SIZE OPTIMIZATION OF WIND PHOTOVOLTAIC SYSTEMS

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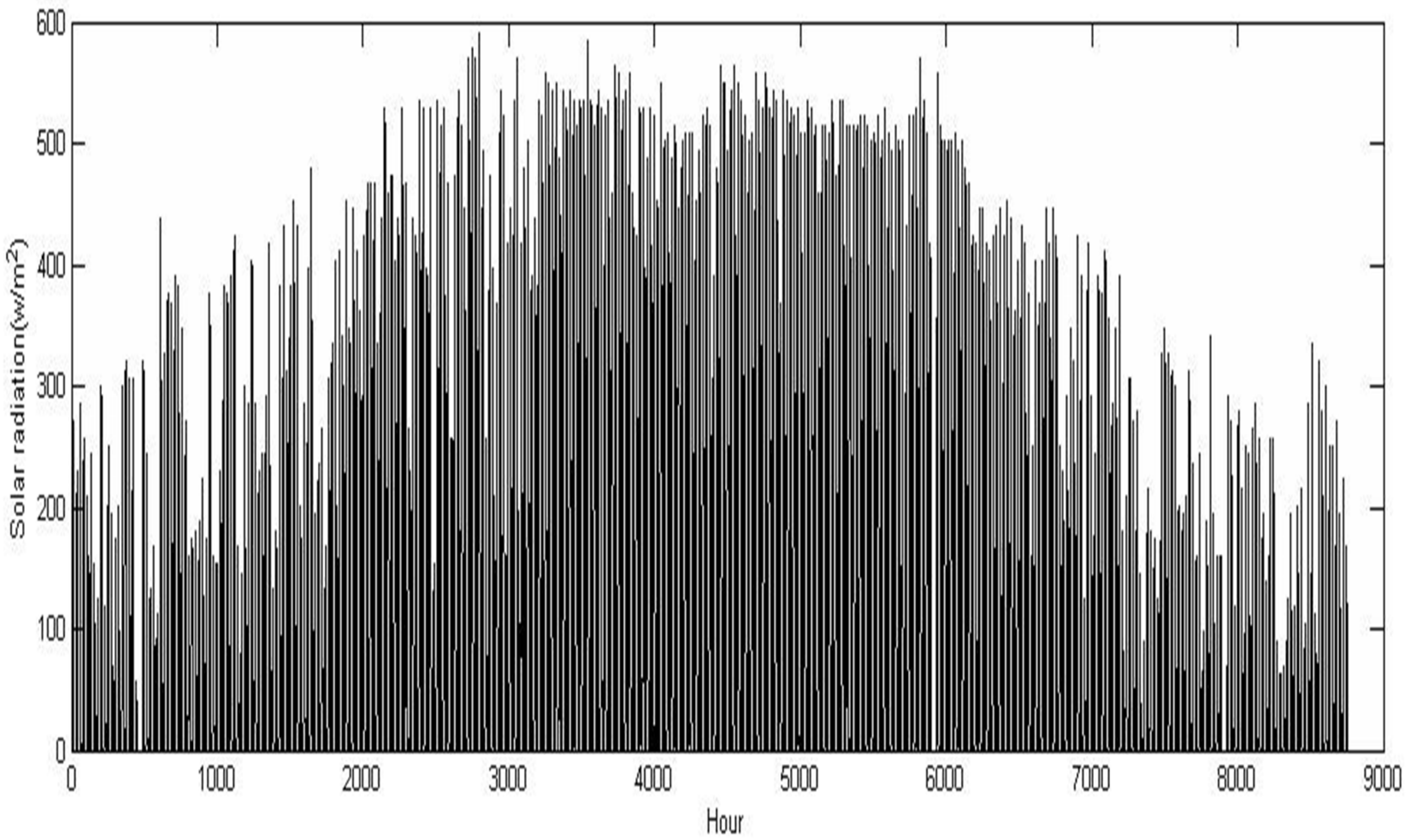
Outline

- Solar Radiation Data Analysis
- Wind Speed Data Analysis
- Load Forecasting
- Size Optimization and System Modeling

Solar Radiation Data Analysis

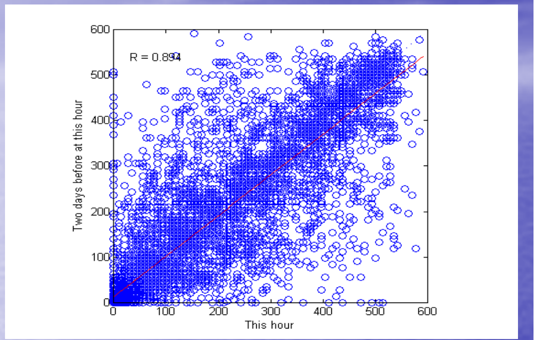


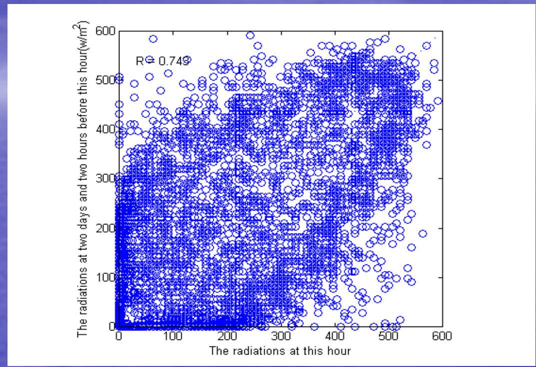
Solar Radiation Data Analysis

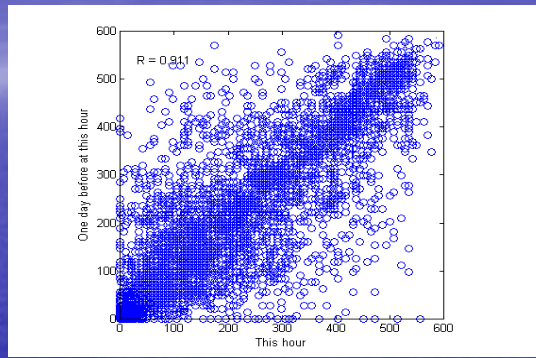
$$Rad = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}$$

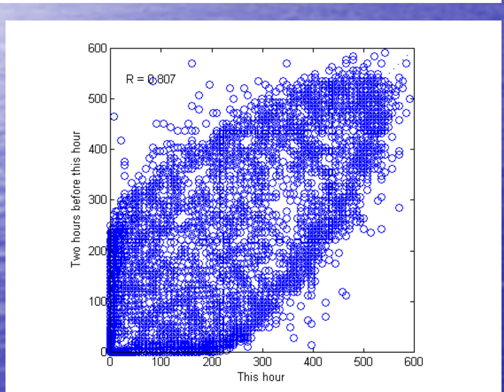
	R	R^2
$x_{44} - x_{34}$	0.911	0.830
$x_{44} - x_{24}$	0.894	0.799
$x_{44} - x_{14}$	0.898	0.806
$x_{44} - x_{43}$	0.938	0.879
$x_{44} - x_{42}$	0.807	0.651
$x_{44} - x_{14}$	0.630	0.397
$x_{44} - x_{33}$	0.870	0.760
$x_{44} - x_{22}$	0.740	0.548

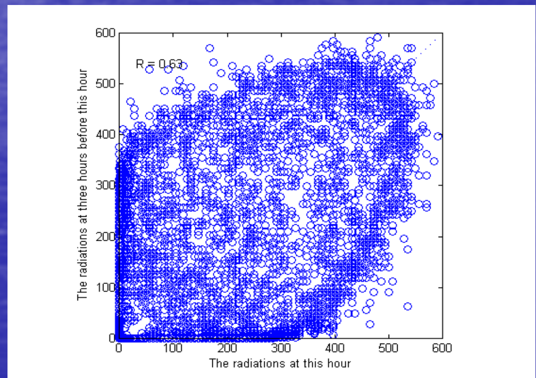
Solar Radiation Data Analysis

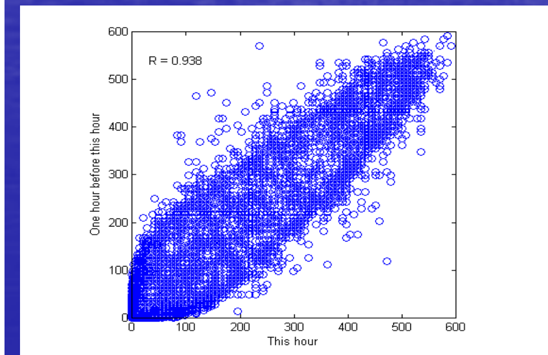


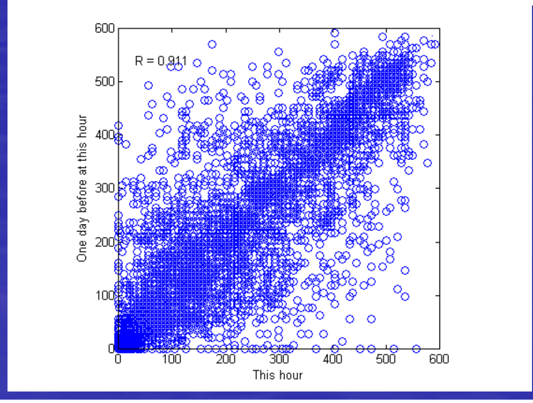




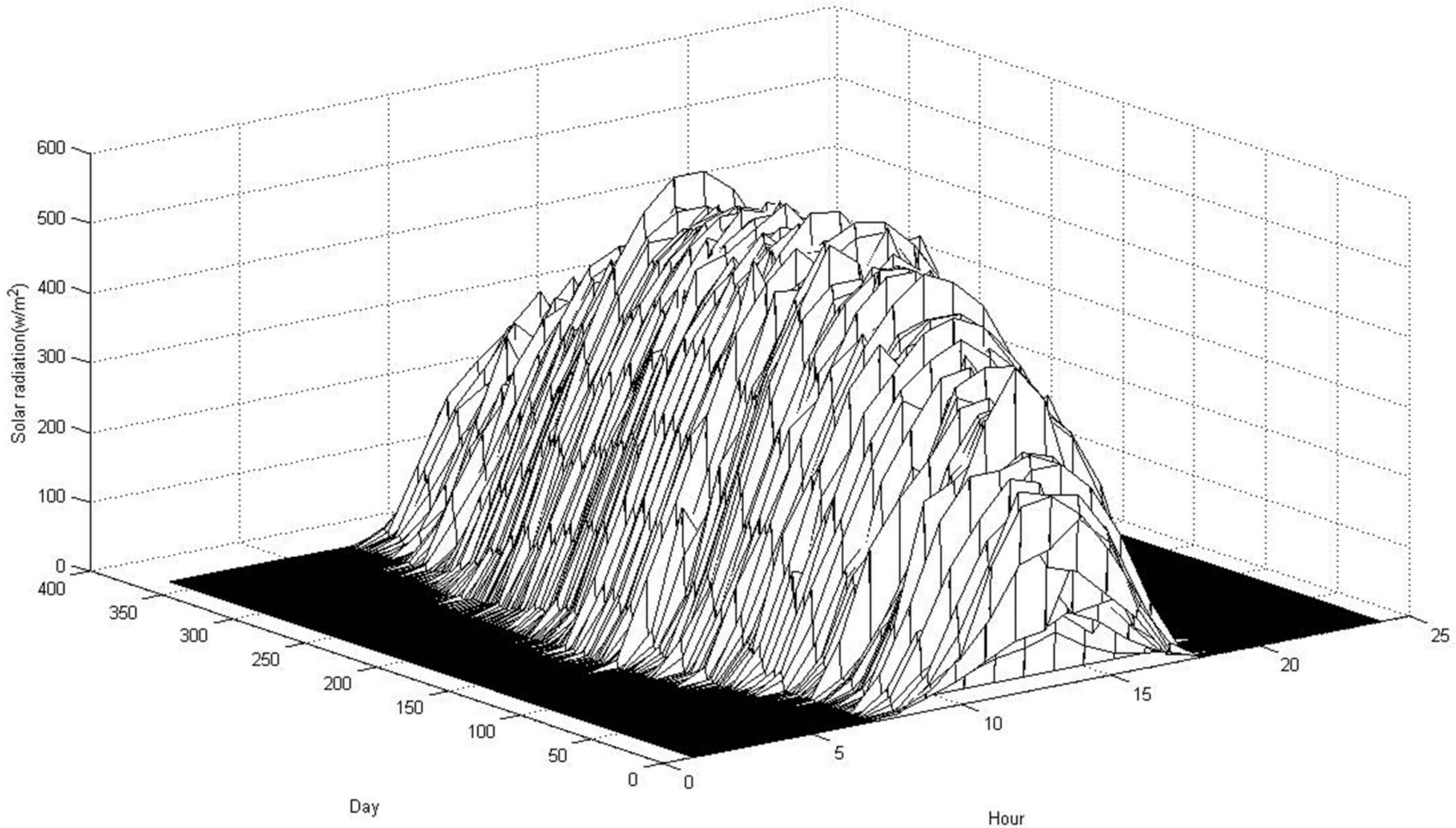




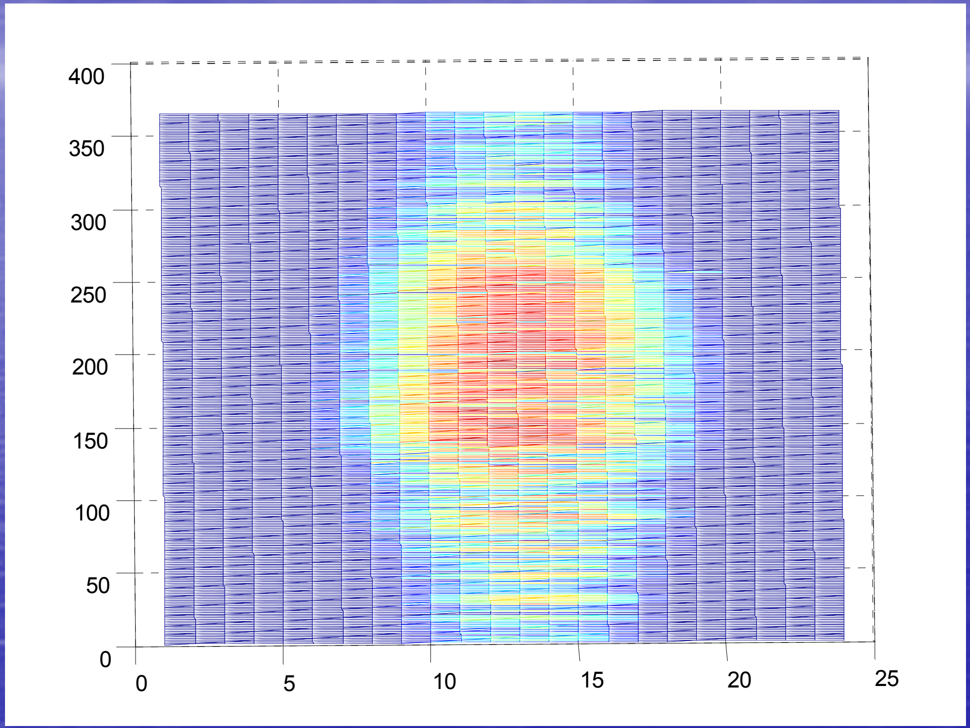




Solar Radiation Data Analysis



Solar Radiation Data Analysis



Optimal Coefficient Linear Prediction Filters

$x_{i,j}$	$x_{i,j+1}$
$x_{i+1,j}$	$\hat{x}_{i+1,j+1} = ?$

$$\hat{x}_{i+1,j+1} = x_{ij}.a_1 + x_{i(j+1)}.a_2 + x_{(i+1)j}.a_3$$

$$\varepsilon_{i+1,j+1} = \hat{x}_{i+1,j+1} - x_{i+1,j+1}$$

$$\varepsilon = \sum_{i=2}^{m} \sum_{j=2}^{n} \varepsilon_{ij}^2$$

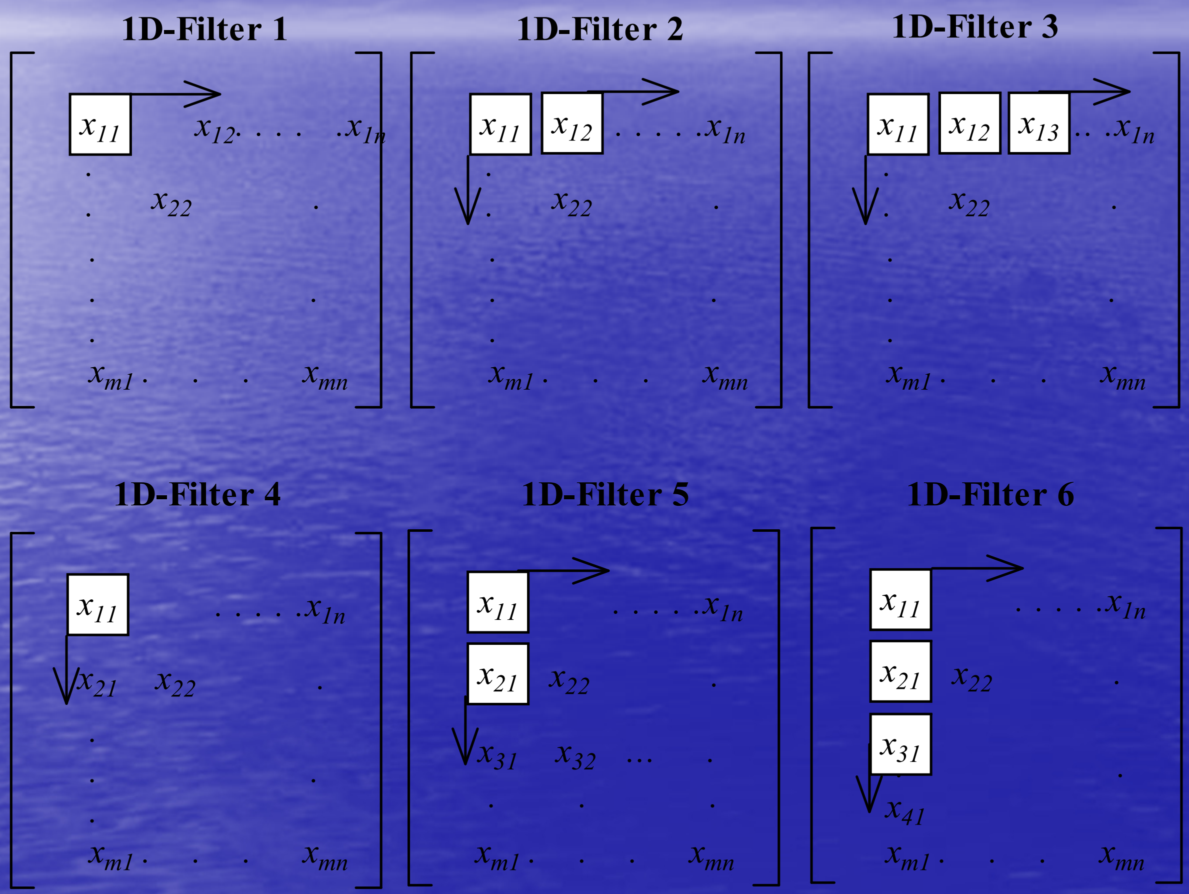
Optimal Coefficient Linear Prediction Filters

$$\frac{\partial \varepsilon}{\partial a_1} = \frac{\partial \varepsilon}{\partial a_2} = \frac{\partial \varepsilon}{\partial a_3} = 0$$

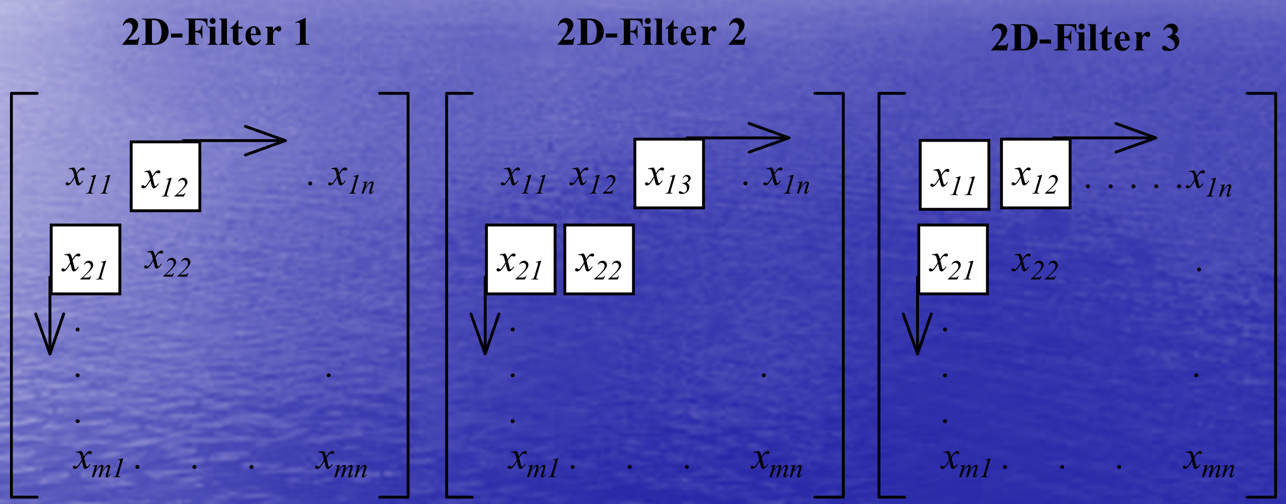
$$\begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} r_1 \\ r_2 \\ r_3 \end{bmatrix}$$

$$a = R^{-1} r$$

Optimal Coefficient Linear Prediction Filters

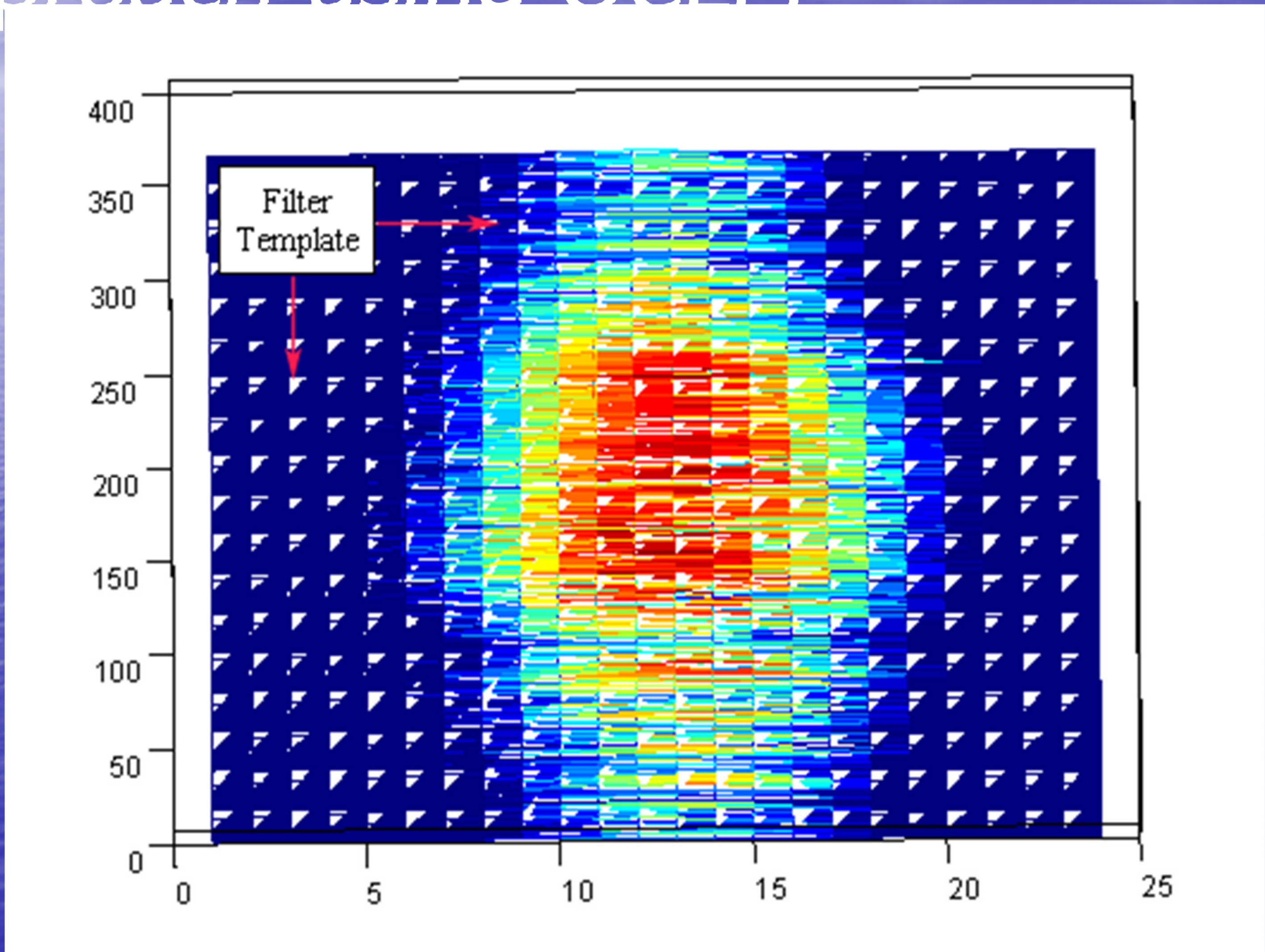


Optimal Coefficient Linear Prediction Filters

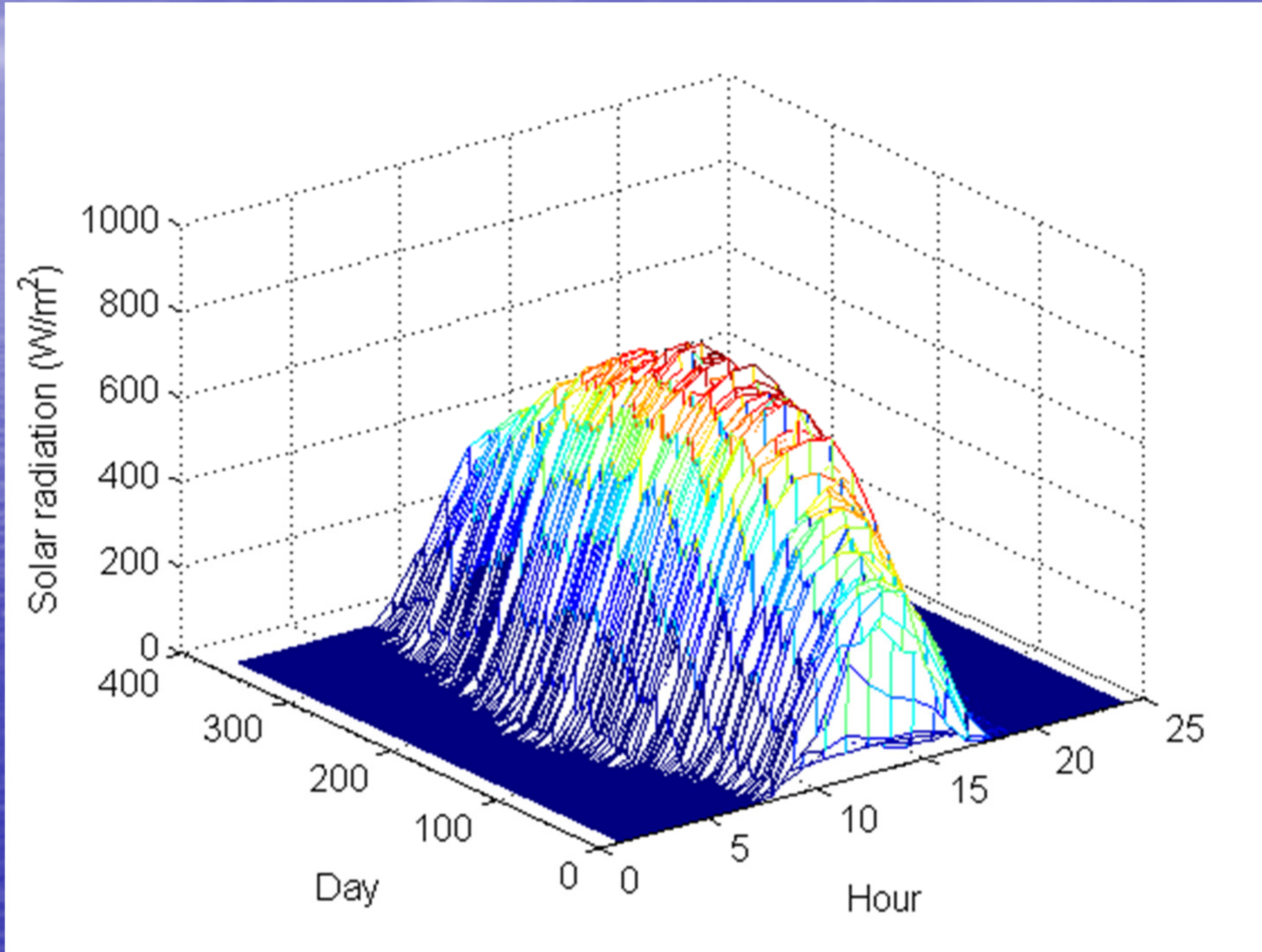


$$RMSE = \sqrt{\frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(Rad(i,j) - \hat{Rad}(i,j)\right)^2}$$

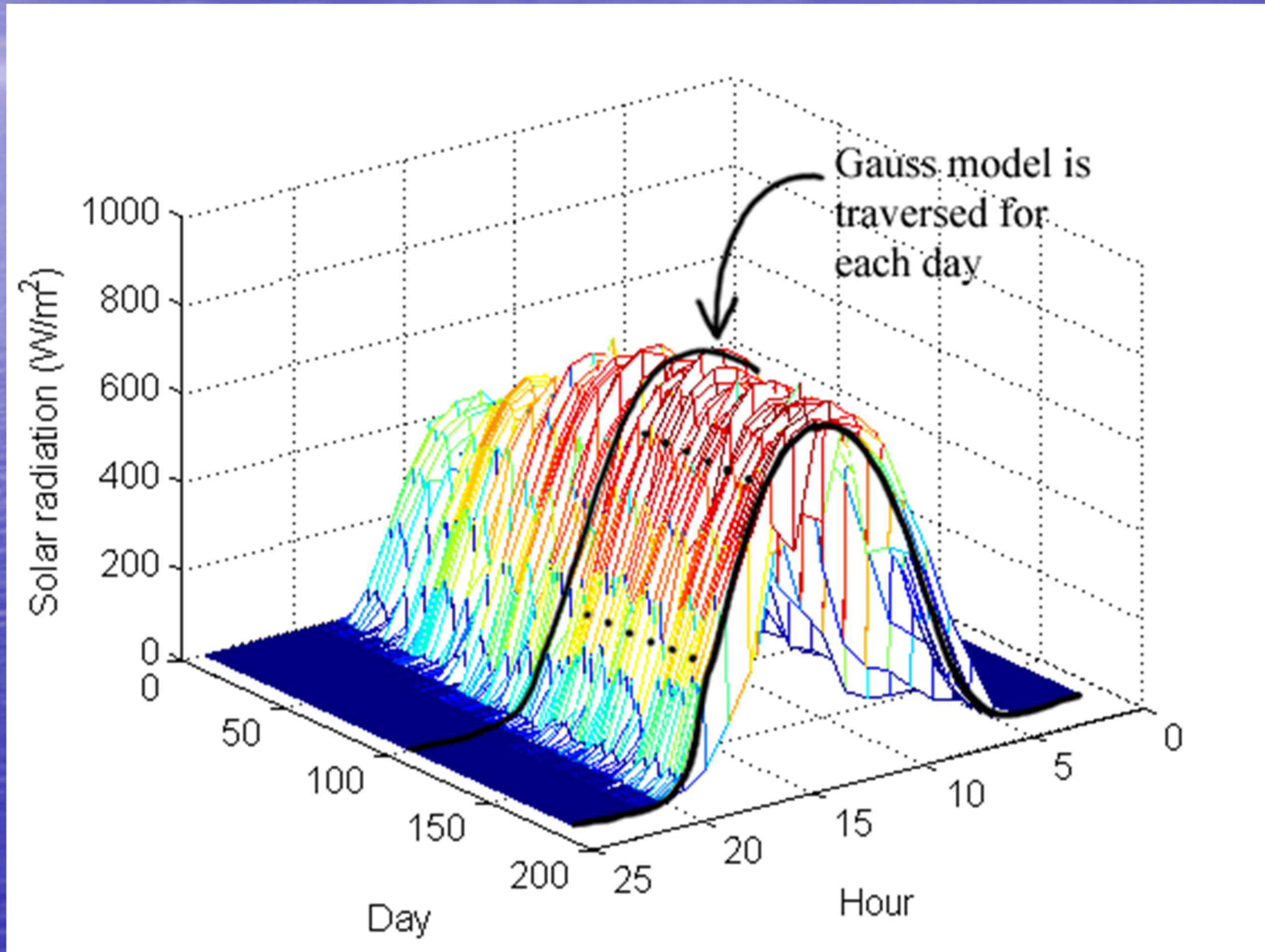
Testing the Performance of 2D Approach using OCLPF



Novel Analytical Modeling Approach for Solar Radiation Data



Novel Analytical Modeling Approach for Solar Radiation Data



Novel Analytical Modeling Approach for Solar Radiation Data

$$g(x) = ae^{-(x-b)^2/c^2}$$

$$g(x) = a_1 e^{-(x-b_1)^2/c_1^2} + a_2 e^{-(x-b_2)^2/c_2^2}$$

Novel Analytical Modeling Approach for Solar Radiation Data

	a	b	c
D1	285.6000	12.9500	2.7280
D2	226.7000	13.4000	2.8410
D3	301.8000	12.9500	2.7710
D4	235.1000	12.1700	2.8930
D5	201.1000	14.5600	1.8690
D6	229.7000	12.7800	3.0010
D7	134.3000	13.2700	3.2470
D8	122.9000	12.9200	3.4460
D9	298.9000	12.1100	2.8850
D10	103.1000	12.3000	3.3970

Novel Analytical Modeling Approach for Solar Radiation Data

	1 Source Gauss	2 Source Gauss
D1	0.9907	0.9981
D2	0.982	0.9971
D3	0.9881	0.9986
D4	0.9596	0.9949
D5	0.9242	0.9974
D6	0.9136	0.9889
D7	0.9293	0.9907
D8	0.9561	0.9964
D9	0.9882	0.9899
D10	0.9155	0.9978

Novel Analytical Modeling Approach for Solar Radiation Data

1 kayanklı Gauss yüzeyi için;

$$a(day) = 364 \times \sin(2 \times pi \times day / 720) + 162.1$$

$$c(day) = 2.117 \times \sin(2 \times pi \times day / 712) + 2.644$$

$$Surface1(day, hour) = a(day) \times e^{-((hour - 12.5)/c(day))^2}$$

2 kayanklı Gauss yüzeyi için;

$$a_1(day) = 276 \times \sin(2 \times pi \times day / 720) + 122.9$$

$$c_1(day) = 1.234 \times \sin(2 \times pi \times day / 720) + 1.715$$

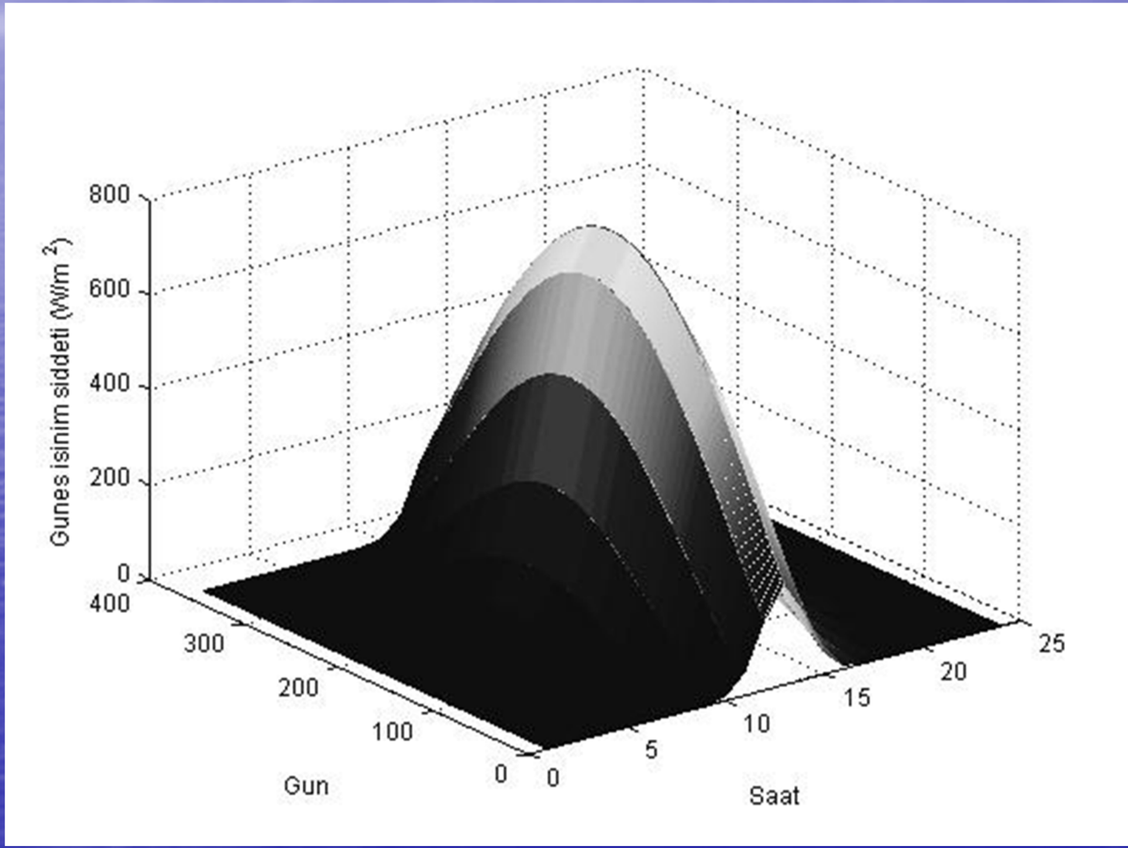
$$a_2(day) = 302.5 \times \sin(2 \times pi \times day / 720) + 85.9$$

$$c_2(day) = 1.537 \times \sin(2 \times pi \times day / 720) + 1.465$$

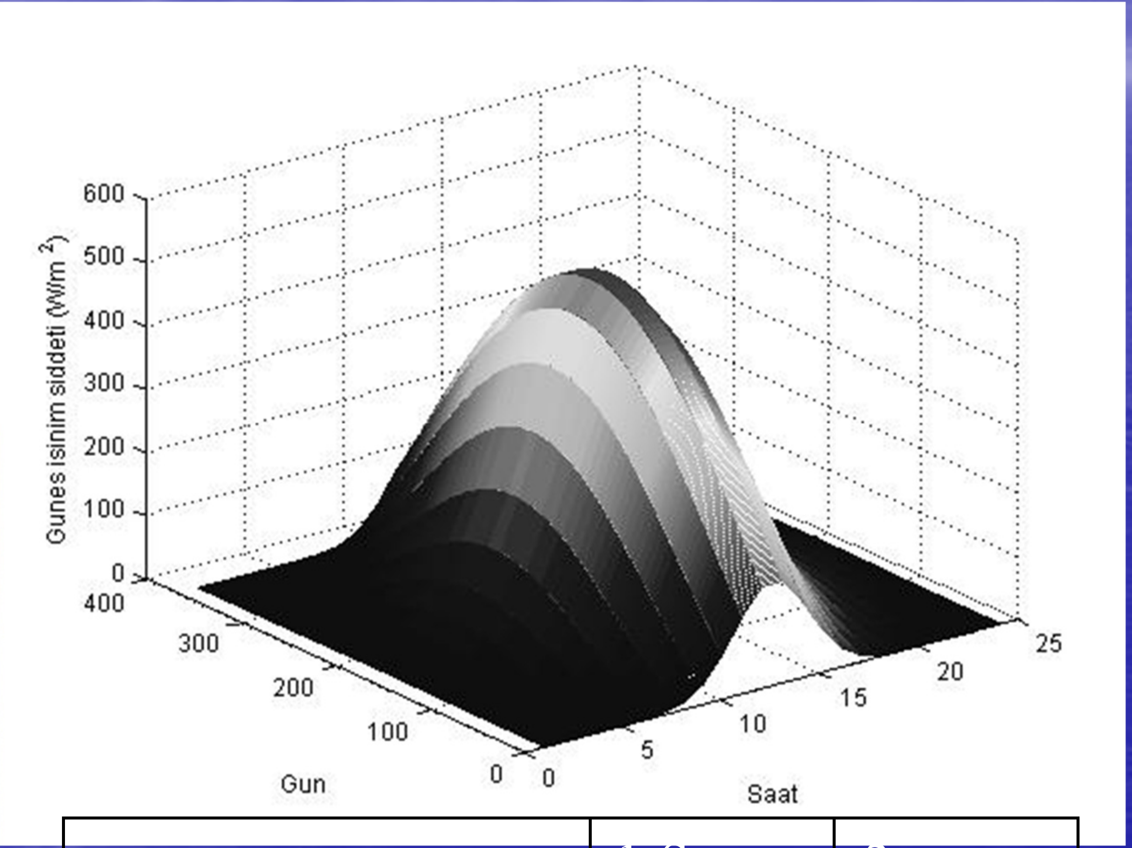
$$Surface2(day, hour) = a_1(day) \times e^{-((hour - 12.5)/c_1(day))^2}$$

$$+ a_2(day) \times e^{-((hour - 12.5)/c_2(day))^2}$$

Novel Analytical Modeling Approach for Solar Radiation Data

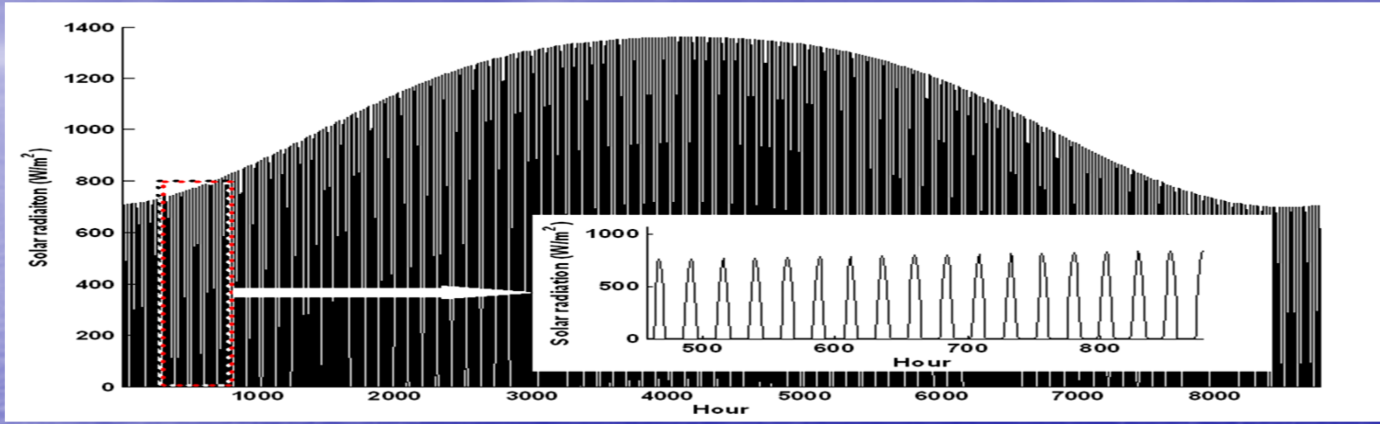


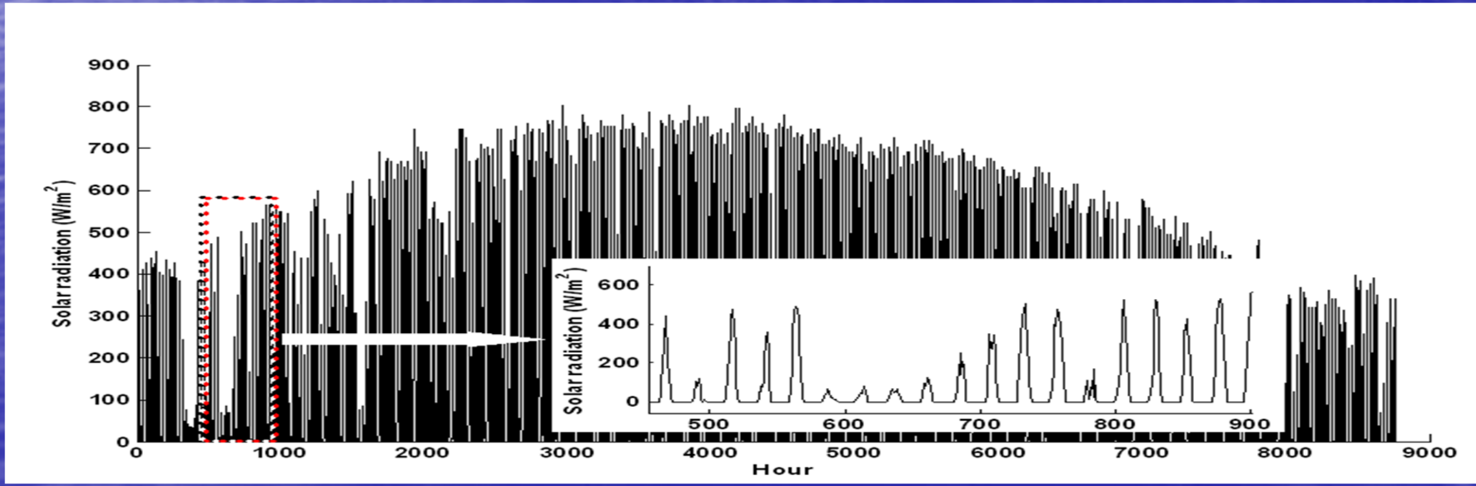
Novel Analytical Modeling Approach for Solar Radiation Data



	1-Source Gauss	2-source Gauss
RMSE	57.20	105.25

A novel modeling approach using extraterrestrial solar radiations





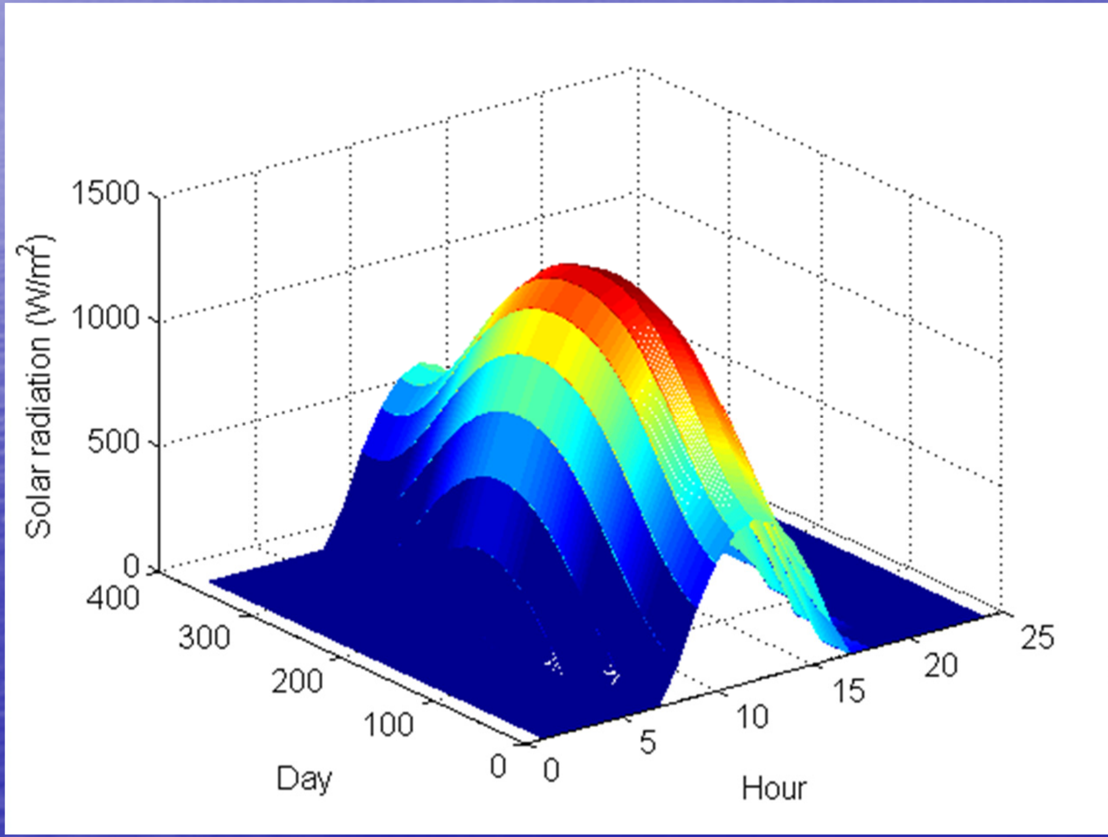
Extraterrestrial Formulation

$$I = C\sin(\varphi)/24R^2$$

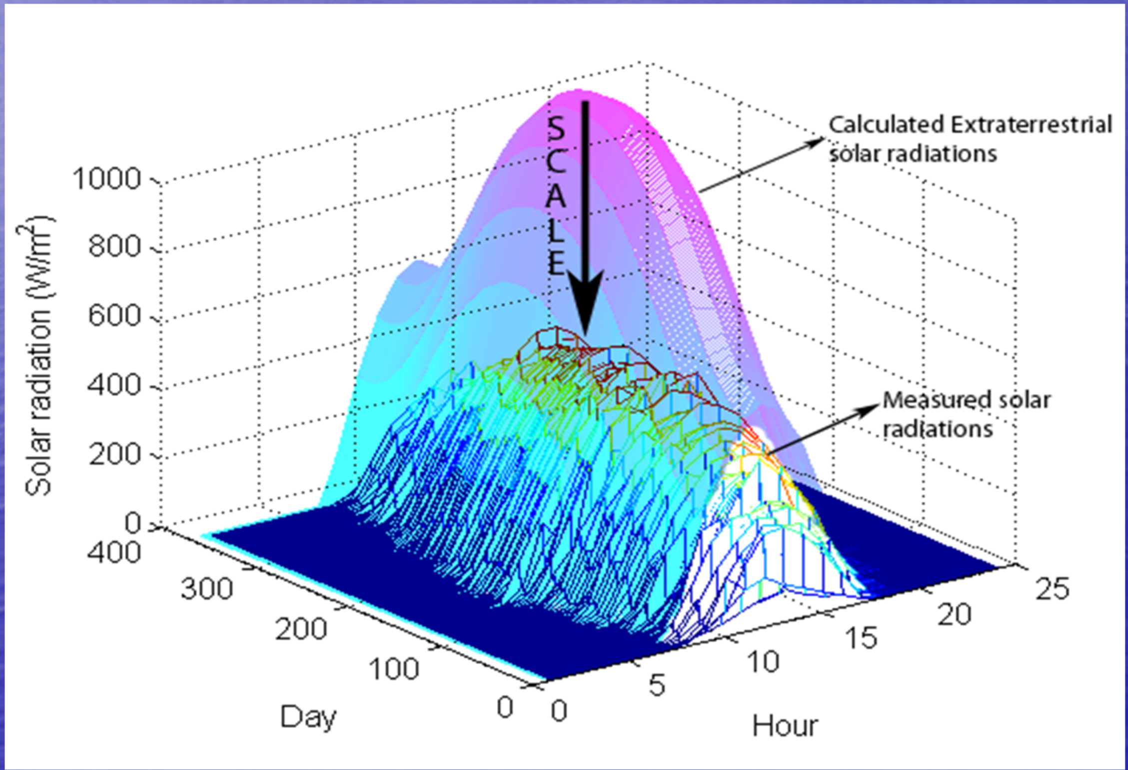
$$\sin(\varphi) = \sin(L)\sin(D) + \cos(L)\cos(D)\cos(h)$$

$$h = 15(h_c - 12)$$

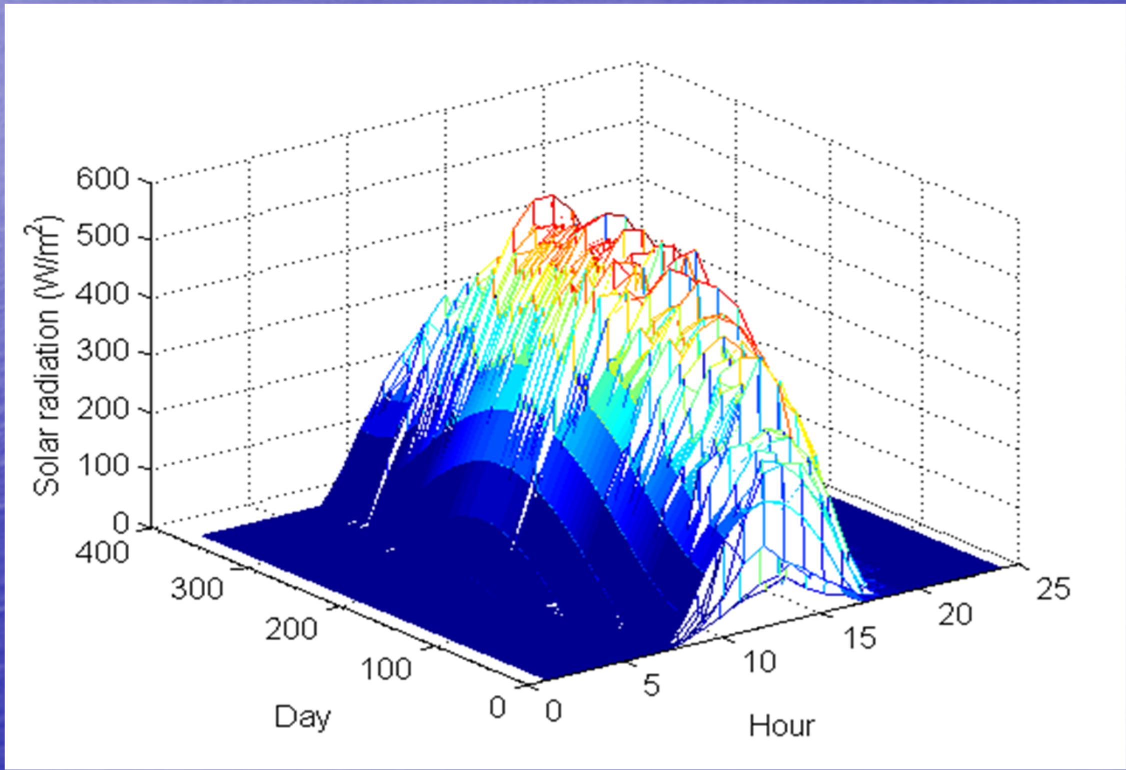
2D Representation of Extraterrestrial Data



Modeling Solar Radiations from Extraterrestrial Radiations



Modeling Solar Radiations from Extraterrestrial Radiations



Model: Markov Processes

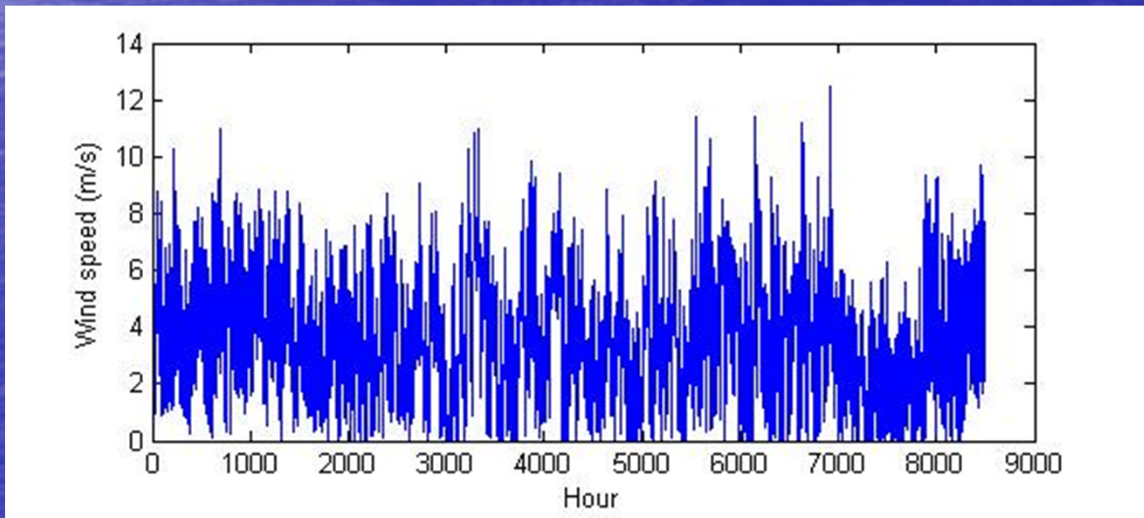
$$0 < p_{ij} < 1$$

$$\sum_{j=1} p_{ij} = 1$$

$$A = \begin{bmatrix} p_{11} & p_{12} & p_{13} & \cdots p_{1n} \\ p_{21} & p_{22} & p_{23} & \cdots p_{2n} \\ . & . & . & \cdots . \\ . & . & . & \cdots . \\ p_{n1} & p_{n2} & p_{n3} & \cdots p_{nn} \end{bmatrix}$$

Wind Speed Modeling using Markov Approach

$$p_{ij} = \frac{m_{ij}}{\sum_j m_{ij}} \qquad i, j = 1, 2, \ldots, n$$



Wind Speed Modeling using Markov Approach

0.61	0.29	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.18	0.47	0.28	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.04	0.20	0.46	0.23	0.06	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.05	0.20	0.45	0.22	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.06	0.26	0.42	0.20	0.04	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.07	0.28	0.41	0.18	0.04	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.01	0.07	0.29	0.39	0.21	0.02	0.01	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.02	0.09	0.30	0.38	0.17	0.02	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.01	0.04	0.12	0.33	0.39	0.08	0.02	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.18	0.27	0.37	0.08	0.05	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.09	0.23	0.41	0.09	0.00
0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.15	0.31	0.08	0.31	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00

0.61	0.29	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.18	0.47	0.28	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.04	0.20	0.46	0.23	0.06	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.05	0.20	0.45	0.22	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.06	0.26	0.42	0.20	0.04	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.07	0.28	0.41	0.18	0.04	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.01	0.07	0.29	0.39	0.21	0.02	0.01	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.02	0.09	0.30	0.38	0.17	0.02	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.01	0.04	0.12	0.33	0.39	0.08	0.02	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.18	0.27	0.37	0.08	0.05	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.09	0.23	0.41	0.09	0.00
0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.15	0.31	0.08	0.31	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00

Wind Speed Modeling using Markov Approach

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	......
0.00	0.61	0.18	0.10	0.05	0.03	0.02	0.00	0.00	0.00	0.00	0.00	......
0.00	0.25	0.24	0.24	0.14	0.06	0.04	0.01	0.00	0.00	0.00	0.00	......
0.00	0.12	0.18	0.28	0.23	0.11	0.05	0.03	0.01	0.01	0.00	0.00	......
0.00	0.05	0.11	0.15	0.23	0.19	0.12	0.07	0.02	0.03	0.00	0.00	......
0.00	0.02	0.04	0.10	0.18	0.30	0.16	0.10	0.04	0.02	0.01	0.00	......
0.00	0.01	0.03	0.05	0.10	0.17	0.28	0.17	0.10	0.04	0.02	0.01	......
0.00	0.00	0.00	0.02	0.04	0.10	0.20	0.25	0.18	0.11	0.05	0.02	......
0.00	0.00	0.00	0.00	0.02	0.06	0.12	0.23	0.25	0.13	0.10	0.05	......
0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.12	0.22	0.25	0.18	0.07	......
0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.13	0.22	0.23	0.16	......
0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.05	0.15	0.22	0.21	......
......	......	......	......	......	......	......	......	......	......	......	......	......

Wind Speed Modeling using Markov Approach

$$P_{ik} = \sum_{j=1}^{k} p_{ij}$$

P_{ik} is transition probability in the i^{th} row at the k^{th} state

0.61	0.29	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.18	0.47	0.28	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.04	0.20	0.46	0.23	0.06	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.05	0.20	0.45	0.22	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.06	0.26	0.42	0.20	0.04	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.07	0.28	0.41	0.18	0.04	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.01	0.07	0.29	0.39	0.21	0.02	0.01	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.02	0.09	0.30	0.38	0.17	0.02	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.01	0.04	0.12	0.33	0.39	0.08	0.02	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.18	0.27	0.37	0.08	0.05	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.09	0.23	0.41	0.09	0.00
0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.15	0.31	0.08	0.31	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00

Wind Speed Modeling using Markov Approach

0.61	0.90	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.18	0.64	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.04	0.23	0.69	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.01	0.06	0.26	0.72	0.93	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.00	0.00	0.06	0.32	0.75	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.00	0.00	0.01	0.08	0.36	0.77	0.95	0.99	1.00	1.00	1.00	1.00	1.00
0.00	0.00	0.01	0.02	0.09	0.38	0.76	0.97	0.99	1.00	1.00	1.00	1.00
0.00	0.00	0.00	0.01	0.03	0.12	0.42	0.80	0.98	1.00	1.00	1.00	1.00
0.00	0.00	0.00	0.00	0.02	0.05	0.17	0.50	0.89	0.97	1.00	1.00	1.00
0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.22	0.49	0.86	0.95	1.00	1.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.27	0.50	0.91	1.00	1.00
0.00	0.00	0.00	0.00	0.08	0.15	0.15	0.15	0.31	0.62	0.69	1.00	1.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00

Wind Speed Modeling using Markov Approach

Assume 2 and 0.76 are generated

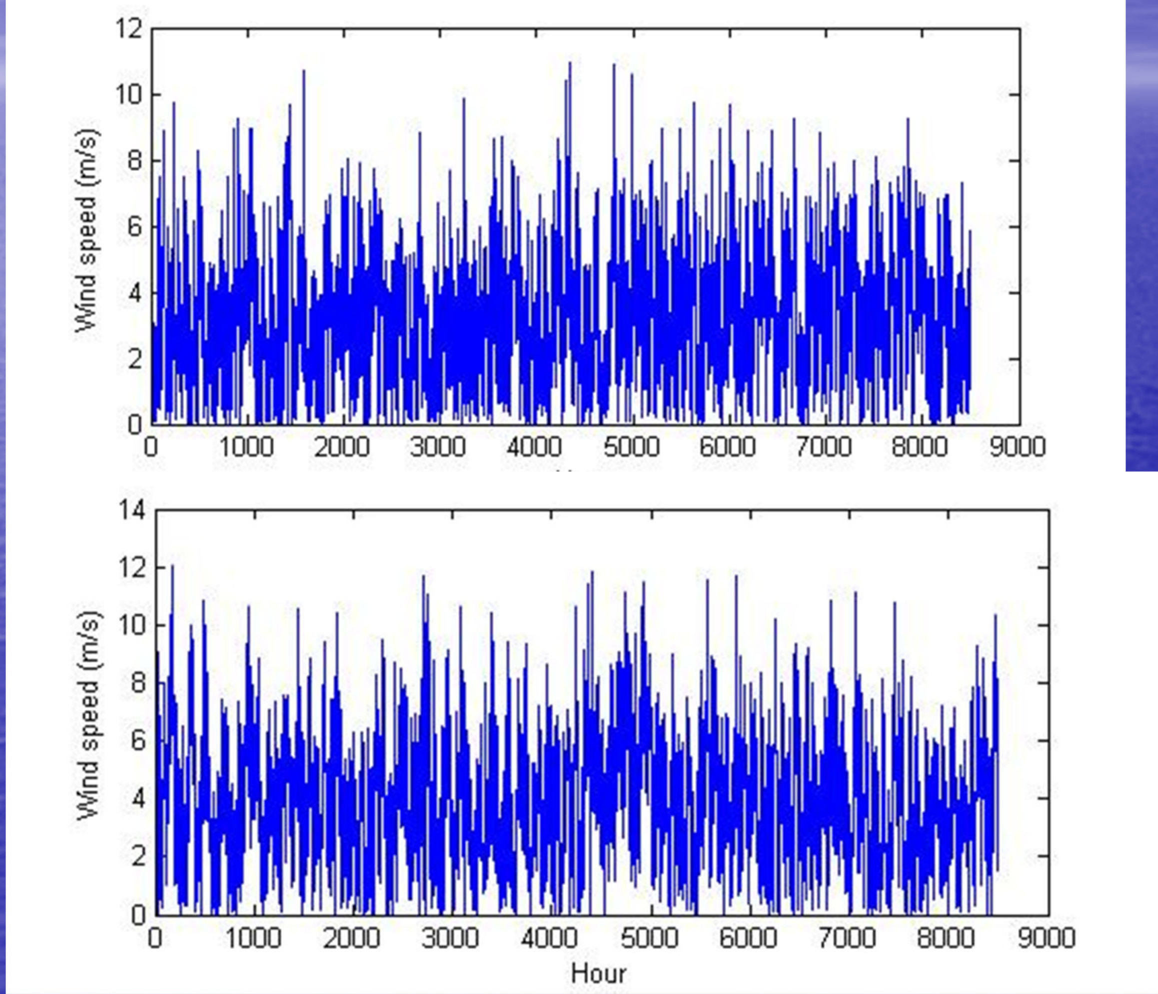
1	0.61	0.90	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.18	0.64	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	0.04	0.23	0.69	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	0.01	0.06	0.26	0.72	0.93	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	0.00	0.00	0.06	0.32	0.75	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00
6	0.00	0.00	0.01	0.08	0.36	0.77	0.95	0.99	1.00	1.00	1.00	1.00	1.00
7	0.00	0.00	0.01	0.02	0.09	0.38	0.76	0.97	0.99	1.00	1.00	1.00	1.00
8	0.00	0.00	0.00	0.01	0.03	0.12	0.42	0.80	0.98	1.00	1.00	1.00	1.00
9	0.00	0.00	0.00	0.00	0.02	0.05	0.17	0.50	0.89	0.97	1.00	1.00	1.00
10	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.22	0.49	0.86	0.95	1.00	1.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.27	0.50	0.91	1.00	1.00
12	0.00	0.00	0.00	0.00	0.08	0.15	0.15	0.15	0.31	0.62	0.69	1.00	1.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00

Wind Speed Modeling using Markov Approach

Let the generated random number be 0.2

1	0.61	0.90	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.18	0.64	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	0.04	0.23	0.69	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	0.01	0.06	0.26	0.72	0.93	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	0.00	0.00	0.06	0.32	0.75	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00
6	0.00	0.00	0.01	0.08	0.36	0.77	0.95	0.99	1.00	1.00	1.00	1.00	1.00
7	0.00	0.00	0.01	0.02	0.09	0.38	0.76	0.97	0.99	1.00	1.00	1.00	1.00
8	0.00	0.00	0.00	0.01	0.03	0.12	0.42	0.80	0.98	1.00	1.00	1.00	1.00
9	0.00	0.00	0.00	0.00	0.02	0.05	0.17	0.50	0.89	0.97	1.00	1.00	1.00
10	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.22	0.49	0.86	0.95	1.00	1.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.27	0.50	0.91	1.00	1.00
12	0.00	0.00	0.00	0.00	0.08	0.15	0.15	0.15	0.31	0.62	0.69	1.00	1.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00

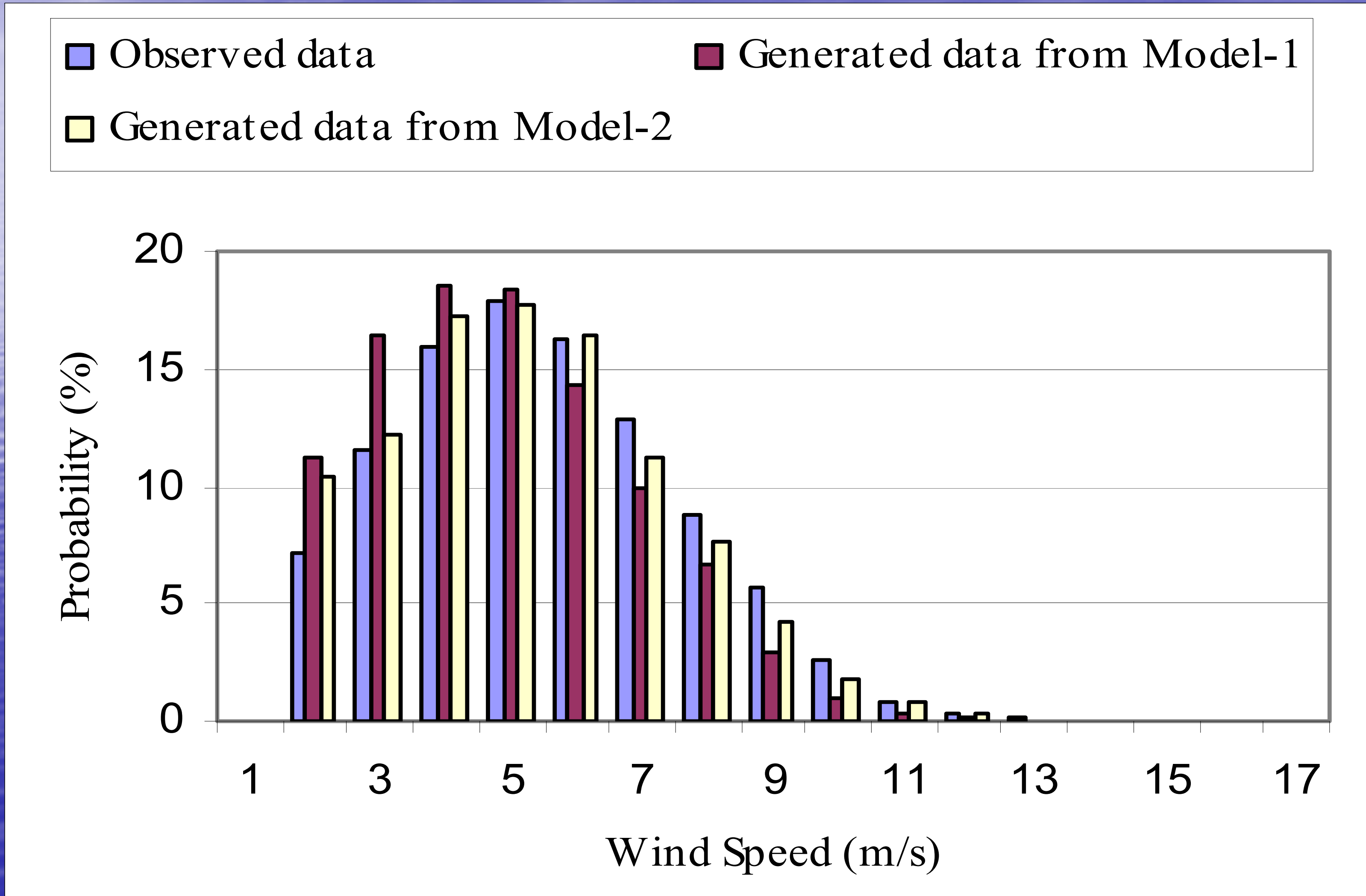
Wind Speed Modeling using Markov Approach



Wind Speed Modeling using Markov Approach

	Observed Data	Generated Data from Model-1	Generated Data from Model-2
Min	0.00	0.02	0.00
Max	12.47	11.44	12.77
Mean	3.52	3.16	3.61
Median	3.35	2.95	3.47
Std	2.11	1.91	2.02

Wind Speed Modeling using Markov Approach



Load Forecasting

- İt is of vital importance to forecast the possible load that the system will meet for proper size determination.
- Once the load forecasted, the alteration curve of energy needs must be obtained.
- In general the resulation of this curve is in hours.

Size Optimization and System Modeling

- Open the pdf File for details