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A Short Term Wind Energy Prediction System for Turkey (SWEPS)

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Abstract

World energy demand is growing rapidly with developing industries and technology. Therefore, many countries today, have started to obtain benefits from renewable energy sources. For power generation, despite the discontinuous nature of wind energy, it is widely used in the world especially in the European Union countries. Moreover, wind power production forecasts are needed due to the fact that wind energy has an increasing share in total energy production and wind power generation systems has lack of energy storage. Within the scope of this project, a short-term (0-72 h) wind energy prediction system (SWEPS) is developed by using four modules for four locations of Turkey, namely, Çanakkale, İstanbul, Balıkesir, and Manisa. These modules are consisted of mesoscale numerical weather prediction by using the Weather Research and Forecast (WRF) model, which is used to increase the resolution of wind energy field estimates of a global atmospheric model; micro scale wind energy prediction by using three diagnostic models, namely, WAsP, WindSIM, and AES RuzgarSIM; model output statistics by using artificial neural network method; and error analyses of modeled versus observation wind field and wind energy values. For four different wind farm locations, WRF model is run to produce 72 h wind field forecast for one-year period of 2010 with 1 km resolution by coupling 3 diagnostic models, the best of which has been chosen to include in SWEPS. After applying artificial neural networks, in order to determine the site-specific SWEPS configuration, the overall performances of these models are tested. As a general result, the normalized RMSE is reduced to 20% for each wind farm location.

Objectives

The main objective of this project is to develop an integrated short-term prediction model to ensure a high accuracy database for use in the decision making process of the energy authority in Turkey. The other objective of the study is to evaluate the performance of SWEPS on various topographical conditions in western Turkey, such as Canakkale, Balikesir, Manisa, and Istanbul.

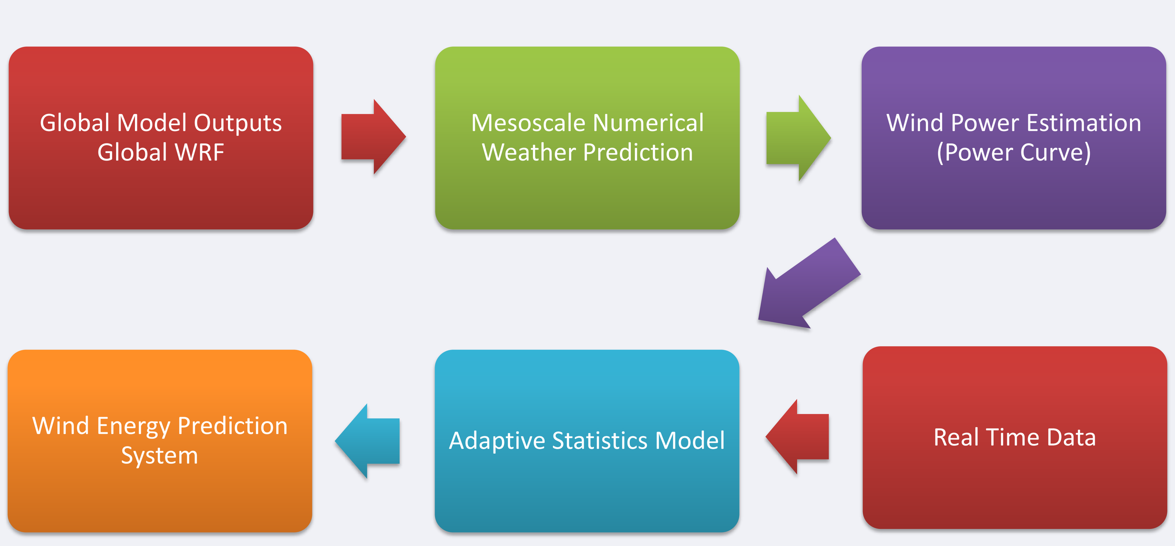

Figure 1. Short term Wind Energy Prediction System (SWEPS)

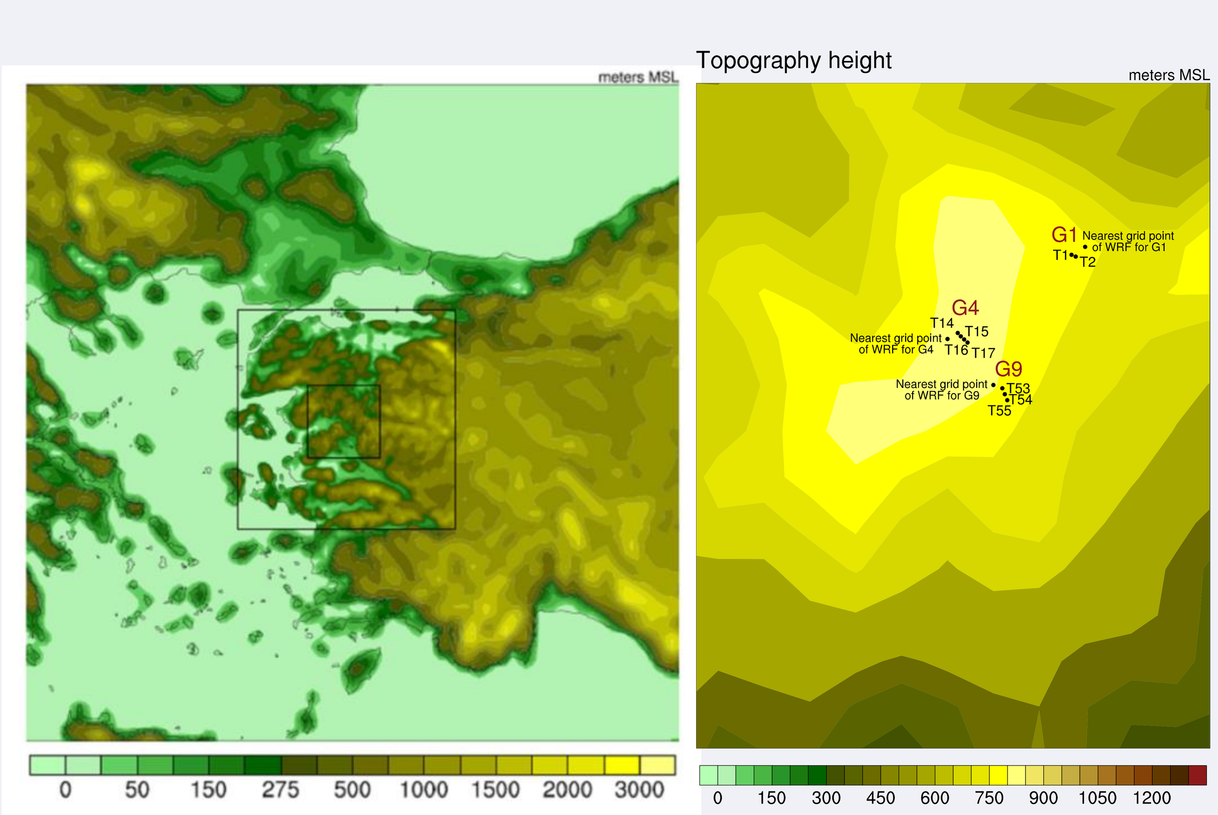

Figure 2. WRF Model Domain Configuration for Soma Region

Methods

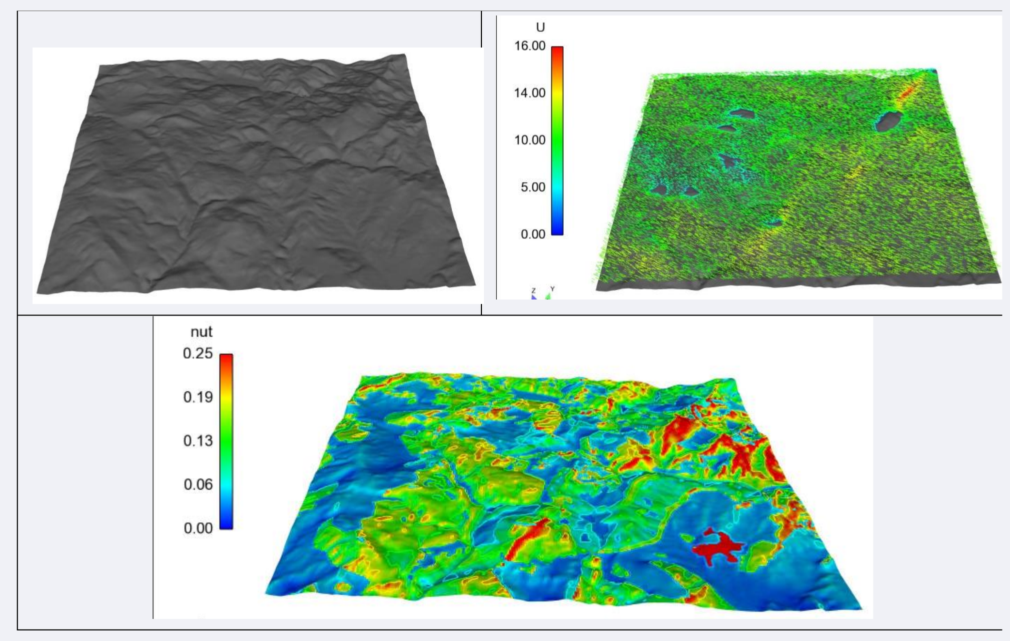

Figure 3. AES RuzgarSIM Domain Configuration for Soma Region

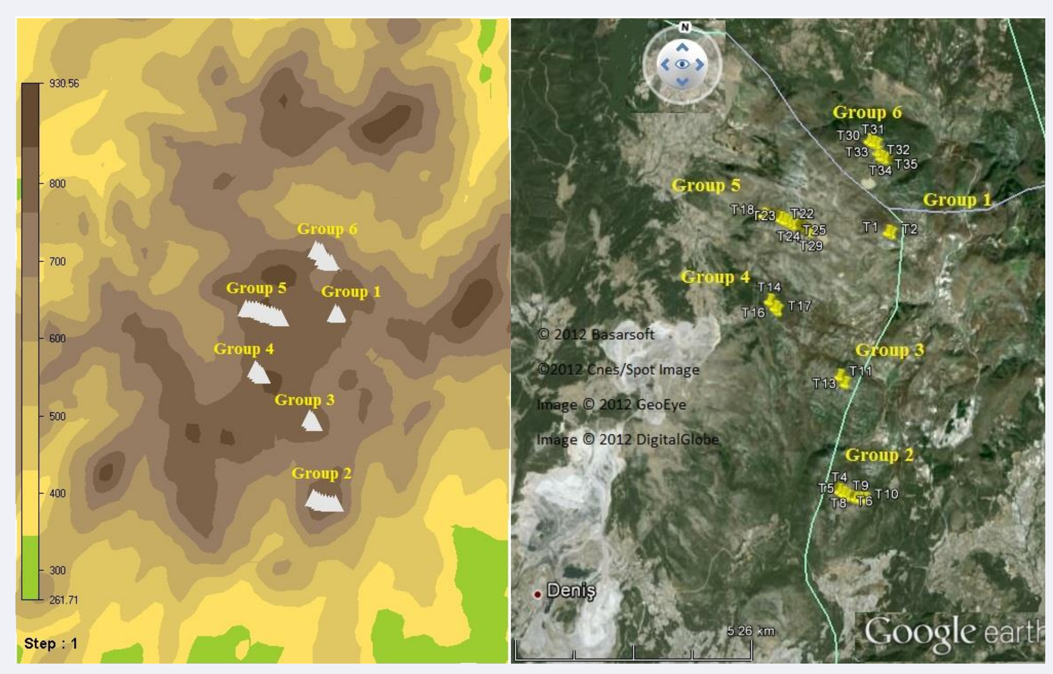

Figure 4. WindSIM Domain Configuration for Soma Region

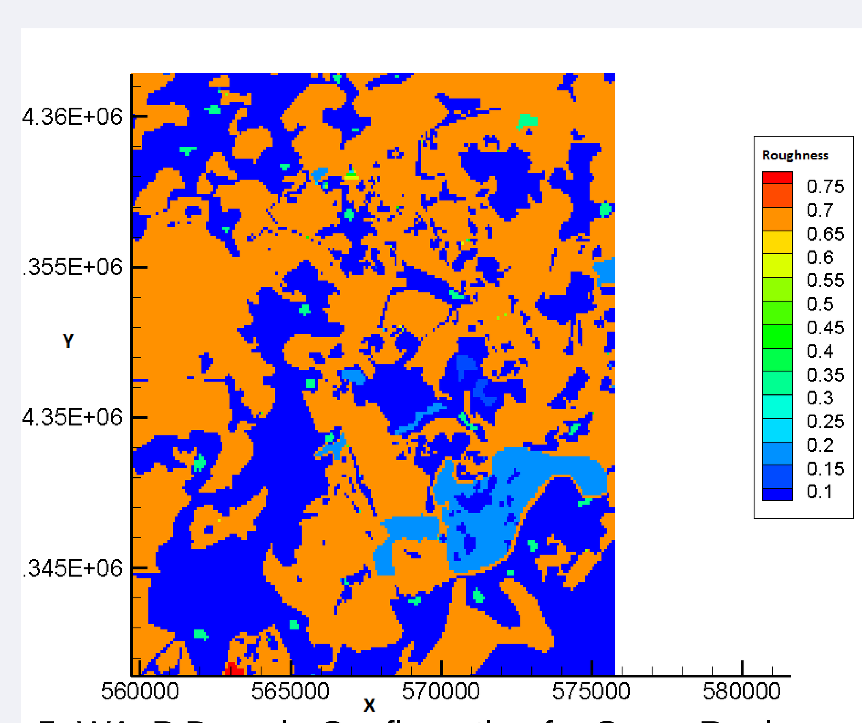

Figure 5. WAsP Domain Configuration for Soma Region

24 hourly Wind Energy Prediction Errors for Soma Wind Power Plant

Turbin ID	WRF		WAsP		WindSIM		AES-RuzgarSIM		WRF&ANN		WAsP&ANN		WindSIM&ANN		AES-RüzgarSIM&ANN	
	RMSE	NRMSE %	RMSE	NRMSE %	RMSE	NRMSE %	RMSE	NRMSE %	RMSE	NRMSE %	RMSE	NRMSE %	RMSE	NRMSE %	RMSE	NRMSE %
1	164.4	18.1	234.8	25.8	175.7	19.3	175.5	19.3	208.9	23.0	222.1	24.4	219.3	24.1	221.5	24.4
2	159.5	17.5	233.1	25.6	170.7	18.8	171.5	18.8	202.1	22.2	221.2	24.3	210.8	23.2	207.9	22.9
3	268.6	29.5	315.2	34.6	269.0	29.6	308.4	33.9	281.7	31.0	270.1	29.7	242.1	26.6	260.6	28.7
4	258.5	28.4	300.1	33.0	260.9	28.7	296.4	32.6	267.5	29.4	255.9	28.2	239.4	26.3	279.5	30.8
5	244.3	26.9	264.9	29.1	251.1	27.6	282.7	31.1	229.8	25.3	225.2	24.8	210.2	23.1	222.4	24.5
6	248.2	27.3	254.5	28.0	256.7	28.2	284.5	31.3	212.6	23.4	225.5	24.8	238.0	26.2	221.3	24.3
7	238.8	26.2	248.1	27.3	250.2	27.5	261.1	28.7	210.1	23.1	200.3	22.0	219.7	24.2	225.1	24.8
8	223.0	24.5	234.7	25.8	236.7	26.0	245.9	27.0	172.7	19.0	168.6	18.5	174.7	19.2	186.1	20.5
9	236.5	26.0	242.2	26.6	277.8	30.5	263.5	29.0	223.3	24.6	197.7	21.7	208.9	23.0	237.0	26.1
10	292.8	32.2	284.8	31.3	279.1	30.7	304.6	33.5	252.2	27.8	242.7	26.7	243.5	26.8	257.5	28.3
11	207.7	22.8	234.0	25.7	280.2	30.8	213.8	23.5	205.1	22.6	205.5	22.6	224.9	24.7	206.0	22.7
12	198.3	21.8	235.4	25.9	283.1	31.1	209.3	23.0	195.4	21.5	199.5	21.9	212.3	23.4	194.7	21.4
13	210.0	23.1	249.9	27.5	219.5	24.1	221.1	24.3	204.8	22.5	205.0	22.5	208.0	22.9	208.5	22.9
14	169.8	18.7	260.2	28.6	203.1	22.3	202.8	22.3	184.8	20.3	213.0	23.4	191.8	21.1	181.4	20.0
15	170.1	18.7	253.1	27.8	190.5	20.9	199.4	21.9	178.0	19.6	205.7	22.6	184.6	20.3	179.6	19.7
16	174.7	19.2	242.5	26.6	192.5	21.2	191.9	21.1	186.8	20.5	209.2	23.0	198.6	21.8	186.1	20.5
17	178.8	19.7	242.5	26.6	181.7	20.0	193.3	21.2	199.5	21.9	222.2	24.4	207.5	22.8	204.3	22.5
18	183.2	20.1	236.6	26.0	185.4	20.4	253.1	27.8	186.9	20.6	217.5	23.9	198.4	21.8	189.4	20.8
19	192.8	21.2	236.6	26.0	214.8	23.6	239.9	26.4	183.2	20.1	190.0	20.9	205.1	22.5	179.0	19.7
20	194.0	21.3	236.9	26.0	244.2	26.8	227.8	25.0	185.7	20.4	205.7	22.6	211.5	23.3	195.5	21.5
21	216.1	23.8	244.5	26.9	288.4	31.7	208.3	22.9	197.1	21.7	218.0	24.0	260.5	28.7	211.3	23.3
22	220.4	24.2	249.7	27.4	299.2	32.9	210.5	23.1	205.9	22.6	221.1	24.3	283.6	31.2	233.5	25.7
23	231.2	25.4	269.3	29.6	294.2	32.3	219.6	24.1	232.9	25.6	249.6	27.5	293.4	32.3	244.0	26.8
24	236.9	26.0	277.9	30.5	364.3	40.0	268.9	29.6	199.4	22.0	232.8	25.7	239.2	26.4	222.5	24.5
25	229.7	25.2	277.8	30.5	351.4	38.6	258.4	28.4	198.0	21.8	233.5	25.8	219.7	24.2	215.7	23.8
26	232.3	25.5	285.2	31.3	331.8	36.5	248.7	27.3	165.6	18.2	225.7	24.8	195.1	21.5	172.7	19.0
27	227.4	25.0	290.2	31.9	293.3	32.2	236.3	26.0	196.5	21.6	243.4	26.8	240.9	26.5	197.8	21.8
28	228.2	25.1	305.4	33.6	291.0	32.0	227.9	25.0	169.2	18.6	246.3	27.1	221.3	24.3	177.4	19.5
29	249.1	27.4	345.1	37.9	275.8	30.3	222.3	24.4	169.9	18.7	262.2	28.8	215.2	23.7	172.3	18.9
30	213.4	23.5	277.1	30.4	231.3	25.4	223.3	24.5	165.7	18.2	186.1	20.5	175.2	19.3	170.6	18.8
31	219.0	24.1	281.2	30.9	250.5	27.5	226.3	24.9	166.0	18.3	204.1	22.5	188.7	20.8	175.0	19.3
32	227.7	25.0	291.2	32.0	252.3	27.7	231.9	25.5	202.8	22.3	230.2	25.3	208.3	22.9	205.3	22.6
33	261.8	28.8	316.1	34.7	296.2	32.6	281.6	30.9	205.1	22.6	226.5	24.9	224.2	24.6	202.4	22.3
34	281.1	30.9	334.4	36.7	338.6	37.2	327.4	36.0	218.8	24.1	239.3	26.3	243.9	26.8	224.4	24.7
35	274.8	30.2	332.9	36.6	329.5	36.2	321.6	35.3	212.7	23.4	252.6	27.8	255.8	28.1	230.9	25.4
36	250.5	27.5	307.0	33.7	252.8	27.8	270.1	29.7	205.8	22.6	232.8	25.6	198.3	21.8	193.0	21.2
37	267.1	29.3	306.7	33.7	262.5	28.8	251.1	27.6	213.0	23.4	235.3	25.9	218.8	24.1	194.0	21.3
38	267.4	29.4	301.2	33.1	263.9	29.0	257.0	28.2	223.7	24.6	235.2	25.9	200.0	22.0	200.3	22.0
39	225.4	24.8	286.9	31.5	222.1	24.4	200.5	22.0	173.8	19.1	208.5	22.9	179.2	19.7	167.7	18.4
40	223.5	24.6	278.3	30.6	225.2	24.7	221.9	24.4	170.5	18.8	203.1	22.3	170.8	18.8	166.9	18.4
41	243.7	26.8	298.0	32.8	244.2	26.8	236.0	25.9	257.6	28.3	268.5	29.5	252.0	27.7	255.4	28.1
42	236.2	26.0	287.4	31.6	235.4	25.9	224.4	24.7	233.2	25.6	246.1	27.1	225.6	24.8	232.6	25.6
43	271.5	29.8	313.1	34.4	271.4	29.8	250.0	27.5	205.7	22.6	241.3	26.5	191.6	21.1	179.3	19.7
44	271.7	29.9	307.5	33.8	277.2	30.5	255.7	28.1	234.9	25.9	238.3	26.2	236.8	26.1	234.3	25.8
45	200.3	22.0	216.5	23.8	199.5	21.9	219.8	24.2	202.9	22.3	210.6	23.2	202.9	22.3	202.9	22.3
46	203.3	22.3	211.8	23.3	260.7	28.7	208.3	22.9	166.5	18.3	187.0	20.6	195.6	21.5	167.3	18.4
47	220.1	24.2	222.2	24.4	242.7	26.7	212.4	23.3	175.4	19.3	192.0	21.2	198.3	21.8	180.2	19.9
48	247.4	27.2	230.6	25.3	229.5	25.2	285.2	31.3	194.1	21.4	185.3	20.4	196.1	21.6	190.4	21.0
49	235.7	25.9	214.0	23.5	222.7	24.5	225.9	24.8	199.2	21.9	193.5	21.3	210.9	23.2	212.9	23.4
50	224.0	24.6	225.9	24.8	218.8	24.0	223.8	24.6	178.2	19.6	186.1	20.5	185.1	20.4	181.4	20.0
Ort	227.0	24.9	268.5	29.5	254.8	28.0	240.0	26.4	202.2	22.2	220.8	24.3	215.5	23.7	205.1	22.6

Results

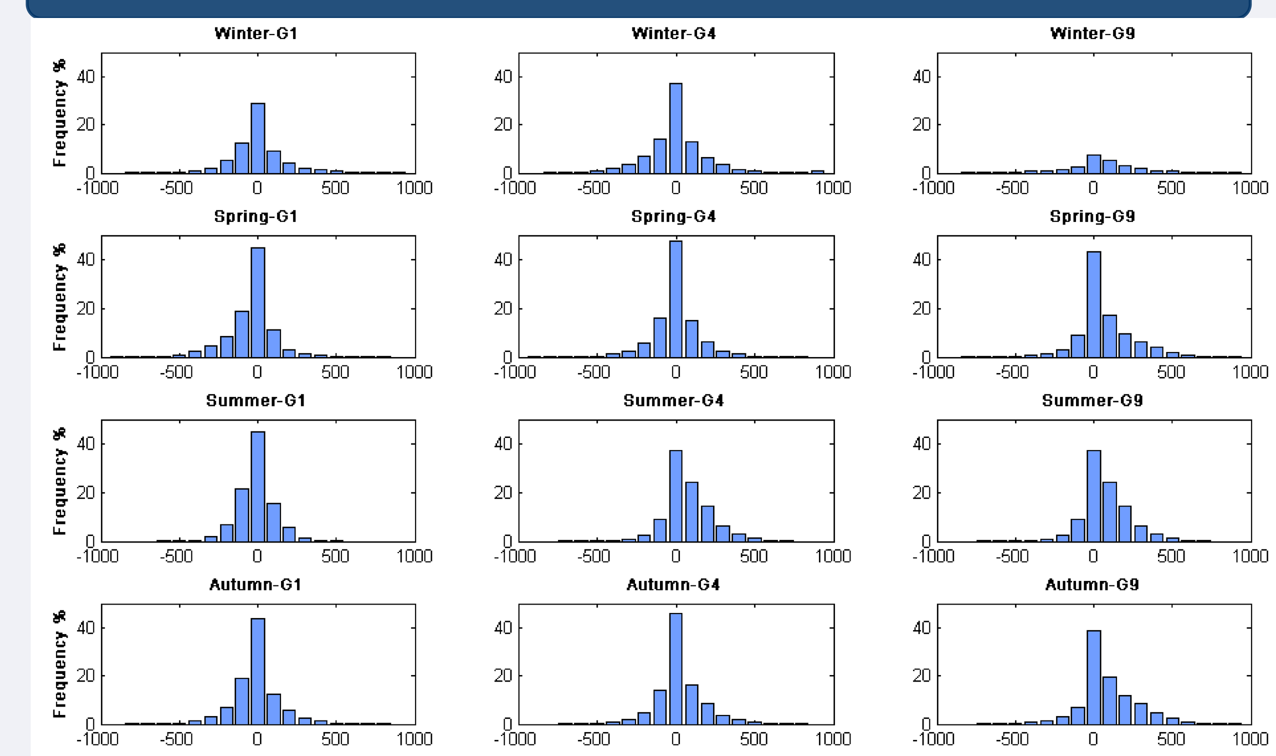

Figure 6. The frequency distribution of wind power absolute errors between WRF based wind power and actual wind power for each turbine groups and each season during the first 24 hourly simulation period (0-24hr).

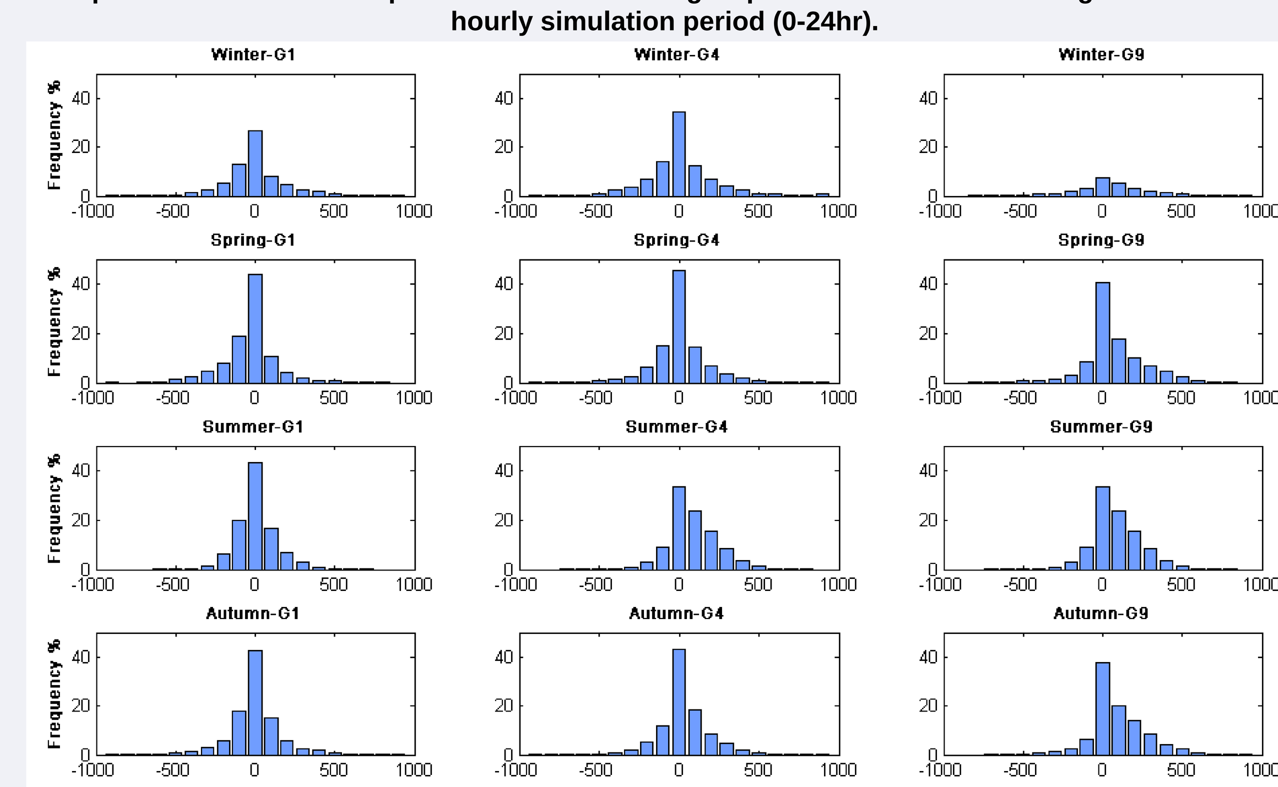

Figure 7. The frequency distribution of wind power absolute errors between WRF based wind power and actual wind power for each turbine groups and each season during the second 24 hourly simulation period (24-48hr).

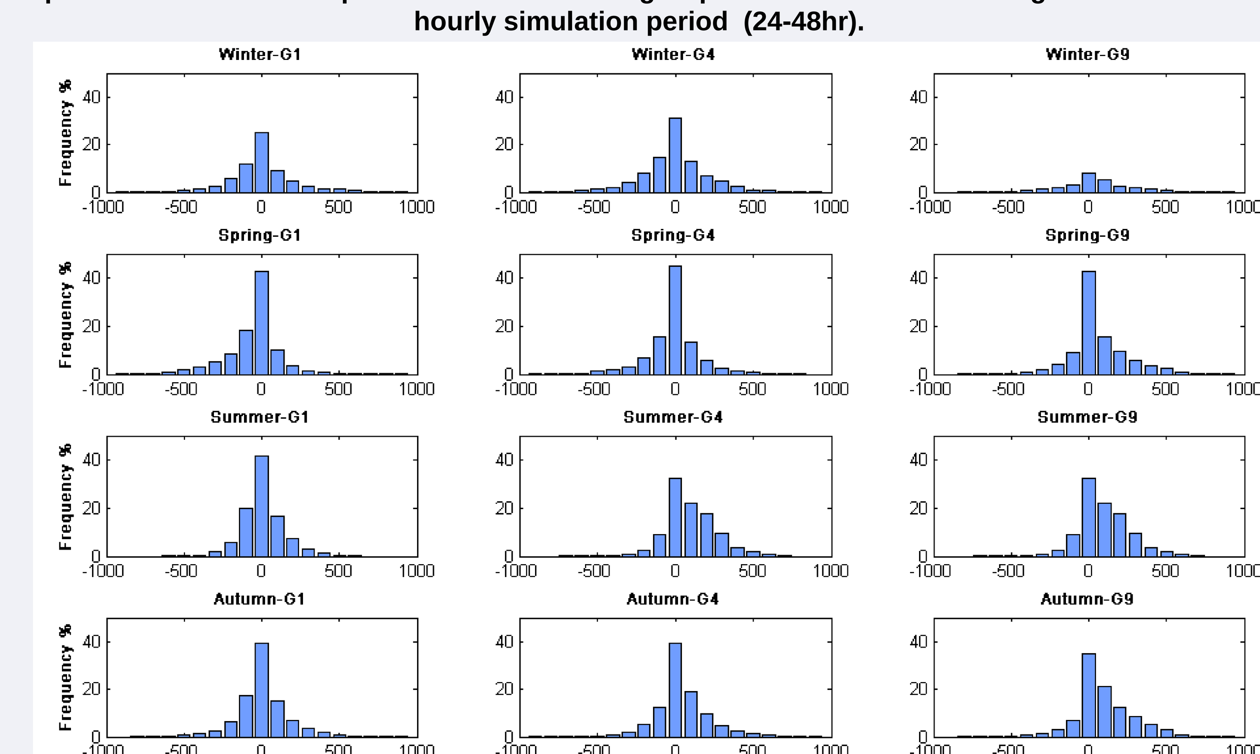

Figure 8. The frequency distribution of wind power absolute errors between WRF based wind power and actual wind power for each turbine groups and each season during the third 24 hourly simulation period (48-72hr).

Conclusions

Within the scope of this project, a short-term (0-72 h) wind energy prediction system (SWEPS) is developed by using four modules for four locations of Turkey, namely, Çanakkale, İstanbul, Balıkesir, and Manisa. These modules are consisted of mesoscale numerical weather prediction by using the Weather Research and Forecast (WRF) model, which is used to increase the resolution of wind energy field estimates of a global atmospheric model; micro scale wind energy prediction by using three diagnostic models, namely, WAsP, WindSIM, and AES RuzgarSIM; model output statistics by using artificial neural network method; and error analyses of modeled versus observation wind field and wind energy values.

References

Mentes S., Tan E., Unal E., Unal Y.S., Barutcu B., Efe B., Ozdemir E.T., Onol B., and Incecik S., The Development of a Short Term Wind Energy Forecast System (SWEPS) in Manisa, Turkey by using the WRF Model, Submitted to Renewable Energy.

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