Forecasting Final Presentation

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SCEL

Overview

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Motivation

Why is it to important forecast solar irradiance?

- It is difficult to integrate renewable sources into electrical grid
- Electrical grids need to generate power equal to the power needed
- Introducing solar energy adds potential instability
    - E.g. PV panels under producing power leads to the grid under providing power

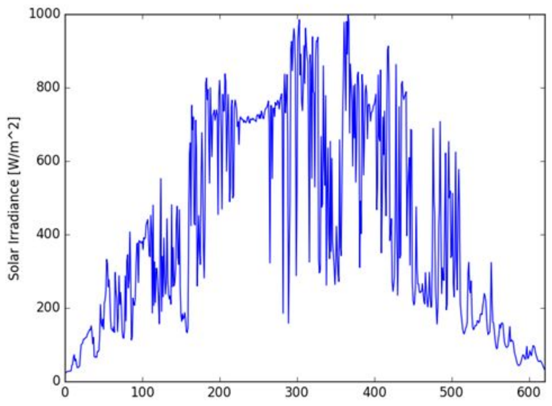
Objective

To develop an algorithm that is able to forecast future solar irradiance

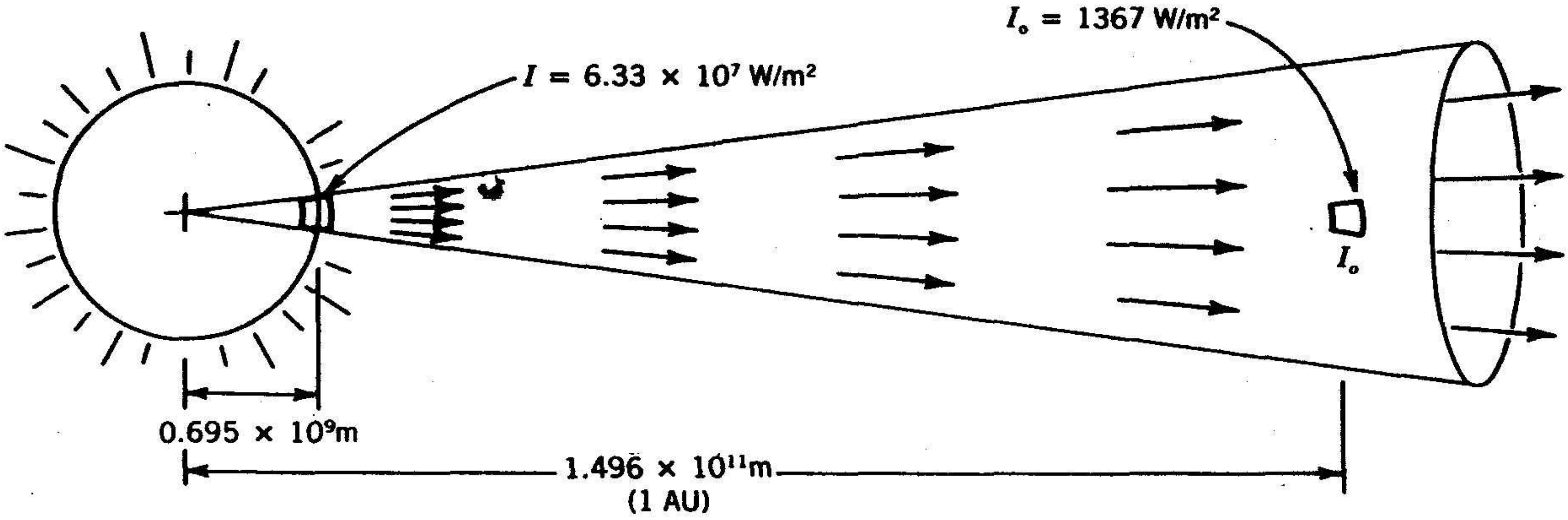
- ➔ Online algorithm
  - ◆ Algorithms that takes data one by one
  - ◆ Useful for dealing with large datasets
- ➔ Find a method to help account for time of day and seasonal effects
  - ◆ Normalization using the zenith angle

Predicting Solar Irradiance Using Data Properties

- In order to make predictions on the data, we need to understand the nature of our data.

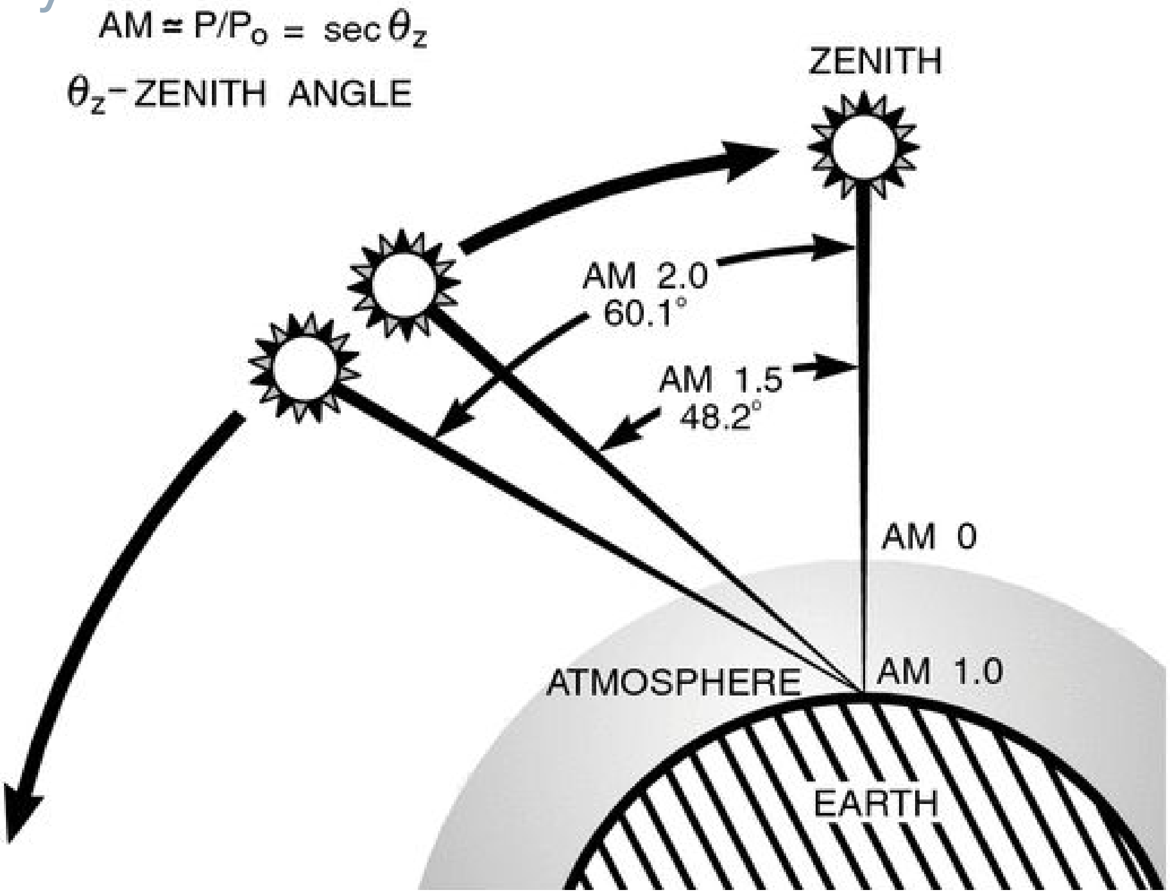


Dispersion of Sunlight throughout Space



Effect of Time of Day

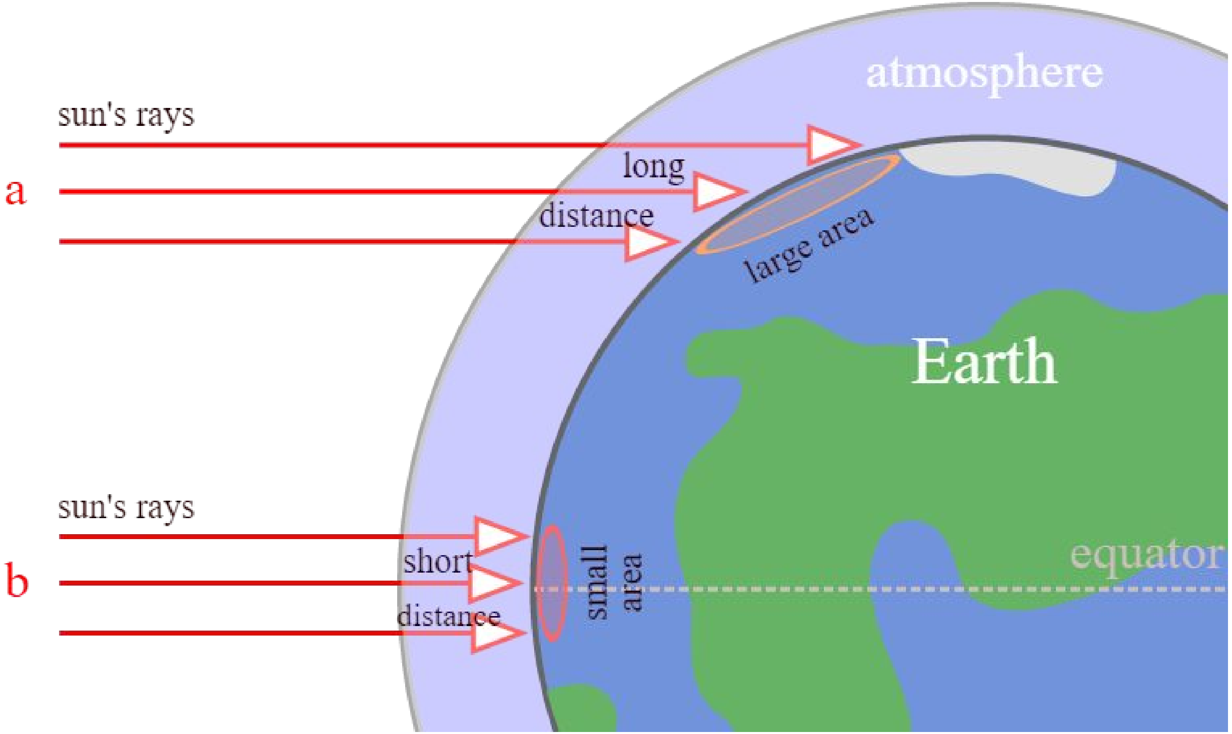
- As the earth spins throughout the day, the angle of incidence of the solar rays changes
- The rays travel through Air Mass which causes scattering and dispersion



Effect of Geographical Location

solar radiation measured in

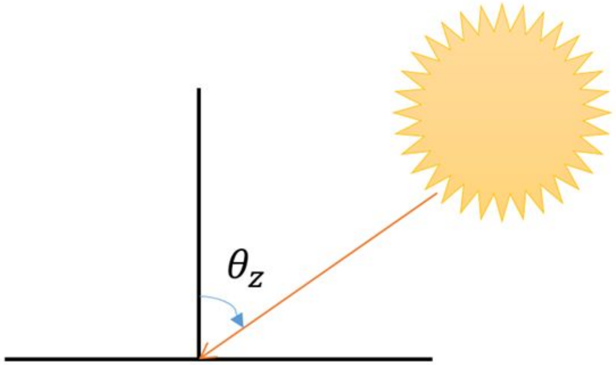
$$\frac{\text{Watts}}{\text{meters}^2}$$



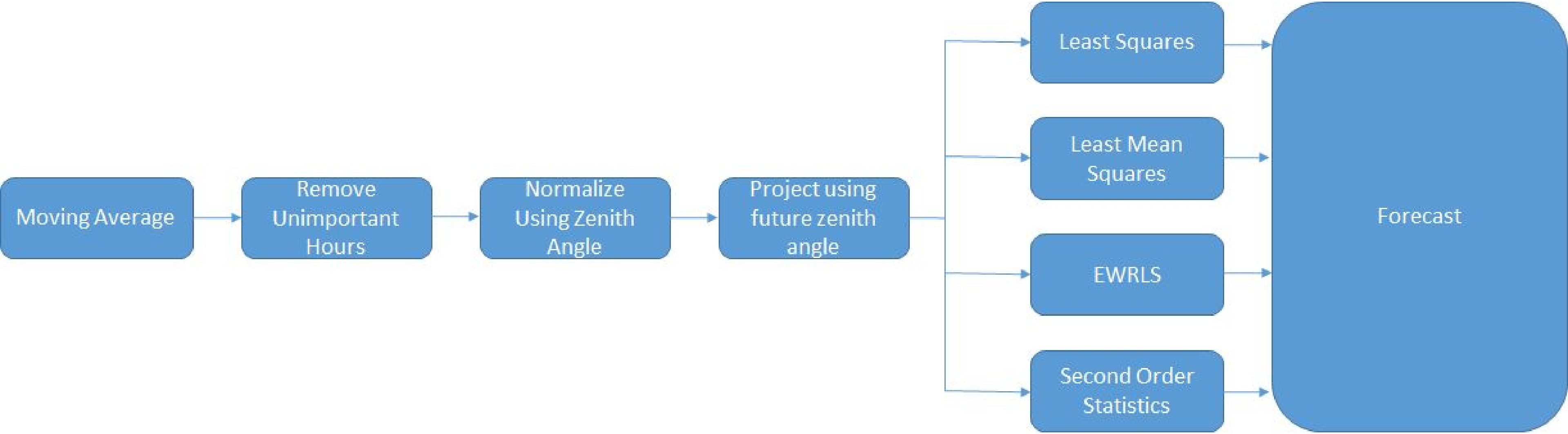
- The latitudinal location also affects the solar radiation as this affects both the distance the rays travel through the atmosphere and the area that the ray is distributed on.

Features Used

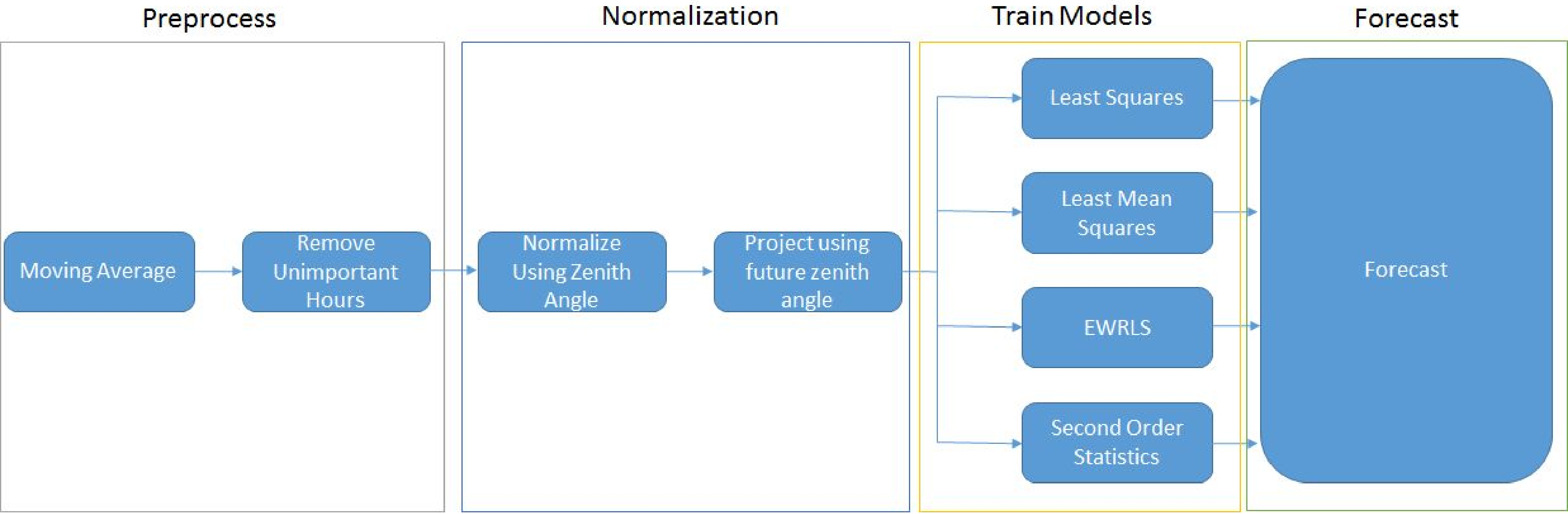
- Tap Filters
  - Using previous solar irradiance values as inputs
- Zenith angle



Block Diagram

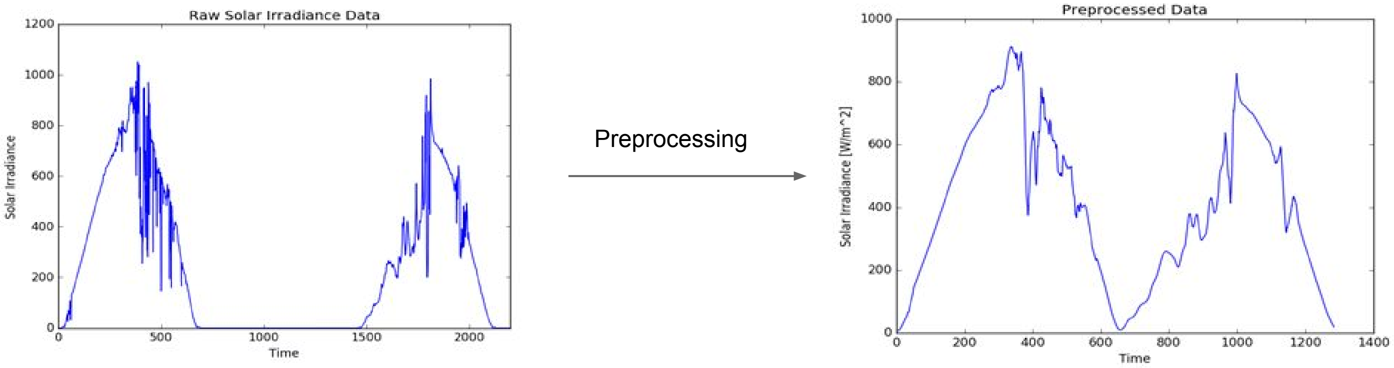


Block Diagram



Preprocessing

- Conduct moving average on the data to smooth the data
- Remove hours outside of our interest (night time)

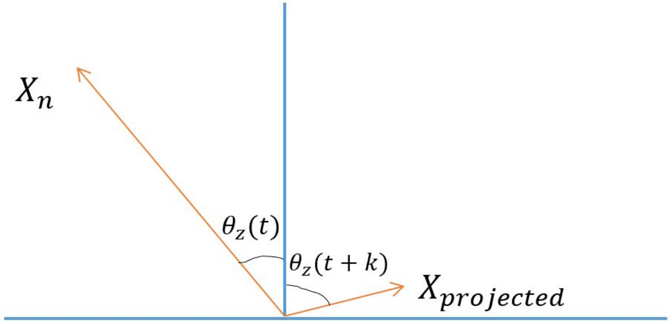


Normalization

- Normalize using the zenith angle
  - Removes time of day and seasonal effects
  - Projecting solar irradiance in the direction of a future zenith angle

$$X_n(t) = \frac{R(t)}{cos\theta_z(t)}$$

$$X_{projected}(t) = X_n(t) * \cos\theta_z(t+k)$$



Train Model

Machine Learning Algorithms

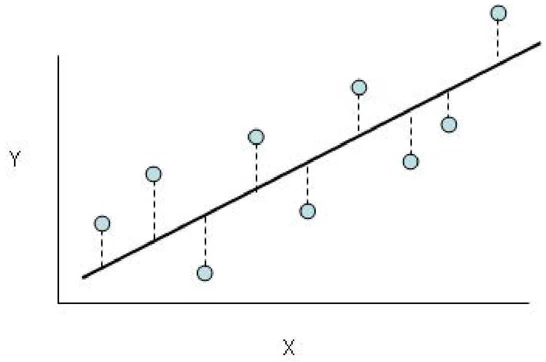
- Least Squares
- Least Mean Squares (LMS)
- Exponential Weighted Recursive Least Squares (EWRLS)
- Second Order Statistics

Example of a mathematical model

$Y = ax^2+bx+c$

Least Squares

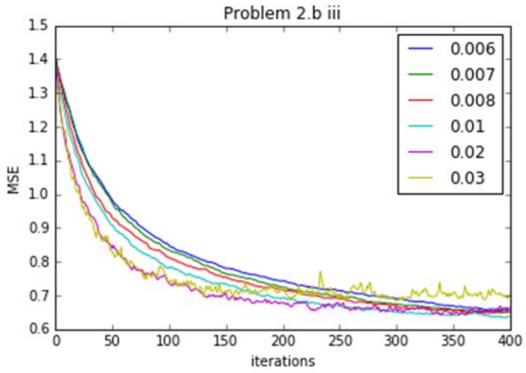
- Fundamental machine learning algorithm
- Offline Algorithm
- Determines weights by minimizing squared error
  - Error is the difference between predicted output and expected output



Least Mean Squares

- Estimate optimal weights
- Online Algorithm
- Adjusts weights based on error
- Low complexity and computation time

```
for i in range(0,d.size):
    x_lms = np.transpose(np.matrix(X[:,i]))
    d_lms = d[i,0]
    e = d_lms-W*x_lms.T
    W = W + step*e.item(0)*x_lms
```



EWRLS & Second Order Statistics

EWRLS

- Online version of least squares
- Forgetting factor λ
  - Previous inputs have less impact

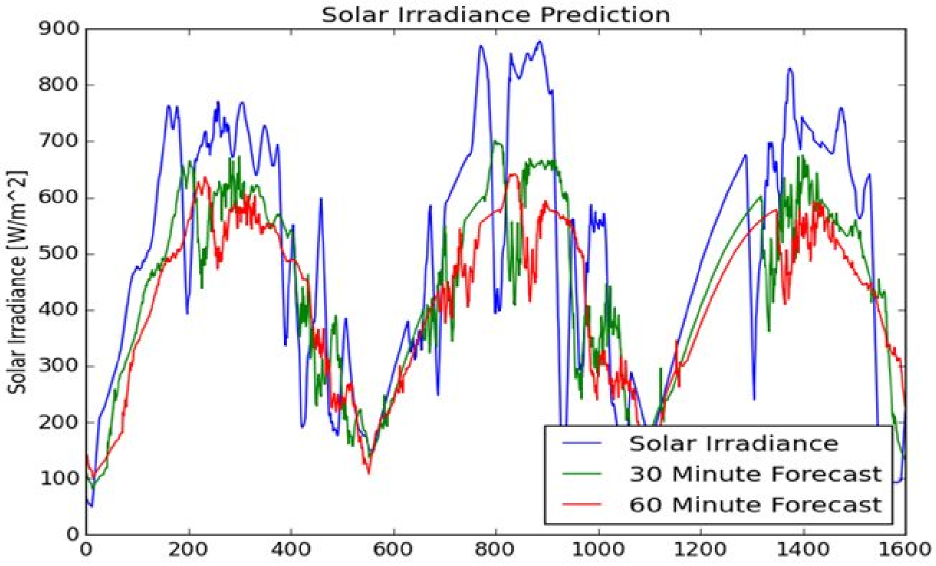
Second Order Statistics

- Uses covariances for current solar irradiance and previous solar irradiance to forecast future irradiance

```
lam_i = lam**-1
for i in range(2,d.size):
    x_n1 = x[0:n,i]
    alpha = (d[i]-np.transpose(w)*x_n1).item(0)
    g = p*x_n1* np.linalg.inv(lam_i + np.transpose(x_n1) * p * x_n1)
    p = lam_i*p - g * np.transpose(x_n1)*lam_i * p
    w = w + alpha * g
```

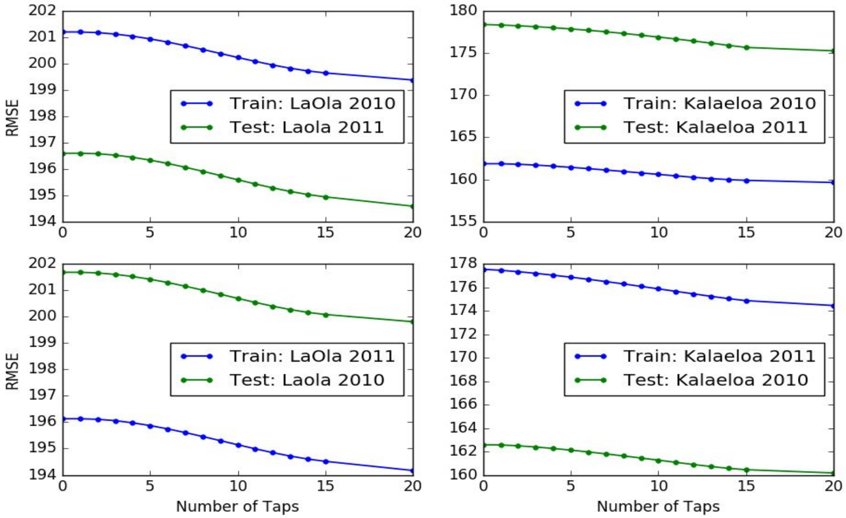
Forecast

- Input data into the model and see the results



Results: Tap Filters

- ▷ Adding tap filters gave little improvements
- ▷ Used two to three taps for algorithms

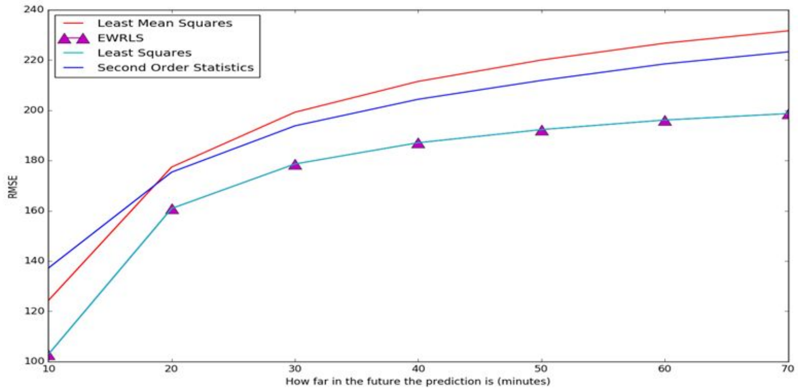


Results: Algorithm Comparisons

- Best Performance
    - EWRLS and Least Squares

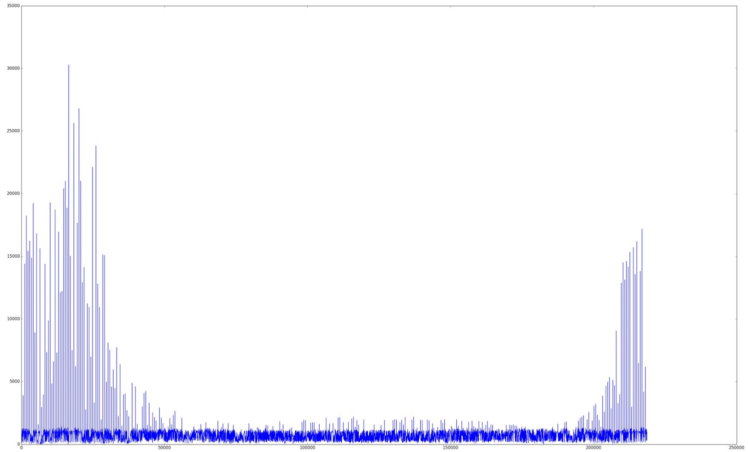
- Computation Time
    - Fastest : LMS
    - Slowest: EWRLS

Algorithm	Run Time (s)
LMS	2.1874
EWRLS	19.7354
Second Order Stats	4.8654



Problems

- Working with large datasets
  - Learning techniques to working with large datasets
    - Debugging
- Zenith angles near 90 degrees
  - Threshold
  - Reduce range of hours



Remaining Problems

- Machine learning takes time to learn
  - With older members graduating, it is important for newer members to understand machine learning
- Solutions
  - Strong Documentation
  - Forecasting researches and develops different methods

Final Status

1. Developed an online forecasting algorithm
2. Normalization using the zenith angle gives our algorithm good performance
3. EWRLS is the best performing online algorithm
    a. Slowest run time

Future Improvements

- Predict solar energy produced
- Learn seasonal effects
- Implement algorithm on other datasets
    - HNEI & Weatherboxes

Thanks for listening!