CS293S: Internet of Things

An In-Depth Analysis on Weather Data from CIMIS: Estimating Evapotranspiration (ET) Values

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Outline

1. Introduction
2. Data Collection
3. Data Overview
4. Feature Selection
5. Regression Analysis
6. Nearest Neighbor Analysis
7. Demo
8. Questions

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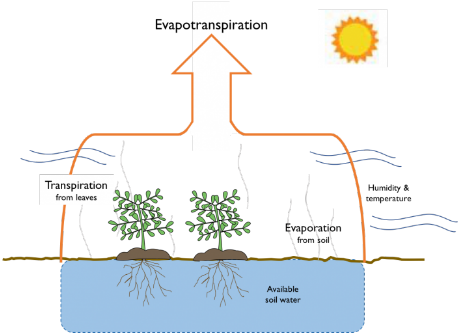
- Loss of water through:
  1. Evaporation and
  2. Transpiration
- Applications:
  - Irrigation scheduling
  - Water resource planning, etc.



Introduction: CIMIS Weather Stations

- *California Irrigation Management Information System*
- 257 CIMIS stations all through California
  - 136 actively reports ET values
- Measures various weather parameters
- some directly influence ET
- Also measures (*calculates?*) ET

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Data Collection

- Publicly available API
- Reports both hourly and daily data
- A record contains 15 different features
- Current working dataset: data of last one year
- Certain analysis uses data from multiple years to capture seasonal variations

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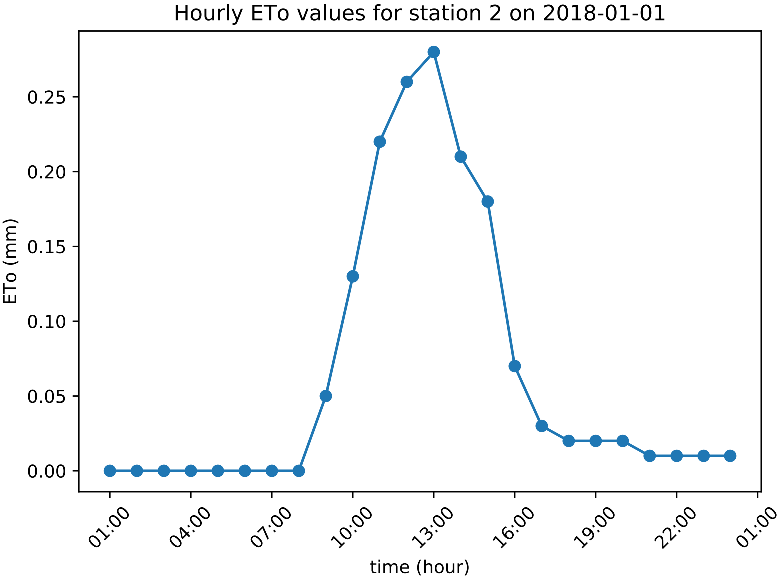
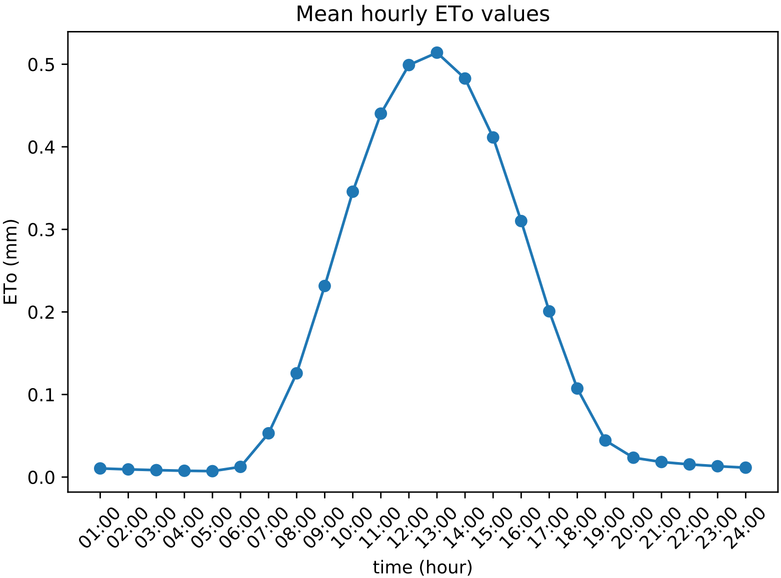
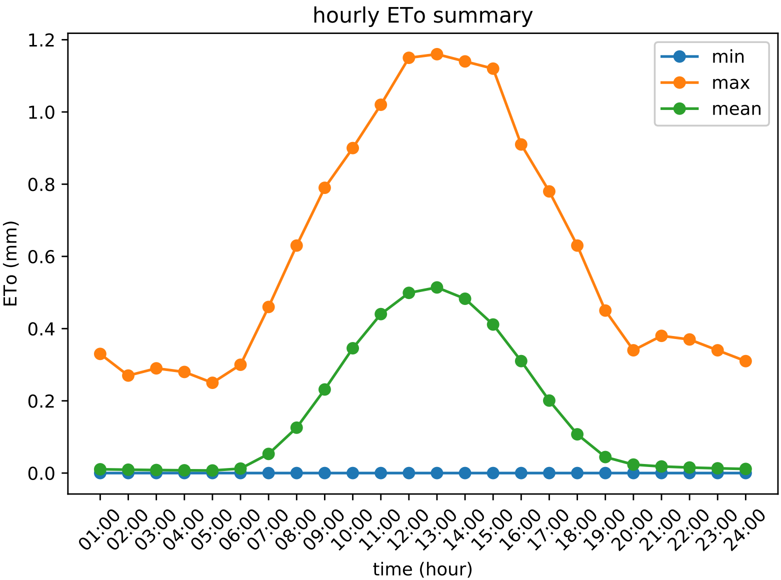
Sample Hourly ET Values

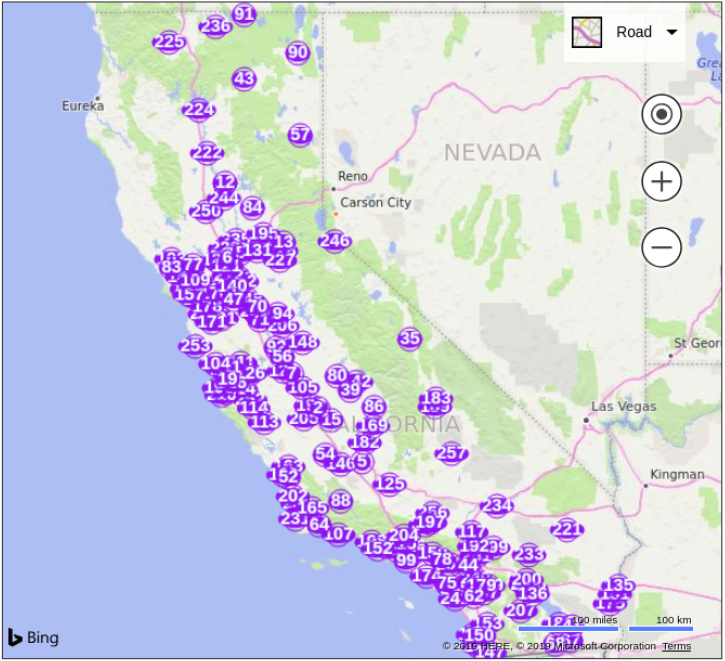


Mean Hourly ET Values



Min/Mean/Max Hourly ET Values




Road
Eureka
NEVADA
Reno
Carson City
Las Vegas
Kingman
100 miles
100 km
Bing
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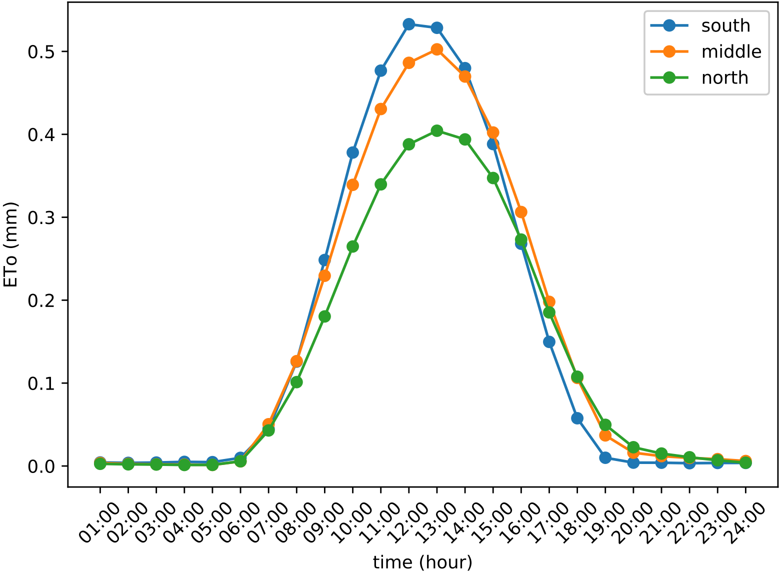
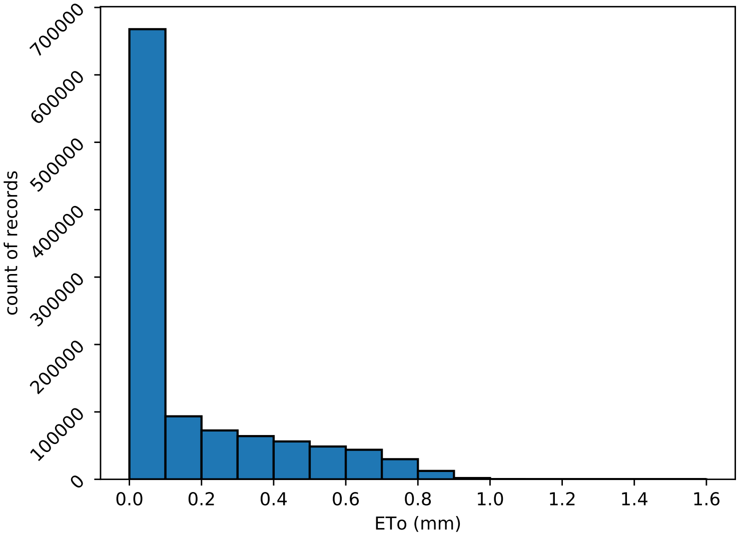
Stations of Interest

- Station with lowest latitude LAT_{MIN} (south)
- Station with highest latitude LAT_{MAX} (north)
- Station with latitude closests to $\frac{LAT_{MIN}+LAT_{MAX}}{2}$ (middle)

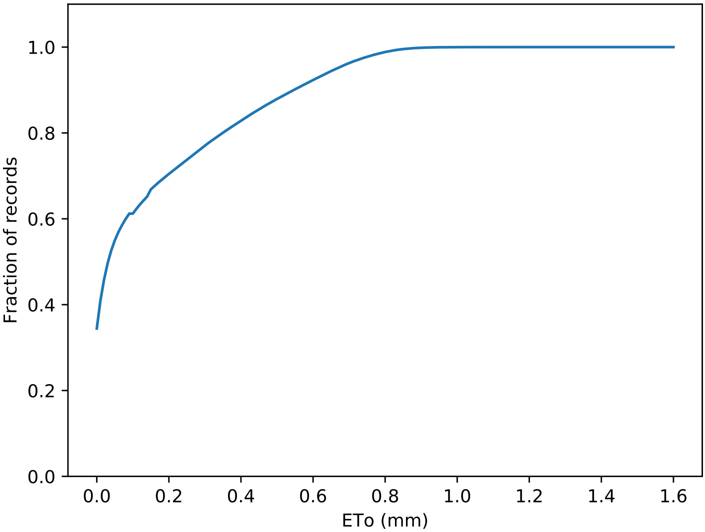
Mean Hourly ET Values of Stations of Interest



Histogram of ET Values



Empirical CDF of ET Values



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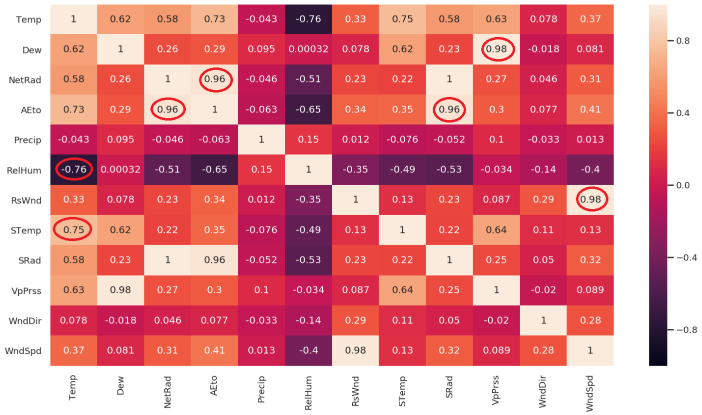
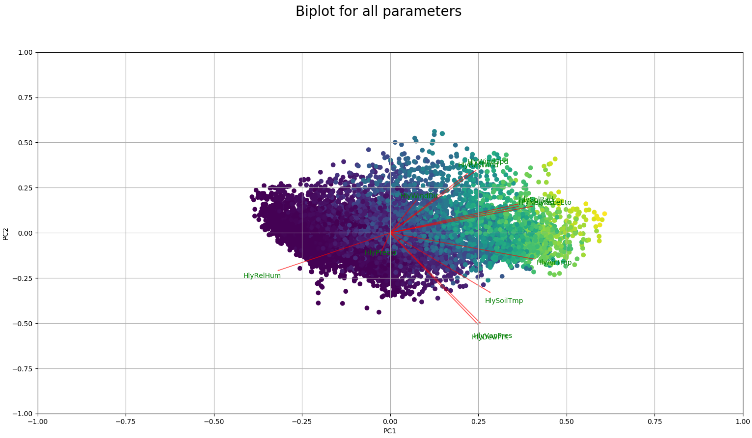
Correlation Analysis

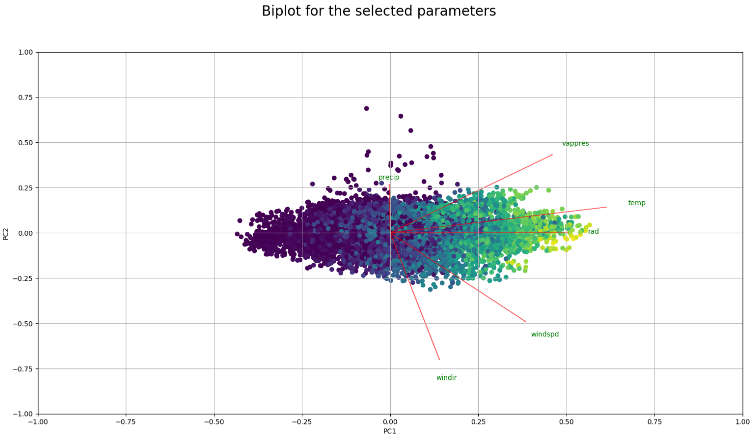
Correleation between the parameters



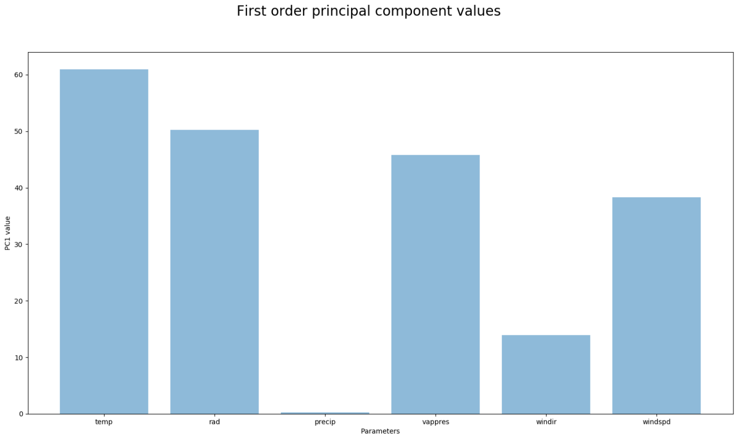
Biplot-all


Biplot for all parameters
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
PC2
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
PC1
HlyRelHum
HlyPrecip
HlyAirTmp
HlySoilTmp

Biplot-selected



PC1 values



First order principal component values
PC1 value
60
50
40
30
20
10
0
temp
rad
precip
vappres
windir
windspd
Parameters

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Estimation of ET Values

Given a set of features, can we estimate ET?

- Which features to choose?
- *How well* is our estimate?

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(CIMIS) Penman Monteith Equation for Calculating ET

$$\boxed{ET_o = \frac{\triangle(R_n - G)}{\lambda[\triangle + \gamma(1 + C_d u_2)]} + \frac{\gamma \frac{37}{T_a + 273.16} u_2(e_s - e_a)}{\triangle + \gamma(1 + C_d u_2)}}$$

Ultimately depends on four weather features

- Solar net radiation
- Vapor pressure
- Air temperature
- Wind speed

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Regression Results

Features	Mean Squared Error	R^2 Value
HlyAirTmp,HlyNetRad,HlyVapPres,HlyWindSpd	0.000970123960314	0.9812940161
HlyAirTmp,HlyNetRad,HlyVapPres	0.00130358866256	0.9747612206
HlyAirTmp,HlyNetRad,HlyWindSpd	0.00131186536214	0.9745279825
HlyAirTmp,HlyNetRad	0.00173654973306	0.9665370047
HlyNetRad,HlyVapPres,HlyWindSpd	0.00248645097725	0.9520098573
HlyNetRad,HlyWindSpd	0.0024909080494	0.9516599092
HlyNetRad,HlyVapPres	0.00302176798112	0.9410658003
HlyNetRad	0.00304665078019	0.9409558541
HlyAirTmp,HlyVapPres,HlyWindSpd	0.0236668111725	0.540318481
HlyAirTmp,HlyWindSpd	0.0242823252297	0.5285606181
HlyAirTmp,HlyVapPres	0.026563048828	0.4850281600
HlyAirTmp	0.0278295291341	0.4597101537
HlyVapPres,HlyWindSpd	0.0407552684279	0.2088275258
HlyWindSpd	0.0412914020576	0.1961185540
HlyVapPres	0.0510006461517	0.0128578989

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Nearest Neighbor Analysis

Given the ET value of k nearest stations of a place, can we estimate ET?

- Arithmetic mean of k values
- Inverse Distance Weighted (IDW) average of k values

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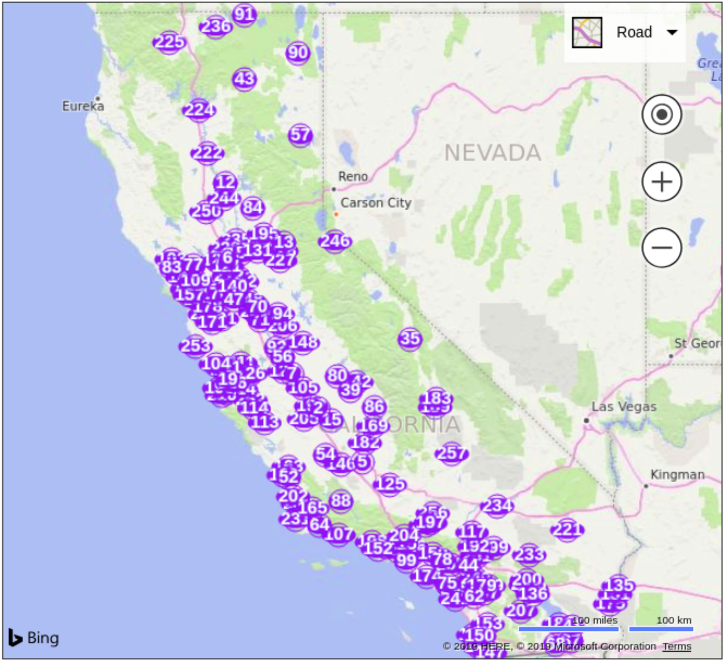
Road
Eureka
NEVADA
Reno
Carson City
Las Vegas
Kingman
Bing
100 miles
100 km
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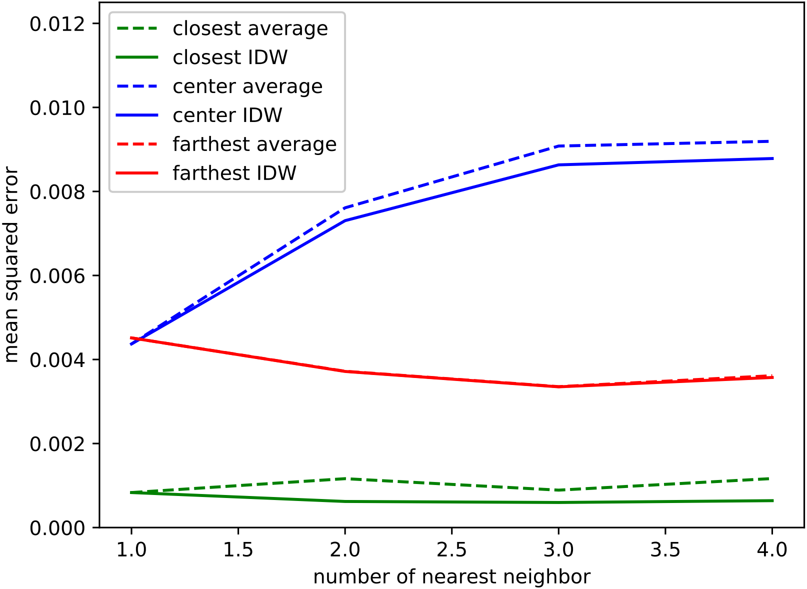
Stations of Interest

- Station with lowest distance D_{MIN} to nearest neighbor
- Station with highest distance D_{MAX} to nearest neighbor
- Station with nearest neighbor at a distance closest to $\frac{D_{MIN}+D_{MAX}}{2}$

Nearest Neighbor Results

Station Number	Num of Neighbors	MSE for Average	MSE for IDW
129	1	0.000832971114168	0.000832971114168
234	1	0.00437018526497	0.00437018526497
57	1	0.00451400872516	0.00451400872516
129	2	0.00116361600992	0.000620877927137
234	2	0.00761026004119	0.00730456269316
57	2	0.00371994564336	0.0037154634375
129	3	0.000890784115612	0.000596760525931
234	3	0.00908058999082	0.00863260116925
57	3	0.00335367604618	0.00334925237208
129	4	0.00116647617403	0.00063999172153
234	4	0.00919325287807	0.00878339044833
57	4	0.00361403432169	0.00357201358681


closest average
closest IDW
center average
center IDW
farthest average
farthest IDW
0.012
0.010
0.008
0.006
0.004
0.002
0.000
mean squared error
1.0
1.5
2.0
2.5
3.0
3.5
4.0
number of nearest neighbor

Nearest Neighbor with Sensor Values

What if we have sensor values from nearby stations instead of only ET values?

MSE decreases according to CIMIS Penman Equation

What if we have sensor values from nearby stations **along with local air temperature?**

MSE decreases even further

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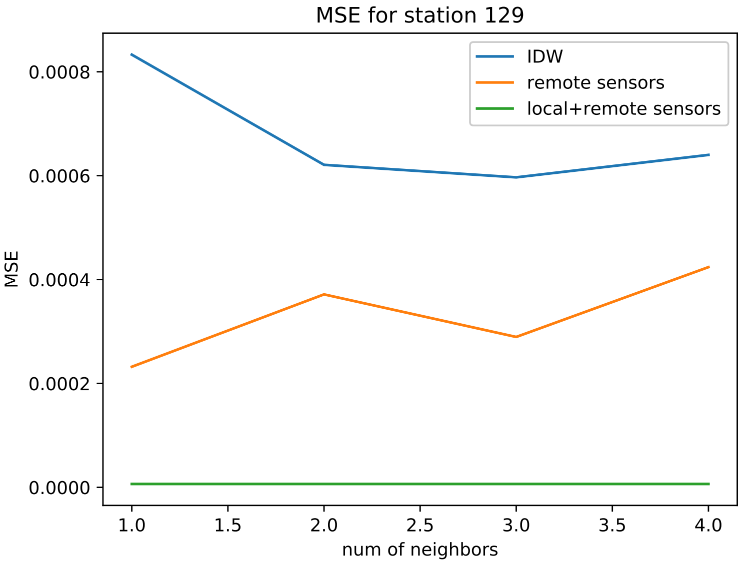
MSE decreases even further

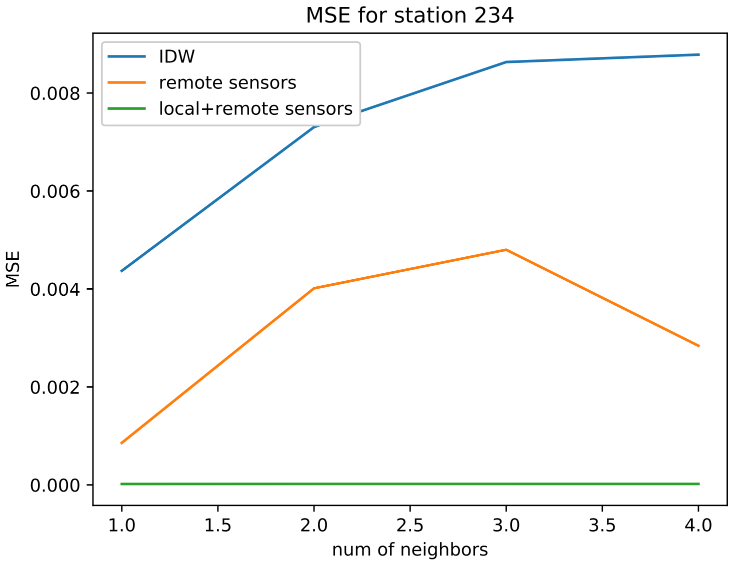
Nearest Neighbor with Sensor Values *(Cntd.)*

Stn No	Num of Nbrs	MSE IDW	MSE	MSE Local
234	1	0.00437018	0.00085818	0.00001899
234	2	0.00730456	0.00401320	0.00002029
234	3	0.00863260	0.00480052	0.00002029
234	4	0.00878339	0.00284048	0.00002034
129	1	0.00083297	0.00023209	0.00000650
129	2	0.00062087	0.00037144	0.00000649
129	3	0.00059676	0.00028950	0.00000649
129	4	0.00063999	0.00042391	0.00000650
57	1	0.00451400	0.00044228	0.00000982
57	2	0.00371546	0.00051686	0.00000982
57	3	0.00334925	0.00031521	0.00000982
57	4	0.00357201	0.00042077	0.00000983

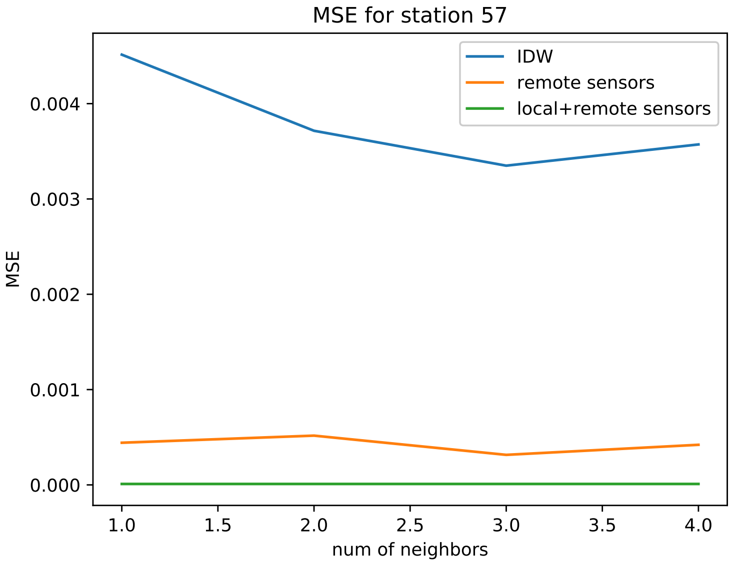
Nearest Neighbor with Sensor Values *(Cntd.)*



Nearest Neighbor with Sensor Values *(Cntd.)*



Nearest Neighbor with Sensor Values *(Cntd.)*



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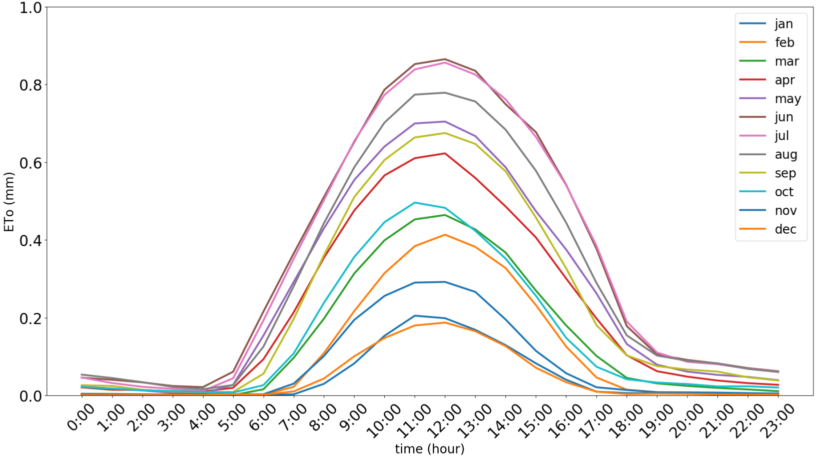
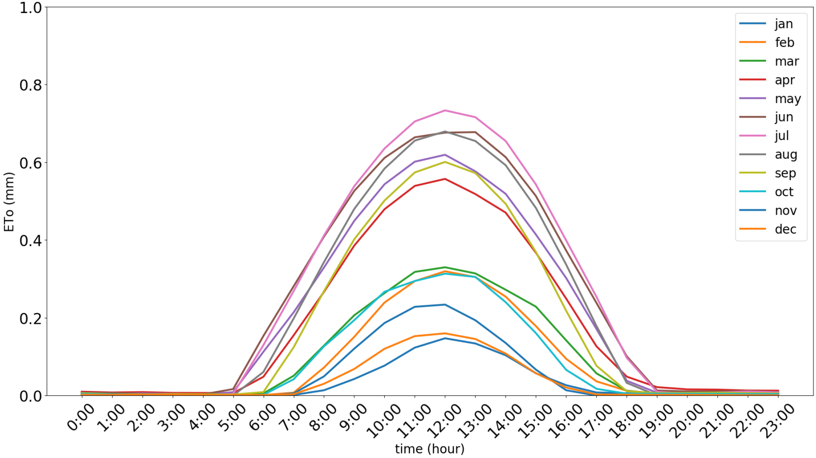
DEMO

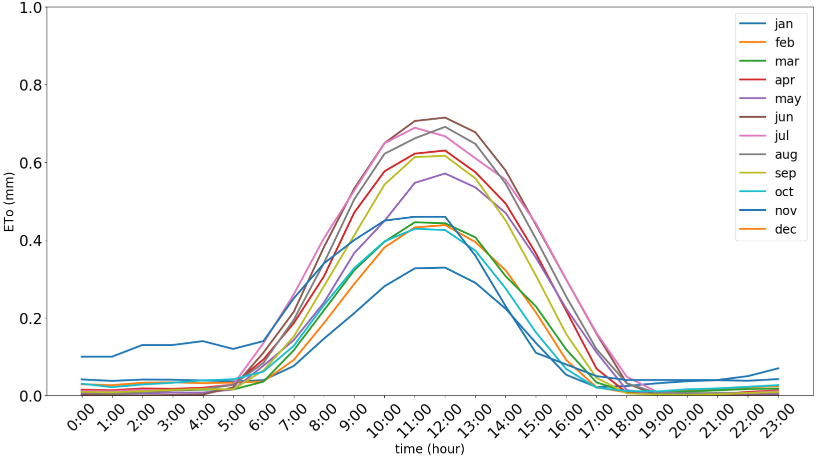
Normal 12-month Graph for Station 2 in 2016



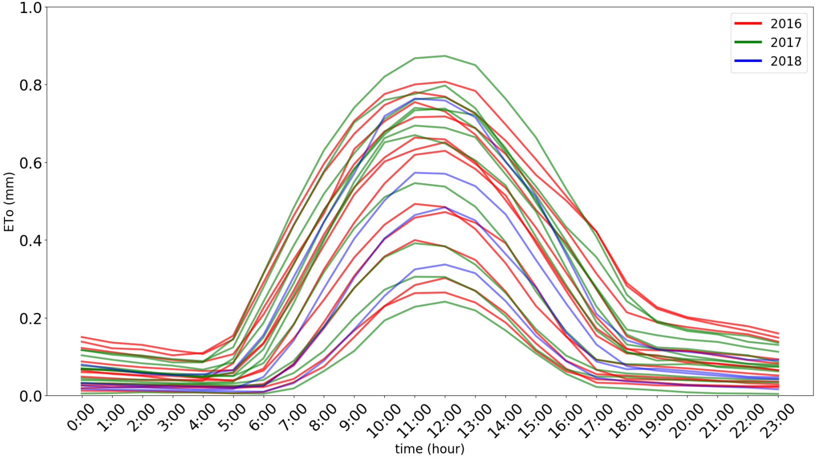
12-month Graph for Station 12 in 2016



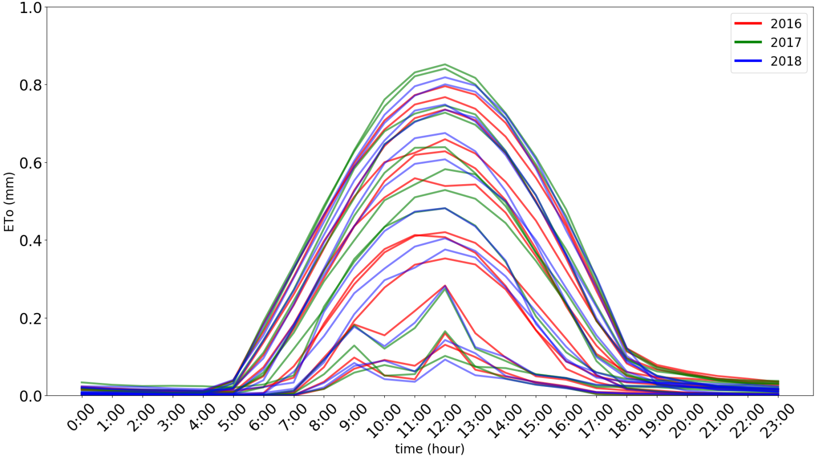
12-month Graph for Station 62 in 2018



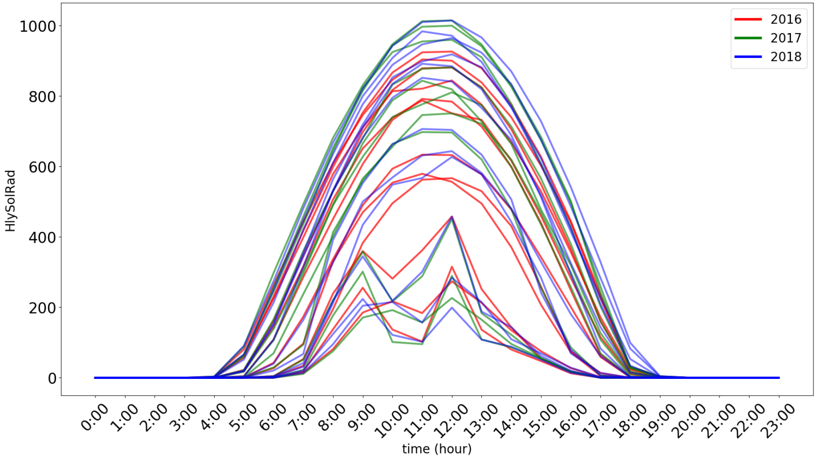
36-month Graph for Station 2



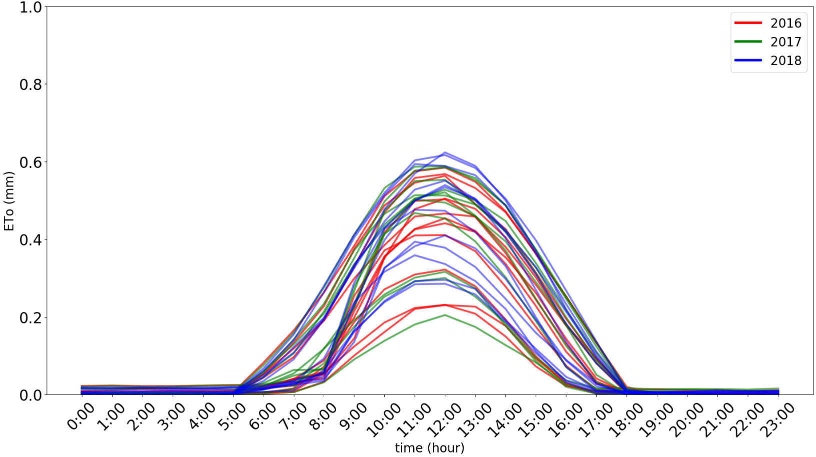
36-month Graph for Station 7



36-month Solar Graph for Station 7



36-month Graph for Station 202



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Questions?