SOLAR RADIATION PREDICTION

the need and effectiveness of a delicate issue

ABOUT THE SPEAKER

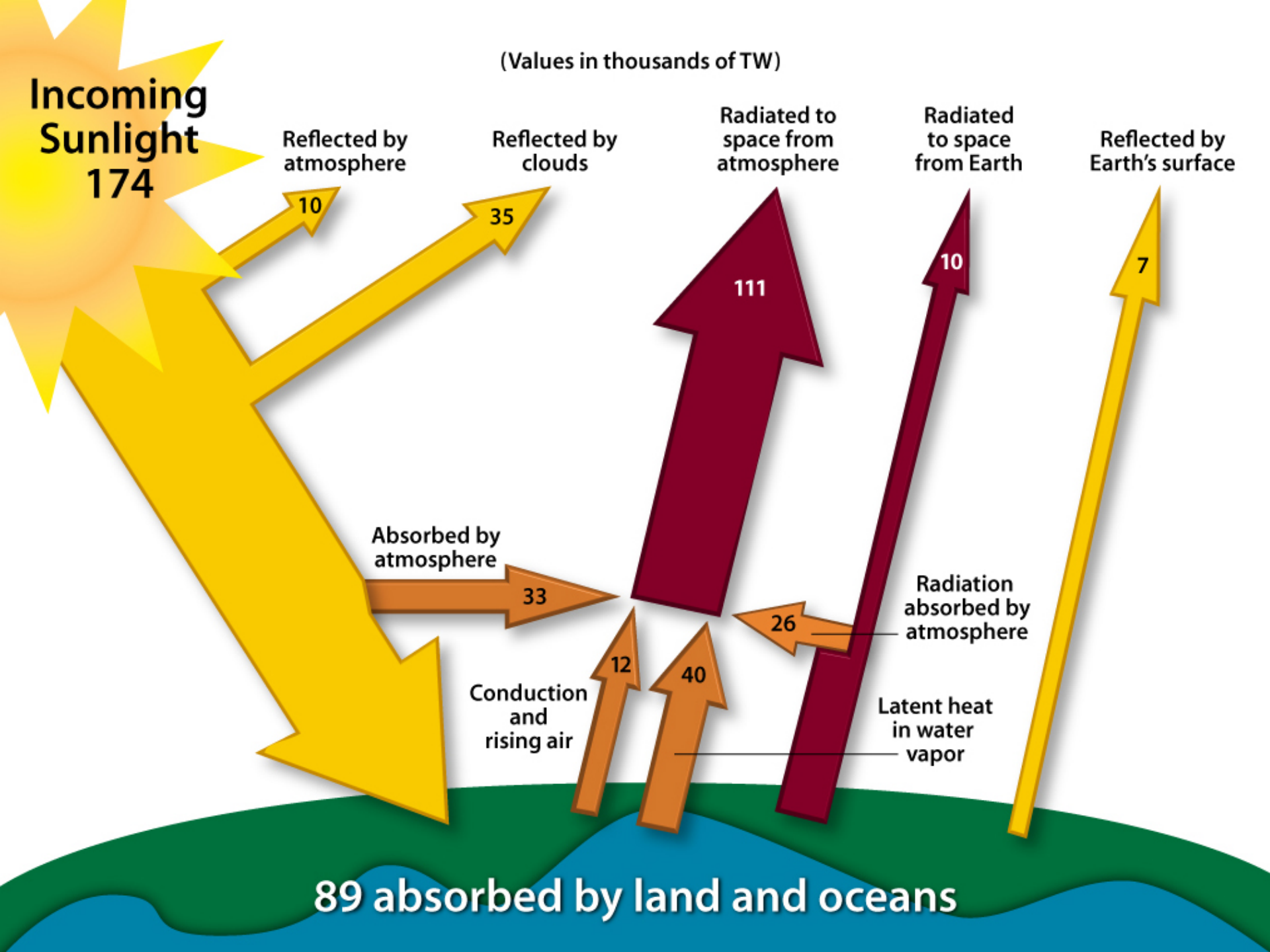
- ***Fatih SERTTAŞ*** (Electrical and Electronics Engineer) is a research assistant in Afyon Kocatepe University, TURKEY.
- He studies about Renewable Energy Systems, especially Solar Radiation modelling and prediction methods with *Prof. Dr. Fatih Onur HOCAOĞLU.*

SOLAR RADIATION

- **Insolation** is a measure of solar radiation energy received on a given surface area and recorded during a given time. It is also called **solar irradiation** and expressed as "hourly irradiation" if recorded during an hour or "daily irradiation" if recorded during a day. The unit recommended by the World Meteorological Organization is megajoules per square metre (MJ/m^2) or joules per square millimetre (J/mm^2) .
- Practitioners in the business of solar energy may use the unit watt-hours per square meter (Wh/m^2). If this energy is divided by the recording time in hours, it is then a density of power called irradiance, expressed in watts per square meter (W/m^2).

ABSORPTION AND REFLECTION

- The object or surface that solar radiation strikes may be a planet, a terrestrial object inside the atmosphere of a planet, or an object exposed to solar rays outside of an atmosphere, such as spacecraft.
- Some of the radiation will be absorbed and the remainder reflected. Usually the absorbed solar radiation is converted to thermal energy, causing an increase in the object's temperature.
- Manmade or natural systems, however, may convert a portion of the absorbed radiation into another form, as in the case of photovoltaic cells or plants. The proportion of radiation reflected or absorbed depends on the object's reflectivity or albedo.


(Values in thousands of TW)
Incoming Sunlight 174
Reflected by atmosphere
10
Reflected by clouds
35
Radiated to space from atmosphere
111
Radiated to space from Earth
10
Reflected by Earth's surface
7
Absorbed by atmosphere
33
Radiation absorbed by atmosphere
26
Conduction and rising air
12
40
Latent heat in water vapor
89 absorbed by land and oceans

IMPORTANCE OF ESTIMATING SOLAR RADIATION DATAS

- Due to strong increase of solar power generation, the predictions of incoming solar energy are acquiring more importance.
- Solar radiation is an important parameter in solar energy application due to generation from photovoltaic (PV) is directly related to this parameter. Solar radiation varies nonlinearly due to atmospheric events such as cloudy weather, rain, humudity etc. Therefore estimation of solar radiation is an attractive issue in solar energy field.

PREDICTION AND MODELLING METHODS IN LITERATURE

- Predicting solar radiation at high resolutions: A comparison of time series forecasts, *Gordon Reikard :* Forecasting experiments are run using six data sets, at resolutions of 5, 15, 30, and 60 min, using the global horizontal component. The data exhibits nonlinear variability, due to variations in weather and cloud cover. Nevertheless, the dominance of the 24-h cycle makes it straightforward to build predictive models. Forecasting tests are run using regressions in logs, Autoregressive Integrated Moving Average (ARIMA), and Unobserved Components models.
- Estimation of solar radiation using data mining process, *Özlem TERZİ, Ecir Uğur KÜÇÜKSİLLE, Gülşah ERGİN, Ahmet İLKER:* In this study, the data mining process is used to estimate solar radiation. Data for 2009-2010 years are modeled with KStar, Linear Regression, RBF Network, Simple Linear Regression, M5'Rules, Decision Table, Random Subspace and Multilayer Perceptron algorithms. Comparing model results with measured values, it is shown that the model (P-Ta-Rh) with three input parameters developed using multilayer perceptron algorithm is the most appropriate model.
- Stochastic approach for daily solar radiation modeling, *Fatih Onur Hocaoğlu :* In this paper, a novel approach for solar radiation modeling is proposed and illustrated. The proposed application consists of hidden Markov processes, which are widely used in various signal processing topics including speech modeling with successful results. In the experimental work, mean of hourly measured ambient temperature values are considered as observations of the model, whereas mean of hourly solar radiation values are considered as the hidden events, which constitute the outcomes of the proposed mathematical model.

PREDICTION AND MODELLING METHODS IN LITERATURE

- Prediction of Solar Radiation Intensity for Cost-Effective PV Sizing and Intelligent Energy Buildings, *Eleni Kaplani and Socrates Kaplanis :* Prediction models for the estimation of the daily and hourly solar radiation profile have been presented and the results where compared with true measured values and values from available databases, revealing very promising methodologies.
- Methodological approaches for the effective sizing of PV systems to adequately cover the loads to a predetermined reliability level, may use either expected values resulting from a thorough analysis of past years data, or mean expected global solar radiation values through the use of stochastic prediction models, which showed to bring more cost-effective PV sizing figures, or, finally, benefit from hourly solar radiation on-line prediction models within the scope of a predictive management system for an intelligent energy building.

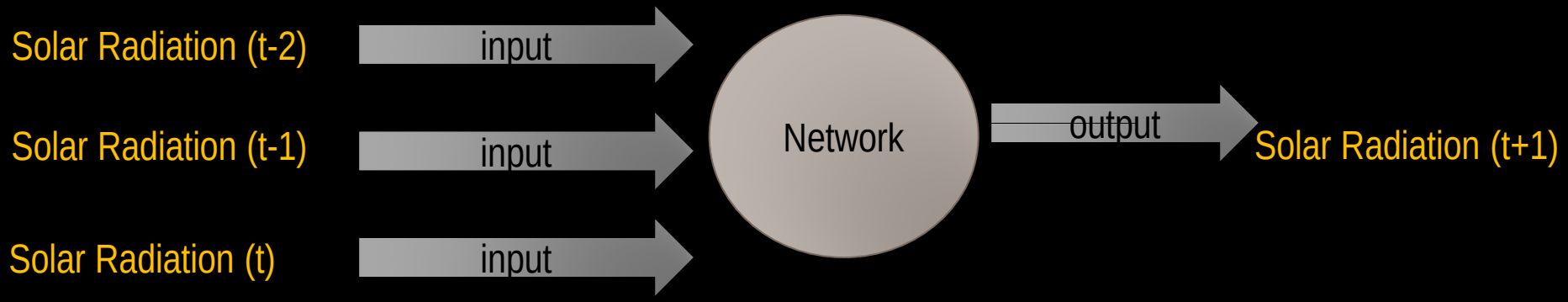
PREDICTION AND MODELLING METHODS IN LITERATURE

- Hourly solar irradiance time series forecasting using cloud cover index, *Yang Dazhi, Panida Jirutitijaroen, Wilfred M. Walsh:* They apply time series analysis to forecast next hour solar irradiance including cloud cover effects. Three forecasting methods are proposed using different types of meteorological data as input parameters, namely, global horizontal irradiance (GHI), diffuse horizontal irradiance (DHI), direct normal irradiance (DNI) and cloud cover. GHI at different zenith angles and under different cloud cover conditions is constructed using nonlinear regression, i.e., we create a look-up table of GHI regression models for different cloud cover conditions. All three methods are tested using data from two weather stations.
- Functional fuzzy approach for forecasting daily global solar irradiation, *Remus St. Boata, Paul Gravila :* A new fuzzy model to forecast daily global solar irradiation at ground level is reported here. The stochastic component of the solar irradiation is mainly determined by the sky condition and it may be quantified by means of the clearness index. Basically the model forecasts daily clearness index, tracking the rules of an autoregressive fuzzy algorithm.

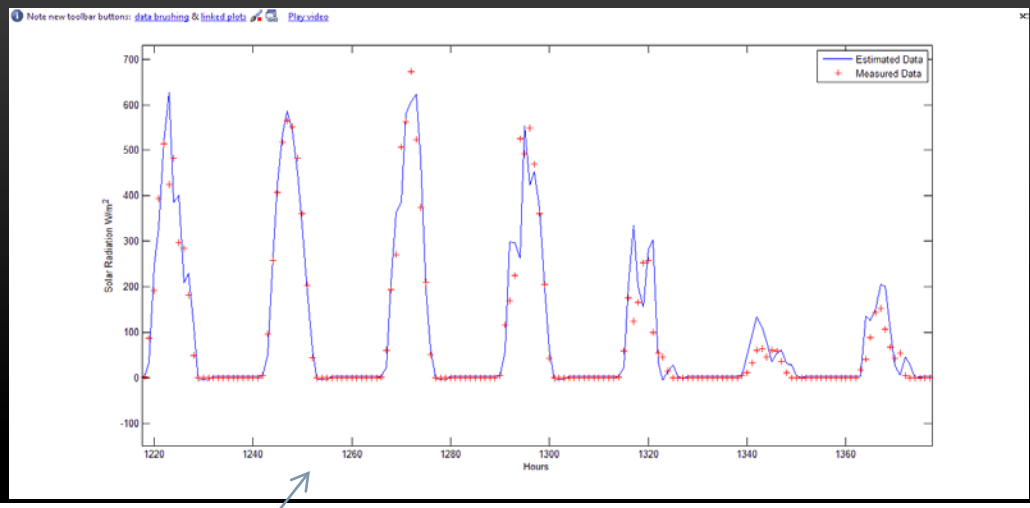
PREDICTION AND MODELLING METHODS IN LITERATURE

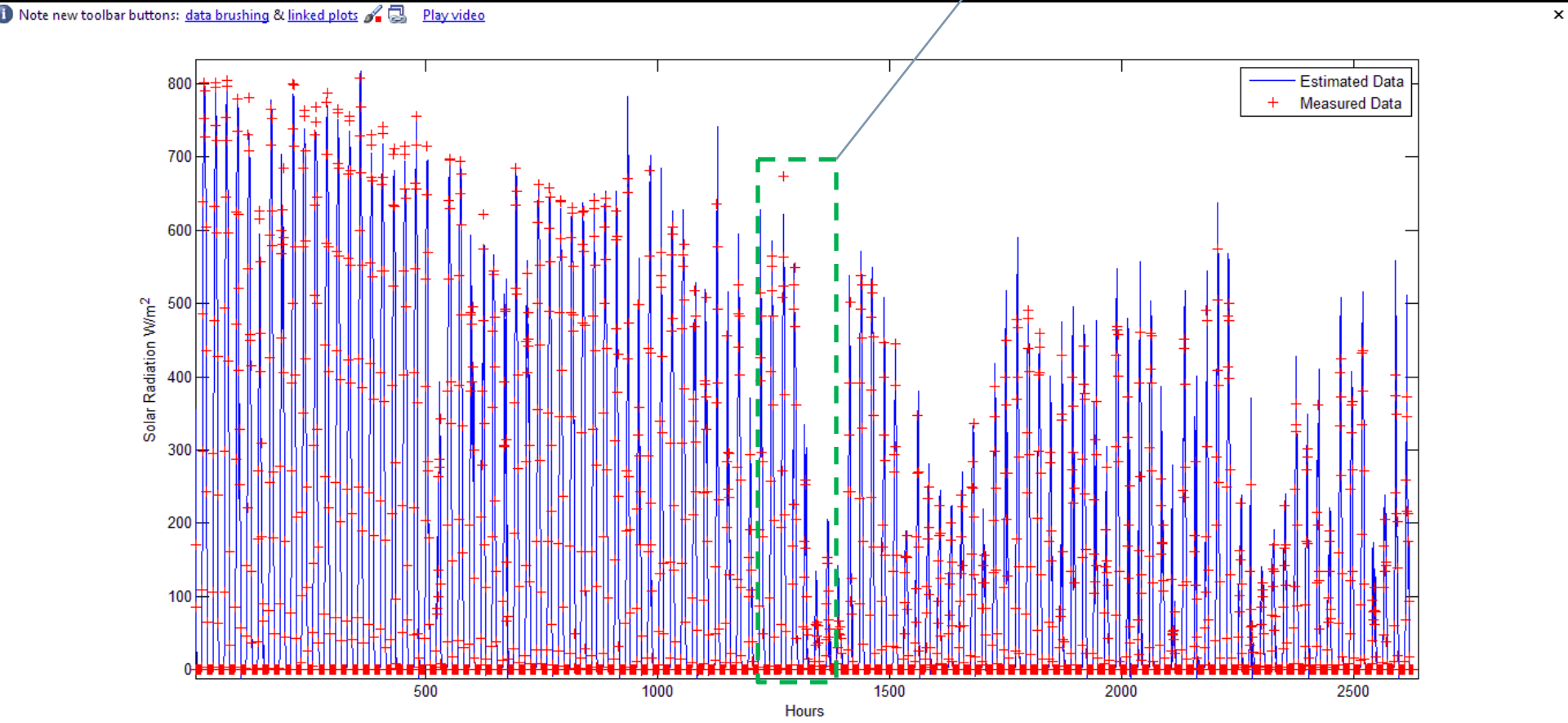
- Short-term forecasting of solar radiation: a statistical **approach usİng satellİte data**, *A. HAMMER, D. HEINEMANN, E. LORENZ† and B. LU¨ CKEHE :* This paper describes the application of a statistical method to detect the motion of cloud structures from satellite images. Extrapolating the temporal development of the cloud situation, solar radiation can be predicted for time scales from 30 min up to 2 h. The forecasts are evaluated with respect to accuracy and an example for the application of the forecast algorithm to predict PV power output is presented.
- Prediction of Hourly Solar Radiation on Horizontal and Inclined Surfaces for Muscat/Oman, *N.Z. Al-Rawahi*, Y.H. Zurigat and N.A. Al-Azri :* In this paper, hourly terrestrial radiation: direct beam, diffuse and global solar radiation are modelled and calculated based on daily measured data for a horizontal surface. In addition, the same parameters were modelled for inclined surfaces.
- Hourly solar radiation forecasting using optimal coefficient 2-D linear filters and feed-forward neural networks, *Fatih O. Hocaoğlu *, Ömer N. Gerek, Mehmet Kurban :* A two-dimensional (2-D) representation model of the hourly solar radiation data is proposed. The model provides a unique and compact visualization of the data for inspection, and enables accurate forecasting using image processing methods. Using the hourly solar radiation data mentioned above, the image model is formed in raster scan form with rows and columns corresponding to days and hours, respectively. Logically, the between-day correlations along the same hour segment provide the vertical correlations of the image, which is not available in the regular 1-D representation.

SOLAR RADIATION PREDICTION USING PAST SOLAR RADIATION DATAS



SOLAR RADIATION FORECASTING WITH PAST SOLAR RADIATION DATAS

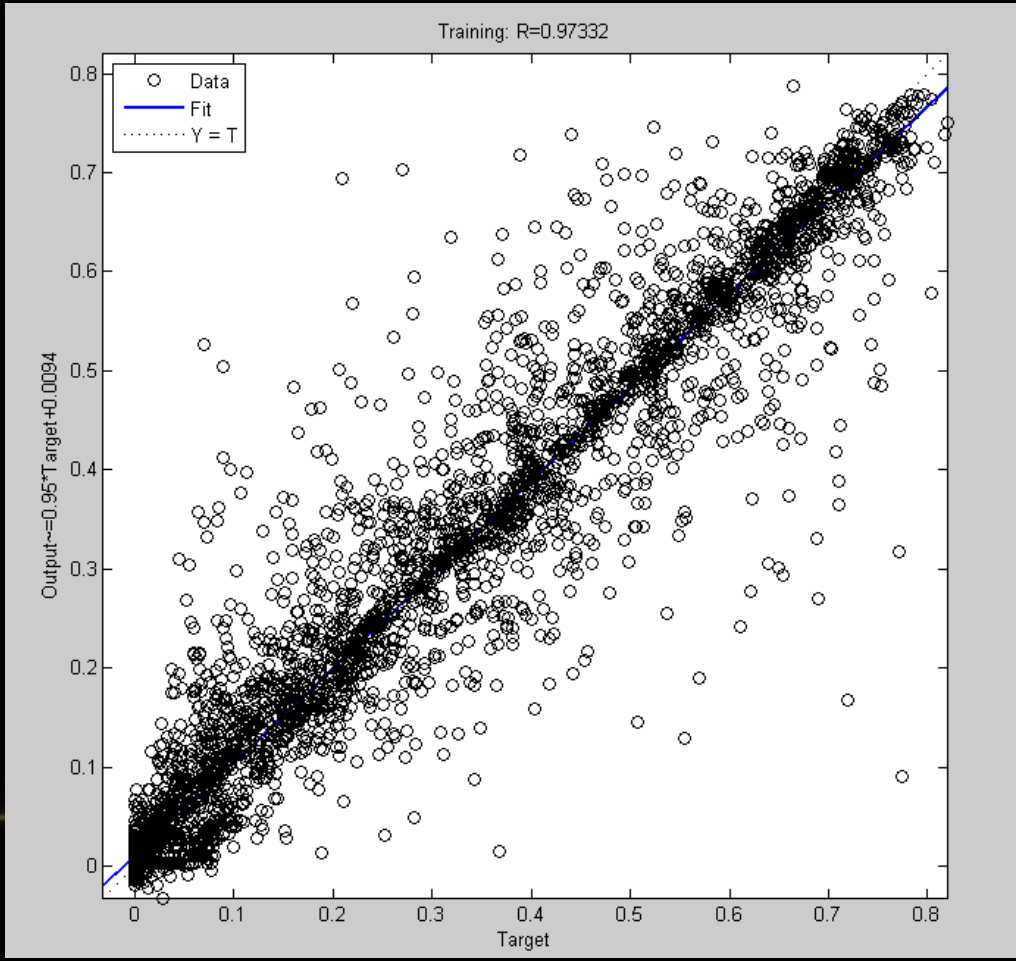




RMSE ~= 49

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(O^t - F^t)^2}{n}}$$

- Regression Plot



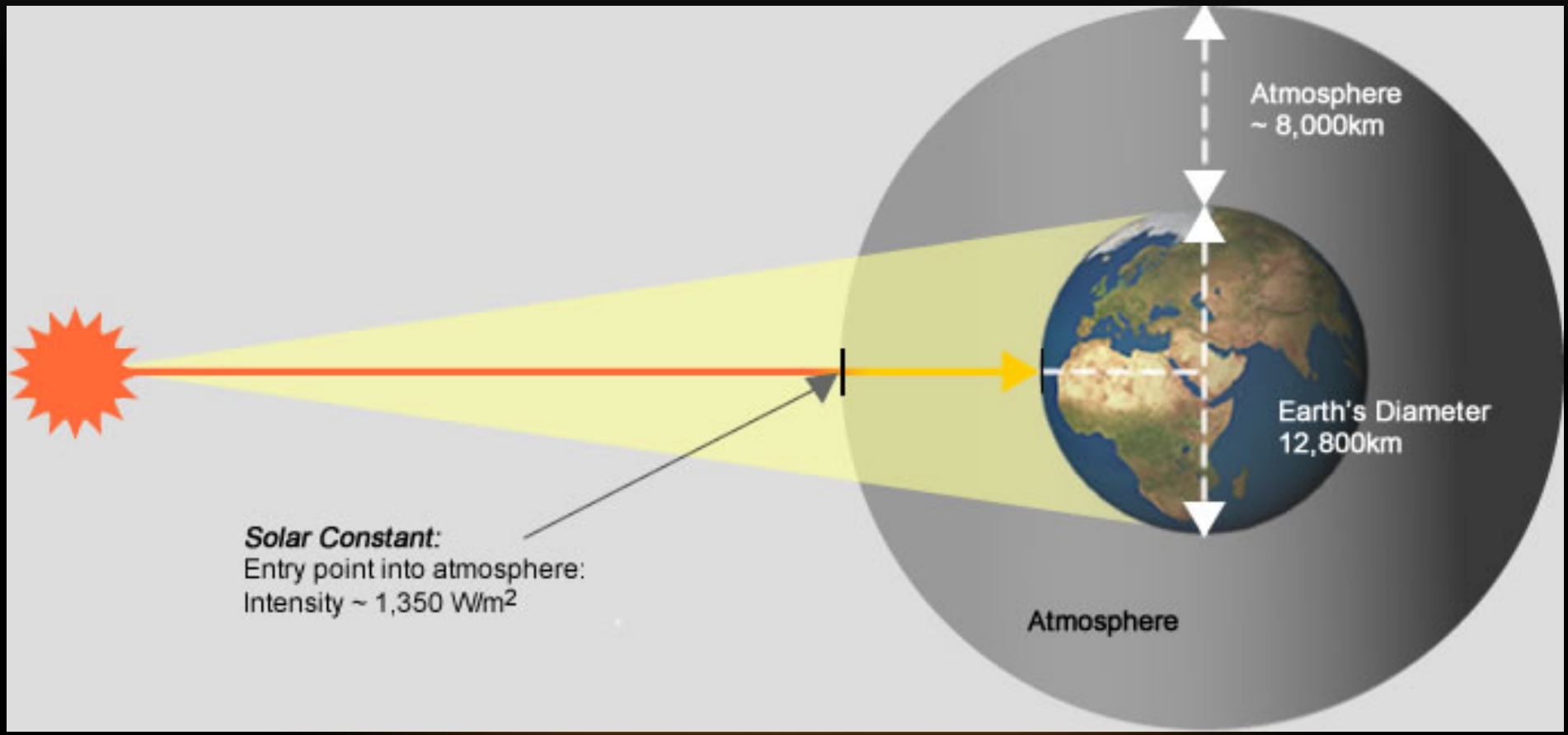
EXTRA TERRESTRIAL RADIATION

- Extraterrestrial radiation (E_a) is the intensity (power) of the sun at the top of the Earth's atmosphere. It is usually expressed in irradiance units (Watts per square meter) on a plane normal to the sun. It varies throughout the year because of the Earth's elliptical orbit, which results in the Earth-Sun distance varying during the year in a predictable way. This effect can be represented empirically with the following equations:

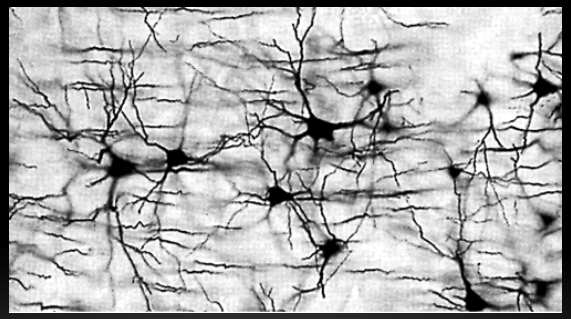
$$E_a = E_{sc} \; x \left(\frac{R_{av}}{R} \right)^2$$

Where E_{sc} is the solar constant $1367 \; W/m^2$. R_{av} is the mean sun-earth distance and R is the actual sun-earth distance depending on the day of the year.

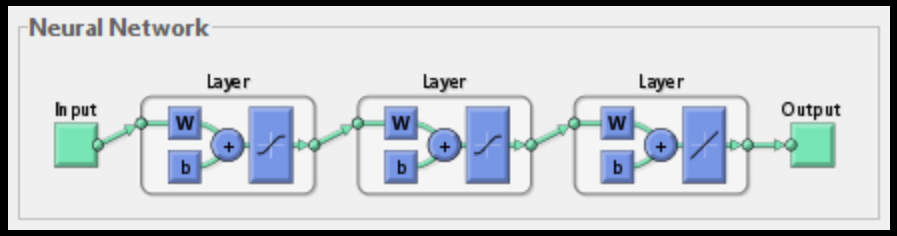
EXTRA TERRESTRIAL RADIATION



NEURAL-NET BASED SOLAR FORECASTING USING EXTRATERRESTRIAL IRRADIANCE FOR AFYON REGION IN TURKEY

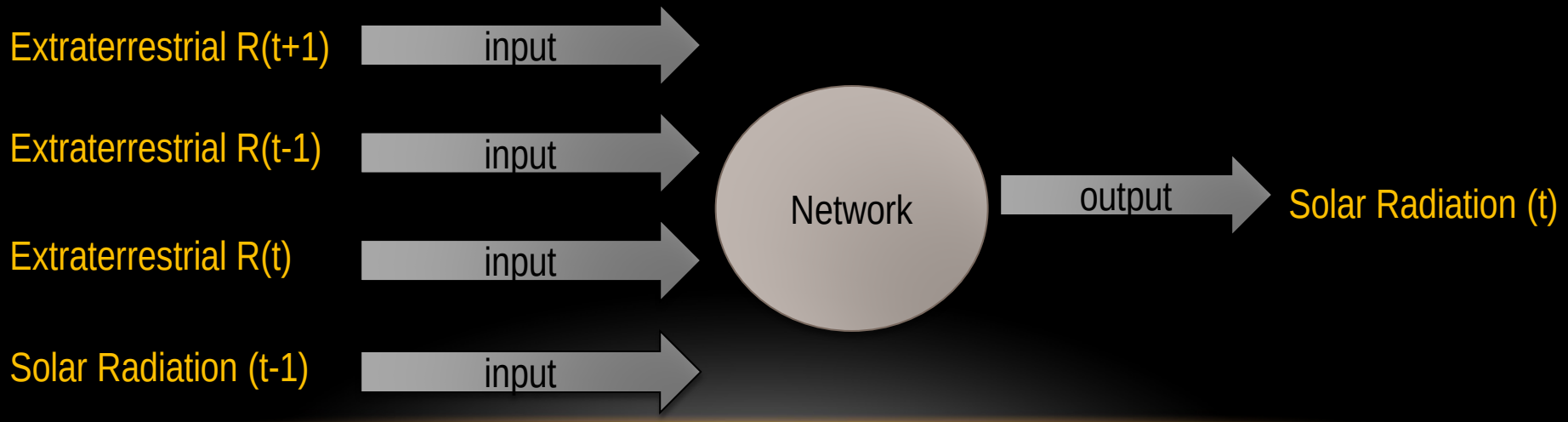


- In this study, a neural network based procedure is developed to predict hourly solar radiation values. In this procedure not only the hourly measured solar radiations but also the hourly calculated extraterrestrial radiation data are employed. Since extraterrestrial values carry considerable information for the behaviour of the data within the day and year, considerable improvement on forecasting is achived.

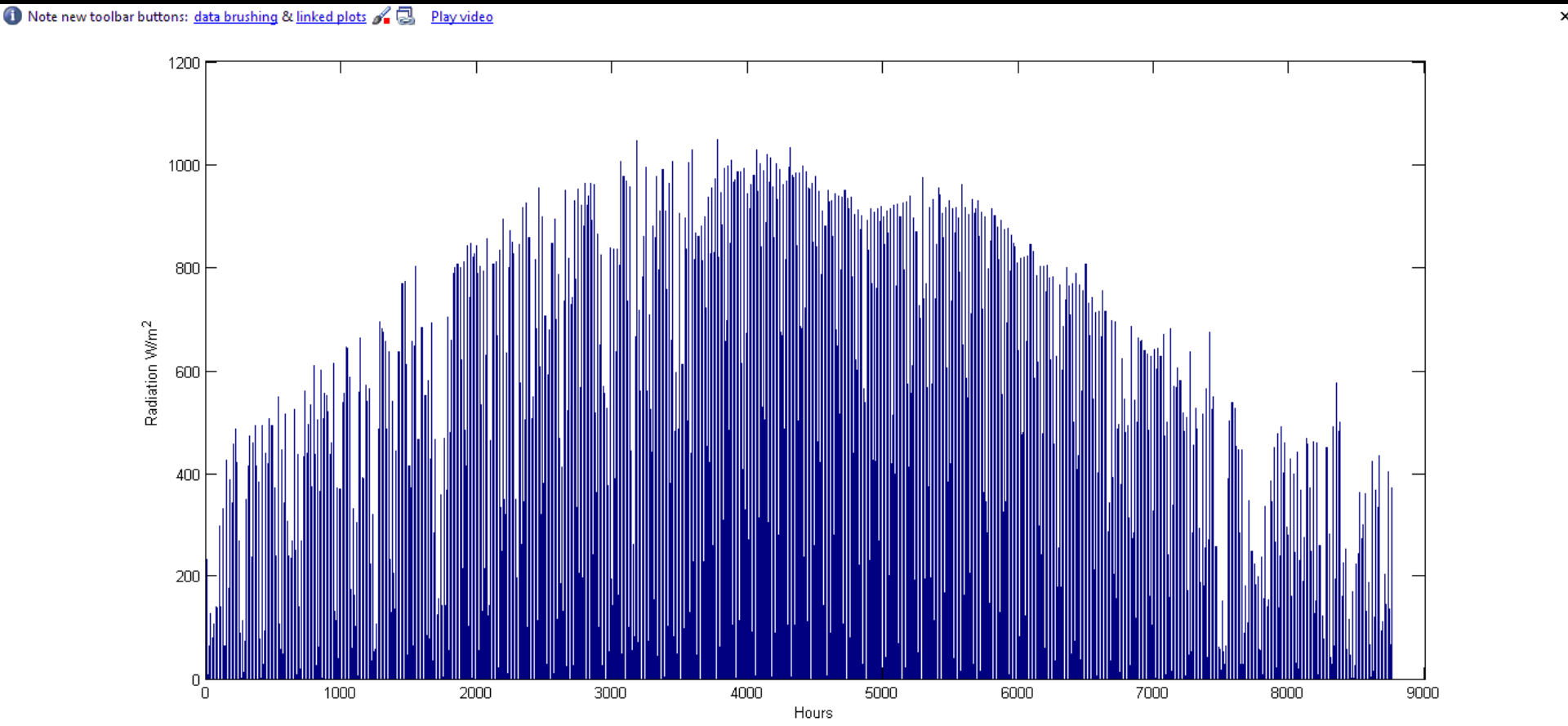


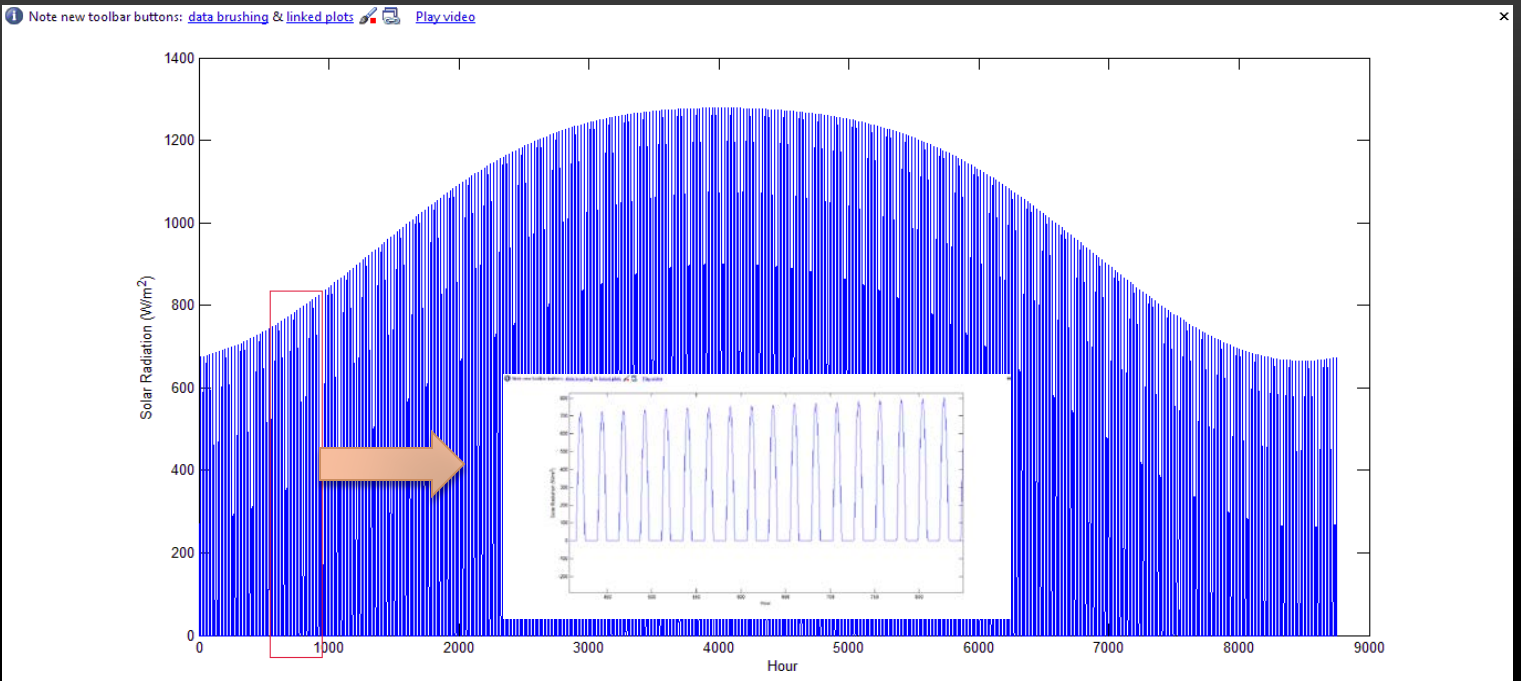
- In model construction phase future calculations of extraterrestrial data are used besides past data. The procedure is tested on hourly measured annual global solar radiation data obtained from Afyon region. The results are presented and compared with previous studies.

- Levenberg-Marquart Feed-Forward Backpropagation with three layers, our inputs and one output structure is used for this study. Our inputs are Extraterrestrial Radiation (t-1),(t) and (t+1), Solar Radiation (t-1). (t = Time // = Hour)
- Suppose that we know extraterrestrial radiation values (we can calculate them for our region) and last measured solar radiation value. And we want to predict solar radiation value.

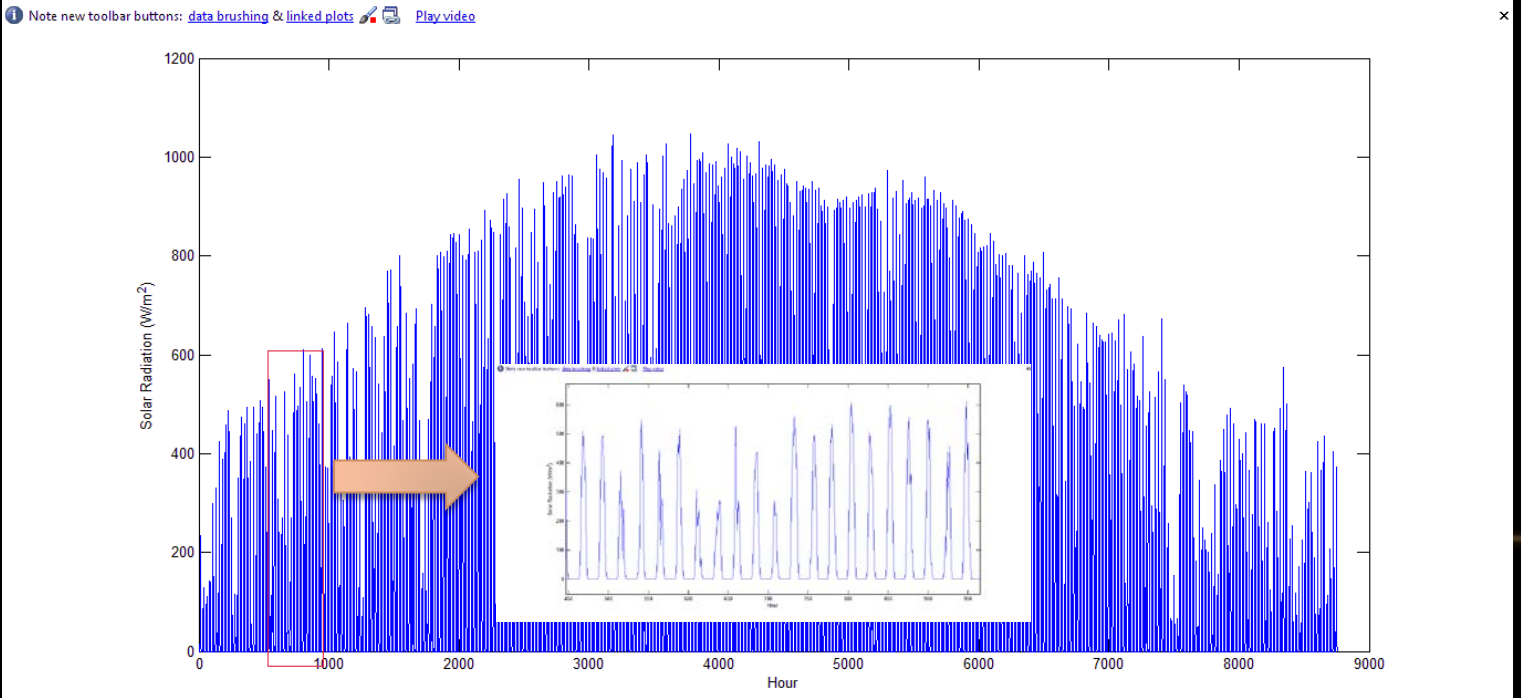


- We have solar radiation datas belong to Afyon in Turkey from January 2012 to January 2013. Characteristic plot is shown below.





- Extraterrestrial Irradiance (Estimated Values)

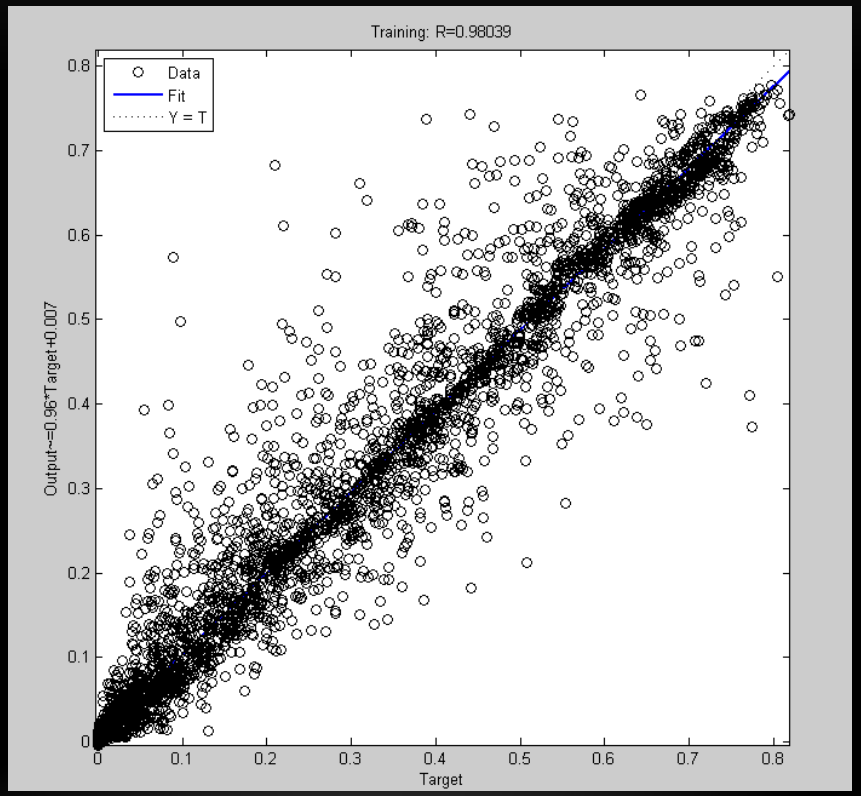


- Solar Radiation (Actual Measured Values)

CONCLUSIONS

- Root Mean Square Error = 40,811 W/m^2

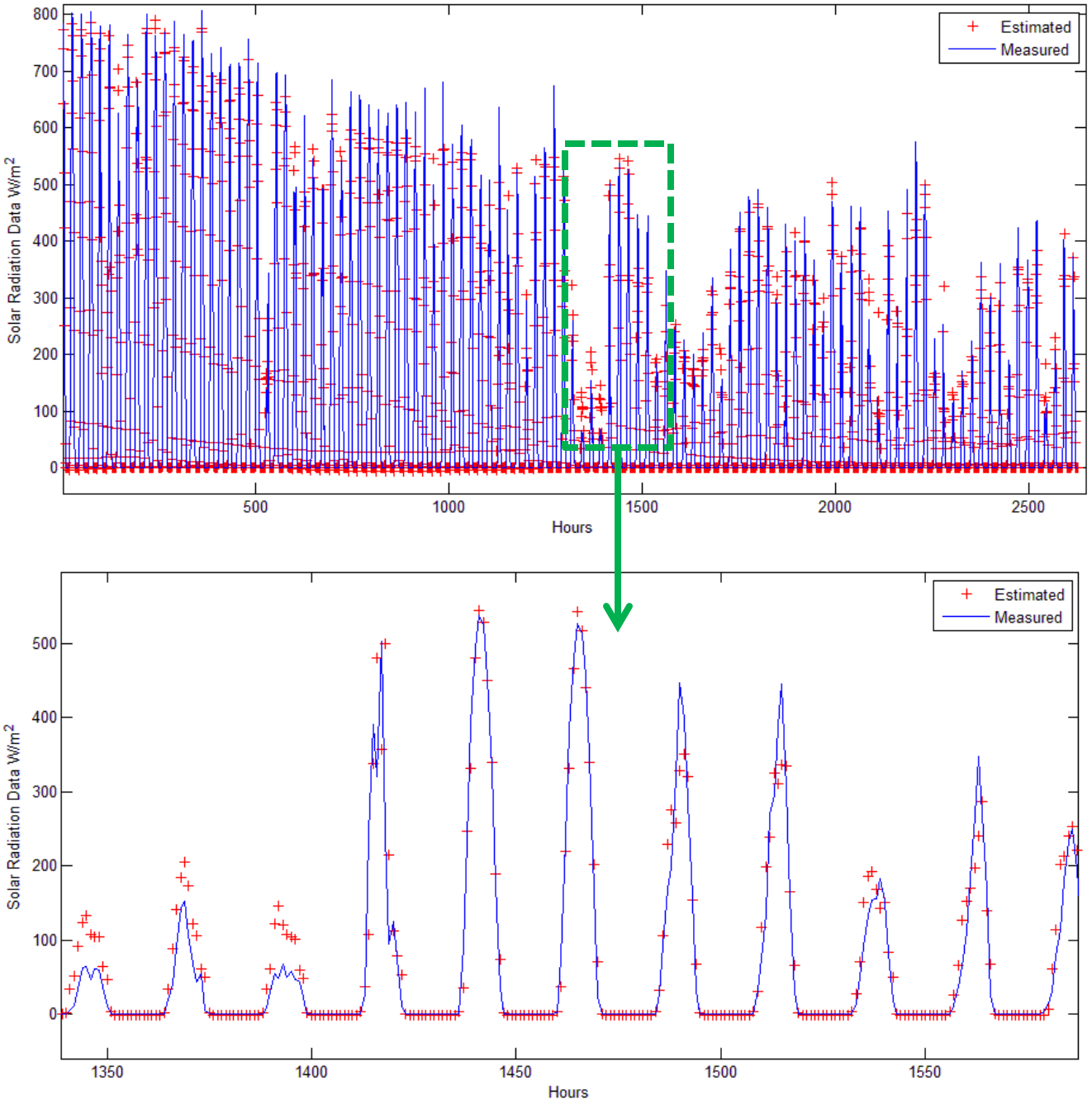
$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} (O^t - F^t)^2}{n}}$$



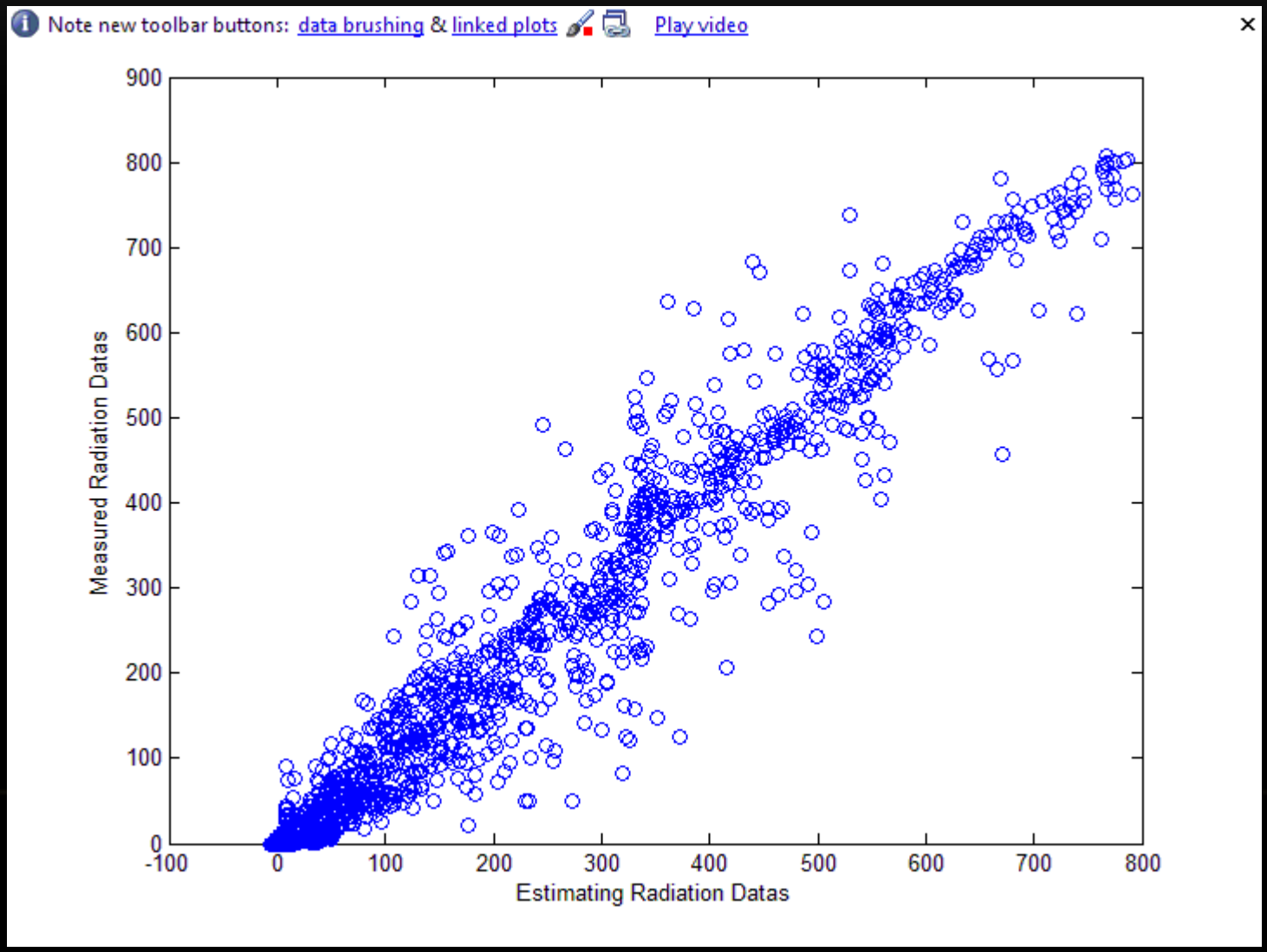
- Regression Plot

- After Artificial Neural Network Process and zoomed version.

- «Red ones» are estimated from our NN Based procedure, «Blue plot» is measured data from Afyon Kocatepe University Renewable Energy Systems Laboratories.



COMPARING THE MEASURED AND ESTIMATED SOLAR RADIATION DATAS



CONCLUSIONS

- As can be seen from the results, in estimation of solar radiation, in addition to the value of the past solar radiation datas, *extraterrestrial radiation* values can be entered to get better results.
- In the future this work might be the light of recent studies that could better results by changing the input-output parameters, time duration, Neural Network method, etc...

- Fatih SERTTAŞ