**Participant Type:** Graduate Student (research assistant)

**Participant:** Abdou Bah

**Person Months Worked:** 9.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

**ARTICLES:**

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**Article Title:** Urban air temperature model using GOES-16 LST and a diurnal regressive neural network algorithm

**Authors:** Joshua Hrisko, Prathap Ramamurthy, Yunyue Yu, Peng Yu, David Melecio-Vázquez

**Keywords:** Air temperatureGOES-16Neural network, Regression, LST, Air temperature model, Satellite remote sensing

**Abstract:** An urban air temperature model is presented using the enterprise GOES-16 land surface temperature product. The model is constructed by fitting the difference between ground-truth air temperature data against satellite LST using a Gaussian function. A time-match algorithm aligns the ground and satellite measurements within 5-min of one another, and the resulting matched values are compared over ten months to investigate their correlation. Land cover, latitude, longitude, local time, and elevation are input to a regressive neural network to fit each unique GOES-16 pixel according to ground-based properties. Over 150 ground stations and satellite pixels throughout the continental U.S. are used near urban areas to construct the diurnal Gaussian relationship and approximate air temperature. Statistics from a five month validation period generates an RMSE of 2.6?K, a bias of 0.8?K, and R2 of 0.86, which are in strong competition with other studies at lower resolution.

**Distribution Statement:** 1-Approved for public release; distribution is unlimited.

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**CONFERENCE PAPERS:**

**RPPR Final Report**  
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**Conference Name:** American Geophysical Union

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Date Published: 12-Dec-2018

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**Paper Title:** Urban Air Temperature Model Using Goes-16 Lst and a Diurnal Regressive Neural Network Algorithm

**Authors:** Joshua Hrisko, Prathap Ramamurthy, Yun Yu, Peng Yu

Acknowledged Federal Support: **Y**

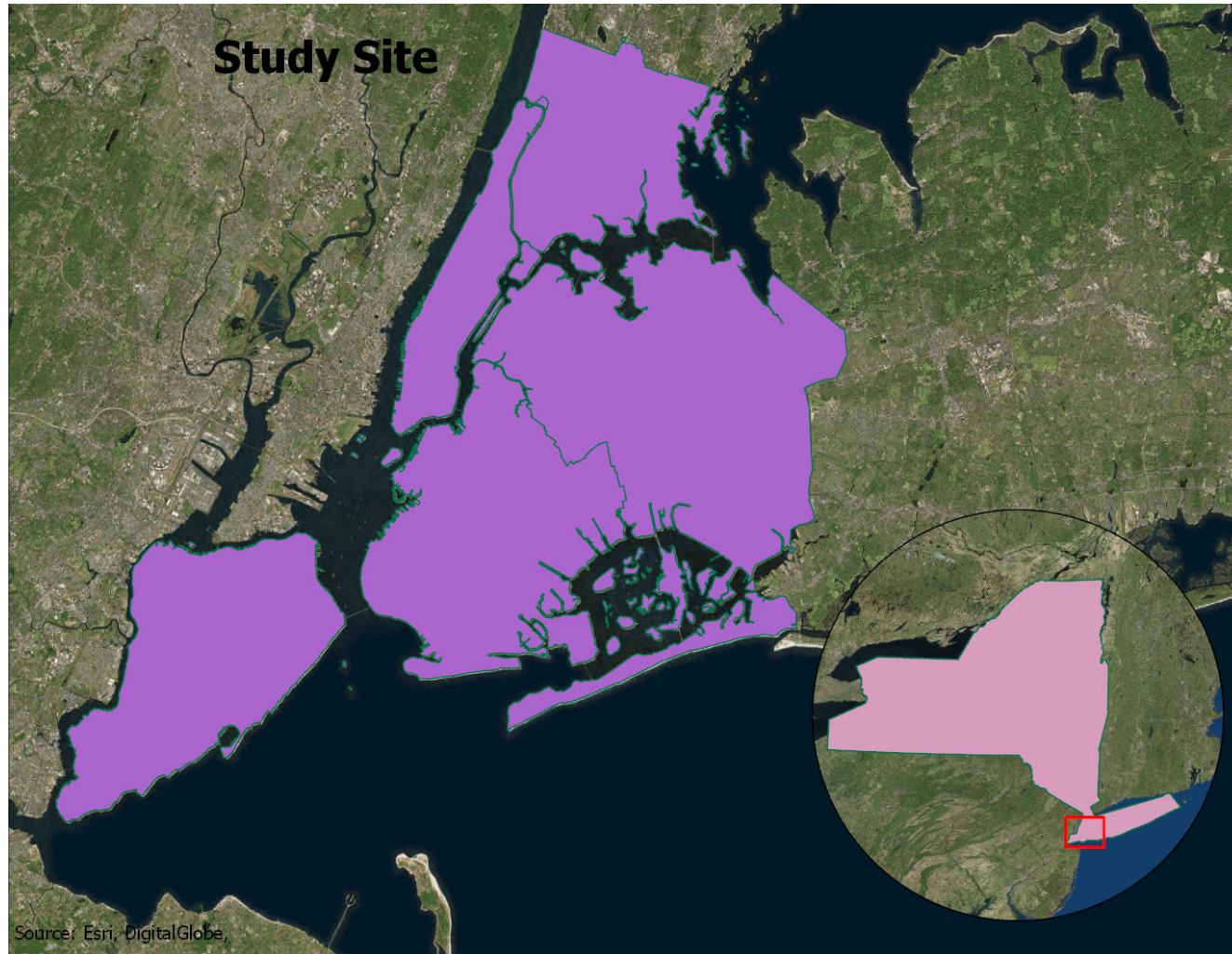
# Research Brief

# OVERVIEW

The slides here describe, 2 projects: **P1** *Downscaling* and **P2** *Air Temperature Modeling*. Both the projects were presented at the AGU 2018.

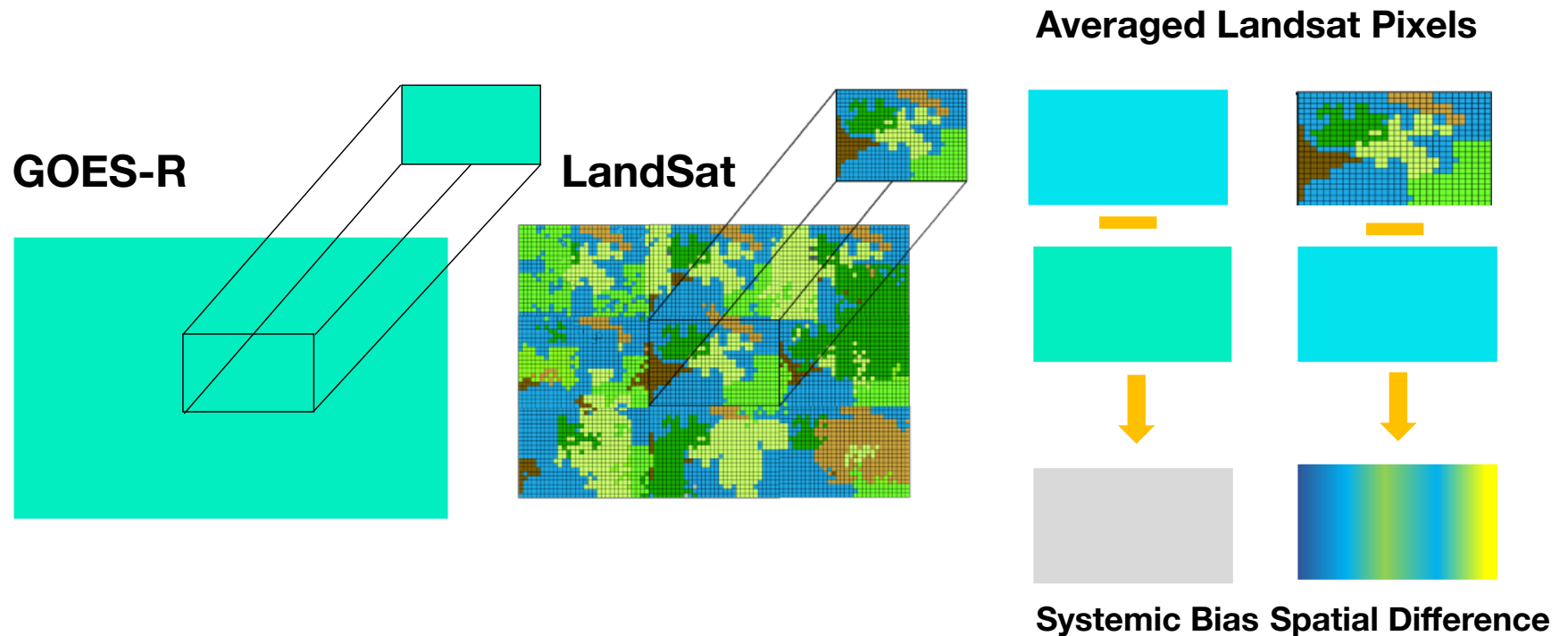
Overall we want to understand/model the *urban surface energy budget* using remote sensing technologies, which is cost effective compared to high-resolution numerical modeling and as well as spatially rich compared to meteorological measurements. Downscaling allows us to use the coarse resolution satellite data in complex urban environments, while the air temperature estimation is one of the first products. We will expand this to quantify other components of the urban surface energy budget.

# P1 - DOWNSCALING



Primary goal is to use a high spatially resolved satellite measurements to downscale low spatially resolved images. Here we use Landsat images for the former and GOES-R for the latter. GOES-R however has high temporal resolution. We will be downscaling the skin temperature.

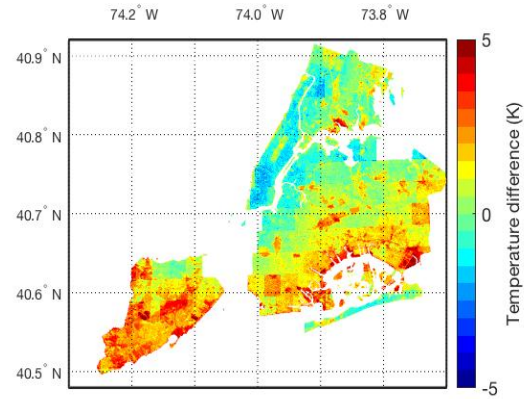
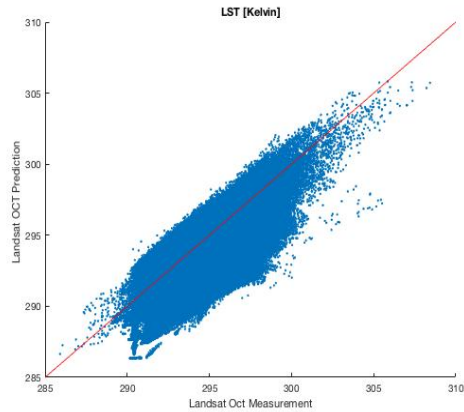
# P1-METHODS



Here we correlate the GOES-R pixel with Landsat pixels using high-resolution landcover dataset. We quantify the normalized difference between Landsat and GOES-R for different urban surfaces. The algorithm is validated using ground based measurements.

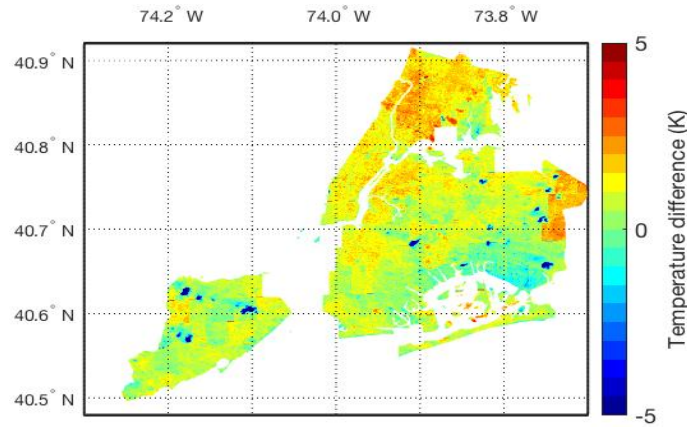
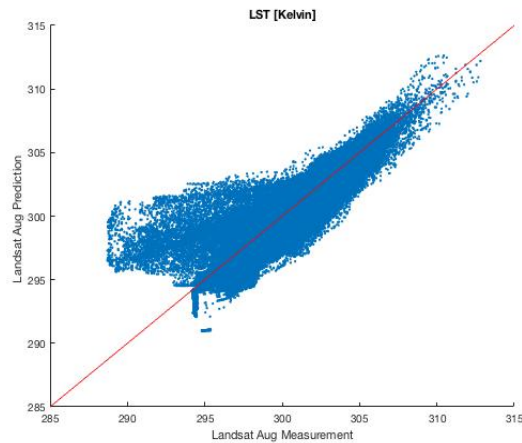
# P1-RESULTS

**August**



**Downscaled GOES-R**

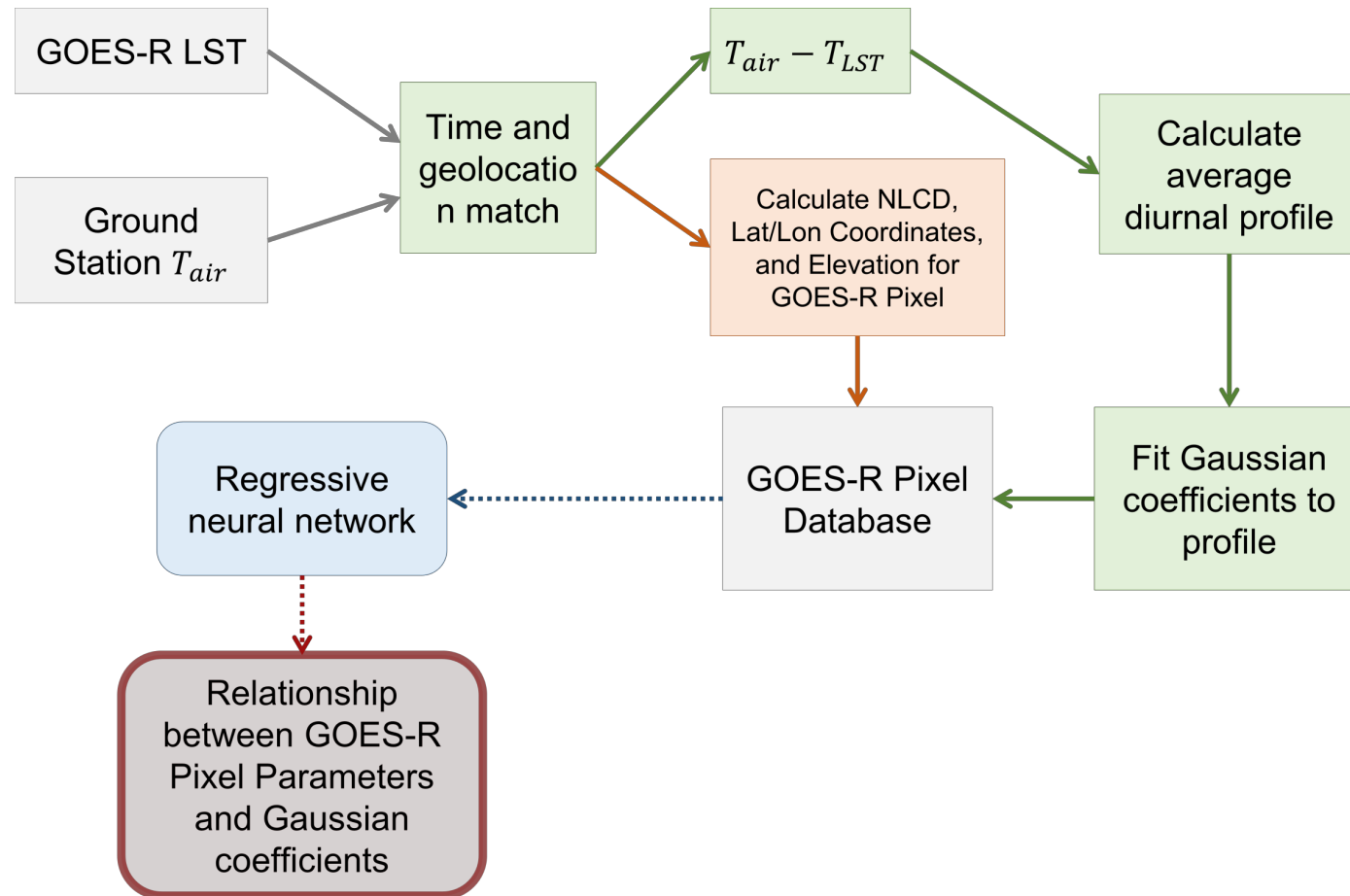
**October**



The difference between the temperature of Landsat measurement and Prediction is minimal between - 4 and 4 K.  
RMSE: 0.43 K , R2: 0.97.

ECOSTRESS data and ground based measurements through infrared cameras and drones will be used to further validate the model.

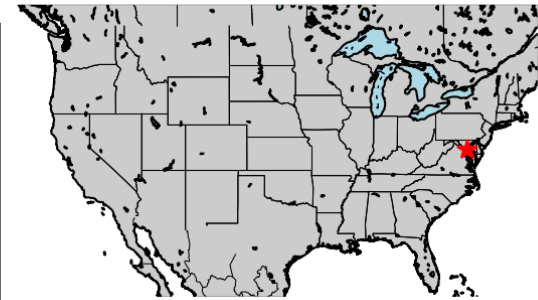
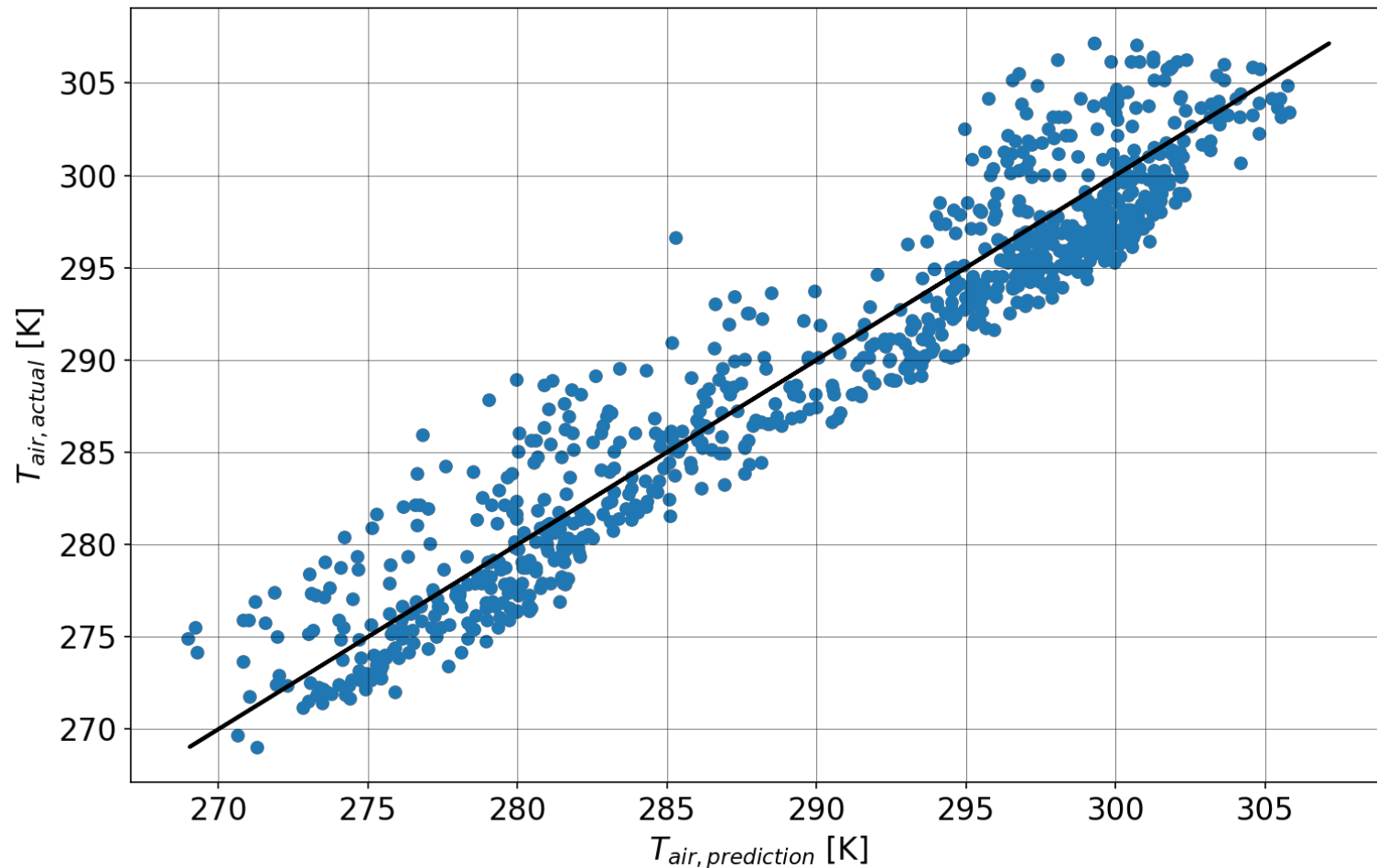
# P2-AIR TEMPERATURE ESTIMATION



Primary goal is to use the GOES-R satellite measurements to estimate diurnal air temperature.

# P2-TRAINING

Air Temperature Prediction From GOES-R LST Against Ground Station: KADW  
Test Dates: 2018-08-01 21:56:00 - 2018-11-29 22:56:00



Model Performance

- $R^2$ : 0.91
- RMSE: 2.91K

GOES-16 Landcover

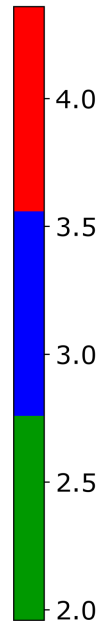
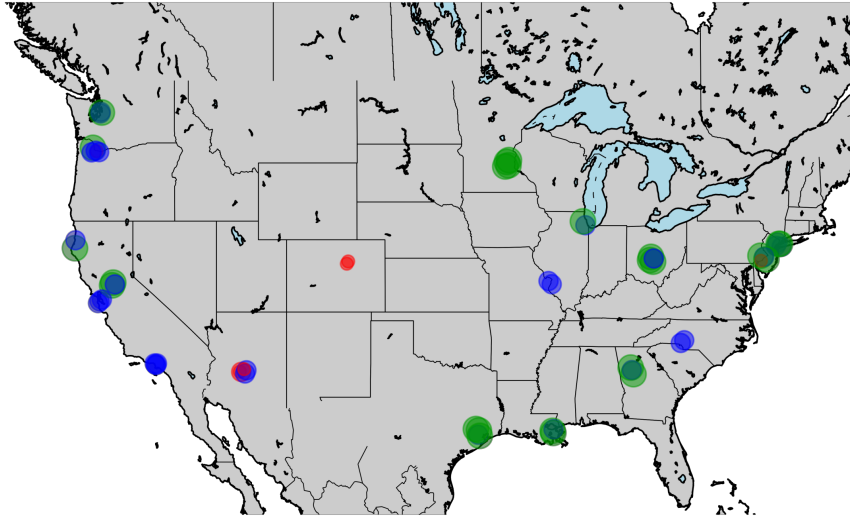
- Water: 0%
- Urban: 92%
- Forest: 7%
- Cultivated: 0%
- Other: 1%

Station Elevation: 86m

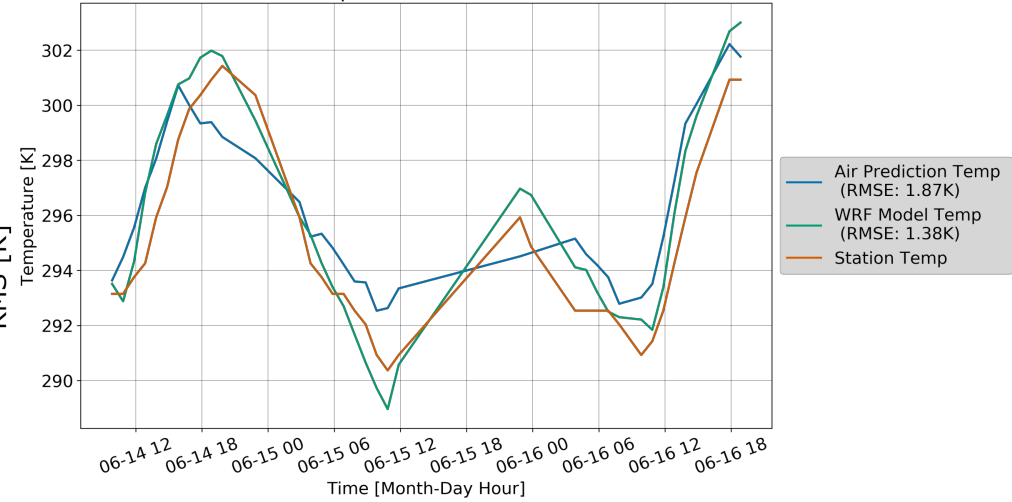
Regressive neural network to predict temperature.

# P2-RESULTS

GOES-R Model Against Ground Station Air Temperature



WRF Comparison with Station: KNYC



Model predicts air temperature with an average RMSE of 1.5 K. It is comparable to the accuracy of the high resolution numerical weather prediction models. Overall, the comparison tests were performed in 65 cities across the US

# STUDENTS

The research described here is currently conducted by 2 PhD students, Abdou Bah & Josh Hrisiko.

