

Wind Capacity Meeting

January 17, 2008



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Goals

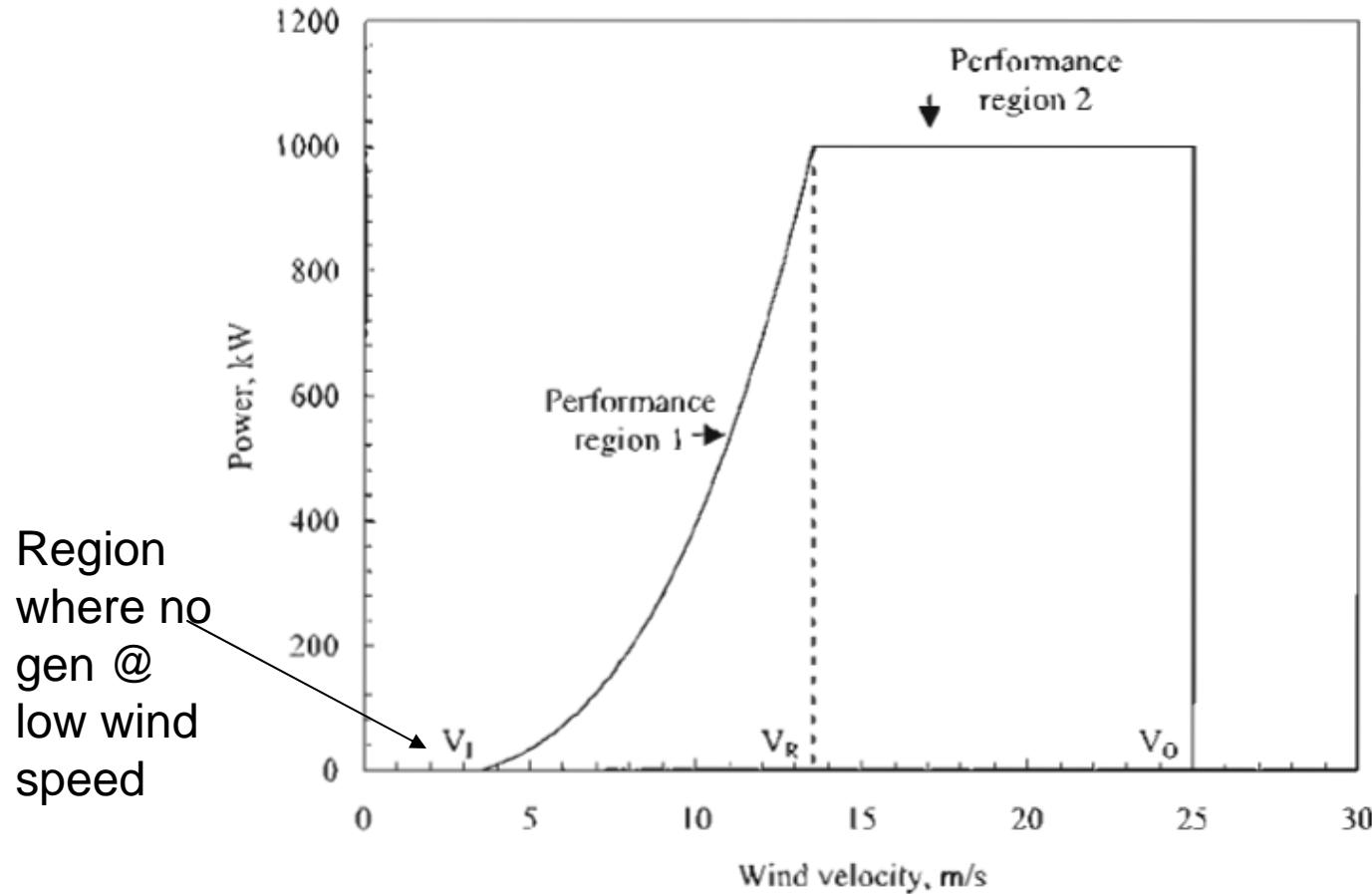
- Develop a “simulated” wind generation database by hour by year for a historical record who’s generation level represents current operating and current construction
- Compare wind data base to load “events” data base for normal and extreme conditions to develop capacity factor
- Wind database can be used in hourly production simulation modeling similar to a hydro year record on an hourly basis

General Methodology

- Develop econometric model from recent data that can be applied for desired historical period
- Apply Econometric Model to Historical Data to develop “back-casted generation”
- Econometric Model:
 - Utilize Power Curve Functional Form (See next page)
 - Wind Generation is dependent variable as a function of wind speed (standard econometric approach, (1))
 - Wind Generation = Function[Wind Speed @ lags/leads, and other dummies]
 - Estimate on recent data (Gen Data only back 4 years at most)
 - Utilize NOAA site data that is as close to generation sites & long history
 - Temperature not considered
 - Recognize “regions” of power curve by 4th degree polynomial
- Econometric Model Flaws
 - Model Period estimated on may be too short to reflect “full” wind generation distribution
 - Econometric models by their nature have errors & explain only so much variation in dependent variable (R-square)
 - “Y Intercept” is critical
- Econometric Model Advantage
 - Measures direct relationship between Generation and usable historical wind
 - Leverages actual historical wind using recognized approach

(1)“Wind Energy” by Sathyajith Mathew, 2006, Springer: Chapter 5 has discussion of econometric methodology approach, Also see standard econometric texts (Maddala, Intriligator, Johnston, Pindyck & Rubenfield) as a reference on $Y = F[X]$ for a discussion of functional form specification & estimation

Power Curve Example Theoretical



Power Curve From “Wind Energy” by Sathyajith Mathew, 2006, Springer: Chapter 5 has discussion of econometric methodology approach

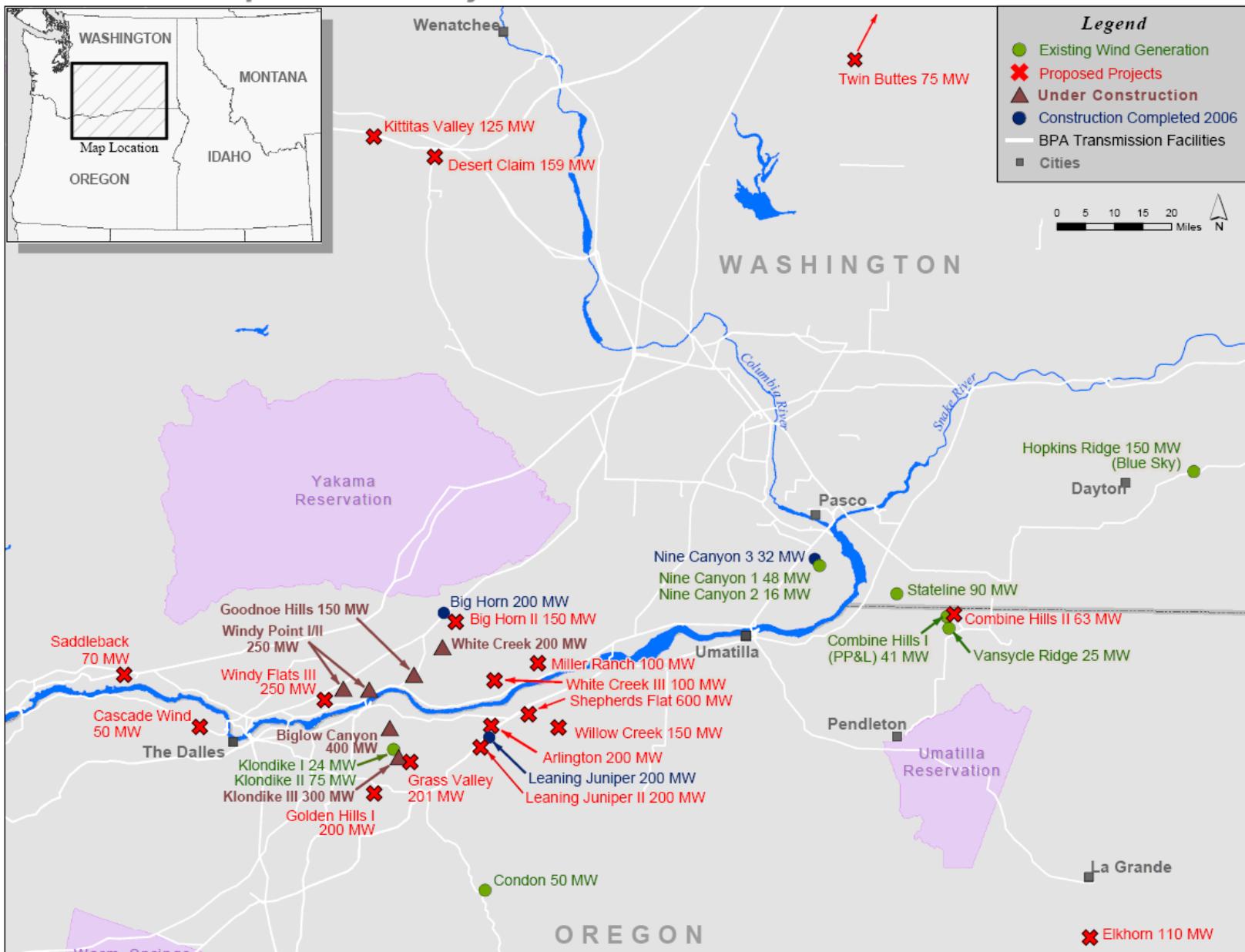
Specific Methodology

- Pendleton Hourly (Wind Speed/Wind Direction) **back to 1938**
- Use Pendleton for ease: Use Pendleton for Gorge (80% of NW wind) to develop back-cast model
- Develop Econometric East Gorge, West Gorge Model (table on page 6) “East Gorge”/”West Gorge” my definition
- Use Non-Gorge forty year hourly data from utility
- Look at annual wind to map simulated years to missing years
- Database backcast & Compare to “System Events”

Econometric Model Data: East Gorge /West Gorge

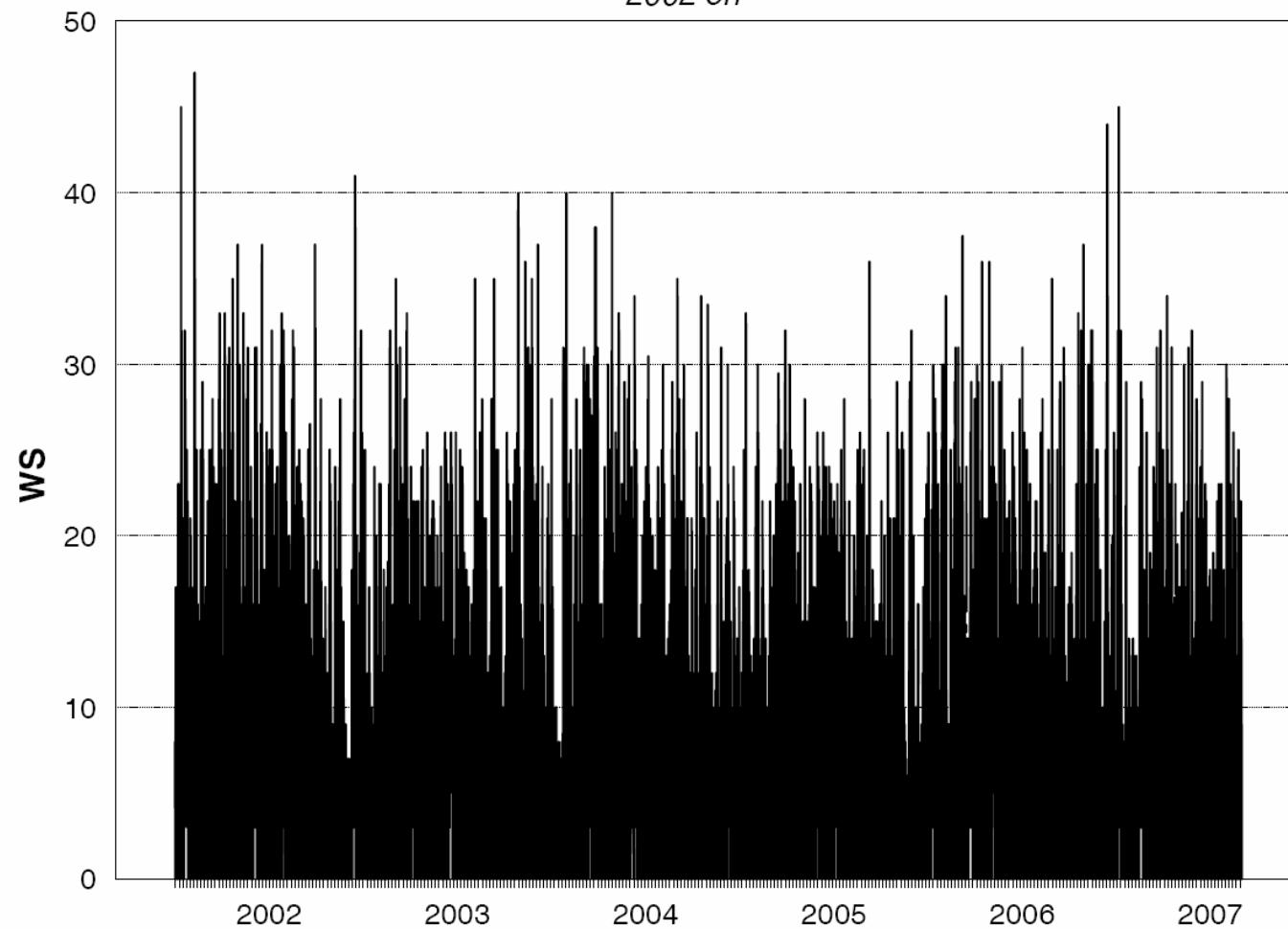
East Gorge	Vansycle	24.9
East Gorge	Stateline	300
East Gorge	Hopkins Ridge	150
West Gorge	Big Horn	199.5
West Gorge	Condon	49.8
West Gorge	Goodnoe Hills	150
West Gorge	Klondike I	24
West Gorge	Klondike II	75
West Gorge	Leaning Juniper	100.5

Current and Proposed Wind Project Interconnections to BPA Transmission Facilities



Pendleton Wind Speed

2002 on



Hourly Wind Speed in Miles per Hour 2002 to 2007

East Gorge Econometric Analysis Example

- Relationship of Wind generation from East Gorge/West Gorge to Pendleton Wind Speed/Direction.
- Generation is Net generation
- Wind is in Miles per Hour
- Standard Functional Form: Y axis is dependent variable; X axis is explanatory variable; Wind Gen = F[WS & other]; $Y = F[x]$
- Econometric model
 - Lead/lag of wind speed
 - Estimated over limited period utilizing Regression Analysis & Time Series (RATS) Package
 - RATS utilized by Federal Reserve

East Gorge Econometric Model (RATS Output)

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Linear Regression - Estimation by Least Squares

Dependent Variable WINDGEN

24/Day of Daily(7) Data From 2005:11:25//01 To 2007:08:05//24

Usable Observations 10115 Degrees of Freedom 10043

Total Observations 14856 Skipped/Missing 4741

Centered R**2 0.521243 R Bar **2 0.517859

Uncentered R**2 0.733114 T x R**2 7415.445

Mean of Dependent Variable 130.87157005

Std Error of Dependent Variable 146.89085250

Standard Error of Estimate 101.99572797

Sum of Squared Residuals 104478619.77

Log Likelihood -61097.61088

96 explanatory Variables

WS = Wind Speed

Lags {#}, Leads {-#}

4th degree Polynomial:

SQR WS**2,CUBE WS**3, QUAD WS**4

Monthly & Operational Dummy Variable

No Constant, Constrain to Non Zero & Below Max

East Gorge Econometric Model (RATS Output)

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Variable	Coeffient	Std Error	T-Stat	Significance
*****	*****	*****	*****	*****
1. WINDSPD{-1}	1.88322917	0.27836414	6.76534	0.00000000
2. WINDSPD{4}	-1.23916121	1.32641391	-0.93422	0.35021335
3. WINDSPD{5}	-2.48025232	1.40420165	-1.76631	0.07737460
4. WINDSPD{6}	-1.98468074	1.39743682	-1.42023	0.15557197
5. WINDSPD{7}	-2.66932149	1.39447354	-1.91421	0.05562114
6. WINDSPD{8}	-2.66406210	1.39844463	-1.90502	0.05680628
7. WINDSPD{9}	-2.70117659	1.40080320	-1.92831	0.05384529
8. WINDSPD{10}	-3.51046509	1.32186866	-2.65568	0.00792728
9. WSSQR{-10}	0.38324730	0.07066932	5.42311	0.00000006
10. WSSQR{-9}	0.20075953	0.07946943	2.52625	0.01154403
11. WSSQR{-8}	0.18646288	0.07966843	2.34049	0.01927811
12. WSSQR{-7}	0.19478156	0.07959110	2.44728	0.01441098
13. WSSQR{-6}	0.18062084	0.07966662	2.26721	0.02339864
14. WSSQR{-5}	0.15800190	0.07937484	1.99058	0.04655422
15. WSSQR{-4}	0.18155493	0.07913232	2.29432	0.02179261
16. WSSQR{-3}	0.27203301	0.07143610	3.80806	0.00014089
17. WSSQR{1}	0.26078984	0.03436855	7.58804	0.00000000
18. WSSQR{2}	0.19621870	0.03875818	5.06264	0.00000042
19. WSSQR{3}	0.13664503	0.07373575	1.85317	0.06388700
20. WSSQR{4}	0.31510912	0.18878771	1.66912	0.09512500
21. WSSQR{5}	0.52380097	0.19821111	2.64264	0.00823896
22. WSSQR{6}	0.43022495	0.19739043	2.17956	0.02931299
23. WSSQR{7}	0.56897391	0.19731366	2.88360	0.00393991

East Gorge Econometric Model (RATS Output)

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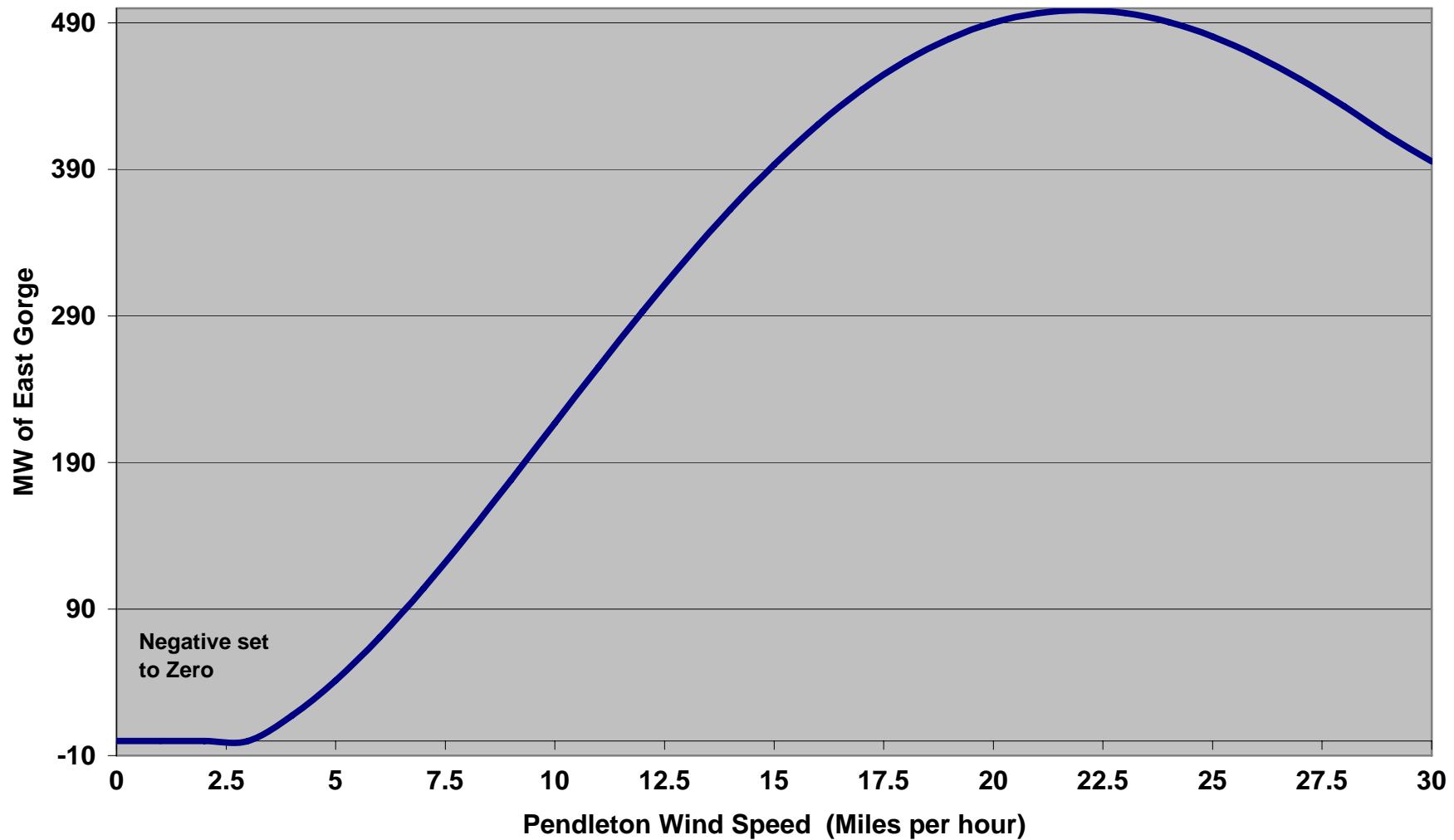
Variable	Coeffient	Std Error	T-Stat	Significance
24. WSSQR{8}	0.58261376	0.19750971	2.94980	0.00318715
25. WSSQR{9}	0.59849269	0.19754517	3.02965	0.00245460
26. WSSQR{10}	0.91614256	0.18215555	5.02945	0.00000050
27. WSCUBE{-10}	-0.01742424	0.00491042	-3.54842	0.00038932
28. WSCUBE{-9}	-0.01096019	0.00546077	-2.00708	0.04476805
29. WSCUBE{-8}	-0.00966379	0.00547267	-1.76583	0.07745540
30. WSCUBE{-7}	-0.01075525	0.00545696	-1.97093	0.04875980
31. WSCUBE{-6}	-0.01026497	0.00546170	-1.87945	0.06021253
32. WSCUBE{-5}	-0.00884320	0.00543360	-1.62750	0.10366150
33. WSCUBE{-4}	-0.00976939	0.00543442	-1.79769	0.07225638
34. WSCUBE{-3}	-0.01286016	0.00490198	-2.62346	0.00871732
35. WSCUBE{1}	-0.00733928	0.00111995	-6.55320	0.00000000
36. WSCUBE{2}	-0.00518658	0.00126912	-4.08675	0.00004409
37. WSCUBE{3}	-0.00346814	0.00497631	-0.69693	0.48586293
38. WSCUBE{4}	-0.01299352	0.00912882	-1.42335	0.15466523
39. WSCUBE{5}	-0.02315496	0.00946627	-2.44605	0.01446024
40. WSCUBE{6}	-0.01917402	0.00942527	-2.03432	0.04194556
41. WSCUBE{7}	-0.02560230	0.00942219	-2.71723	0.00659427
42. WSCUBE{8}	-0.02666749	0.00942437	-2.82963	0.00466940
43. WSCUBE{9}	-0.02792574	0.00943151	-2.96090	0.00307460
44. WSCUBE{10}	-0.04379142	0.00864921	-5.06306	0.00000042
45. WSQUAD{-10}	0.00022095	0.00008653	2.55354	0.01067794
46. WSQUAD{-9}	0.00016120	0.00009546	1.68867	0.09131331
47. WSQUAD{-8}	0.00013378	0.00009560	1.39943	0.16171522
48. WSQUAD{-7}	0.00015461	0.00009537	1.62106	0.10503578

East Gorge Econometric Model (RATS Output)

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Variable	Coeffient	Std Error	T-Stat	Significance
49. WSQUAD{-6}	0.00015715	0.00009545	1.64637	0.09971801
50. WSQUAD{-5}	0.00014087	0.00009499	1.48297	0.13811496
51. WSQUAD{-4}	0.00013582	0.00009510	1.42819	0.15326829
52. WSQUAD{-3}	0.00014714	0.00008619	1.70725	0.08780586
53. WSQUAD{3}	-0.00001672	0.00008679	-0.19264	0.84724183
54. WSQUAD{4}	0.00014966	0.00013567	1.10315	0.26998913
55. WSQUAD{5}	0.00029221	0.00013915	2.09997	0.03575645
56. WSQUAD{6}	0.00024260	0.00013868	1.74936	0.08025971
57. WSQUAD{7}	0.00033765	0.00013866	2.43505	0.01490694
58. WSQUAD{8}	0.00035552	0.00013865	2.56413	0.01035791
59. WSQUAD{9}	0.00038110	0.00013884	2.74494	0.00606288
60. WSQUAD{10}	0.00060693	0.00012777	4.75012	0.00000206
61. JAN	-6.19964554	4.61610653	-1.34305	0.17928728
62. FEB	2.30963705	5.20965891	0.44334	0.65753120
63. MAR	-27.37952625	4.98411222	-5.49336	0.00000004
64. APR	-42.31061215	4.62663246	-9.14501	0.00000000
65. MAY	-46.63037363	4.74608587	-9.82502	0.00000000
66. JUN	-31.15365233	4.71192432	-6.61166	0.00000000
67. JUL	-43.42111753	4.58879031	-9.46243	0.00000000
68. AUG	-70.43212156	5.92752483	-11.88221	0.00000000
69. SEP	-55.89027407	5.54840012	-10.07322	0.00000000
70. OCT	-48.66876236	5.24617584	-9.27700	0.00000000
71. NOV	3.35399073	5.37860282	0.62358	0.53291742
72. DUM1	-27.56780839	3.53321562	-7.80247	0.00000000

East Gorge Model January Summary
Lead/Lag Model at single wind speed for 24 hours



East Gorge Back-cast Examples

- Graphs at end of Handout
- East Gorge Backcast using Pendleton Wind Speed (WS) back to 1938
 - Some NOAA data problems (43-44 no data)
- Wind Generation (WG) Max is 500
- Database results & Use
- Graphs labeled WG represent Wind Generation on Y axis in MW for East Gorge Model

Total NW Wind Projects by Backcast Area

Location	Name	MW	Total	
East Gorge	Combine Hills I	41.0		
East Gorge	Elkhorn	100.0		
East Gorge	Hopkins Ridge	150.0		
East Gorge	Nine Canyon	63.7		
East Gorge	Stateline	300.0		
East Gorge	Vansycle	24.9	679.6	28%
West Gorge	Big Horn	200		
West Gorge	Biglow Canyon Ph I	125		
West Gorge	Condon	50		
West Gorge	Goodnoe Hills Small	0		
West Gorge	Goodnoe Hills	94		
West Gorge	Klondike I	24		
West Gorge	Klondike II	75		
West Gorge	Klondike III	221		
West Gorge	Leaning Juniper	101		
West Gorge	Marengo I	140		
West Gorge	White Creek	205	1,235	51%
Outside Gorge	Foote Creek 1	41.4		
Outside Gorge	Foote Creek 2	1.8		
Outside Gorge	Foote Creek 4	16.8		
Outside Gorge	Fossil Gulch	10.5		
Outside Gorge	Golden Valley	10.5		
Outside Gorge	Horseshoe Bend	9.0		
Outside Gorge	Judith Gap	135.0		
Outside Gorge	Lewandowski Farms	0.2		
Outside Gorge	Martinsdale (Two Dot)	2.8		
Outside Gorge	Two Dot	0.9		
Outside Gorge	Wild Horse Wind	228.6		
Outside Gorge	Wolverine Creek	65	522	21%
		1,914	2,436	100%

BPA Event Analysis: Backcast Econometric

Summary of BPA Events Analysis by Backcasted Area

Start	Finish	East Gorge Ave MW	West Gorge Ave MW	Total Gorge Ave MW	Outside Gorge Ave MW	Total System Ave MW
1/12/2007	1/14/2007	2	9	12	NA	NA
11/27/2006	11/29/2006	135	167	302	251	552
12/14/2005	12/16/2005	0	24	24	172	196
1/5/2004	1/7/2004	2	90	92	159	251
12/11/2000	12/13/2000	115	203	318	17	335
12/21/1998	12/23/1998	69	143	211	119	330
1/31/1996	2/2/1996	54	120	175	40	215
12/21/1990	12/23/1990	93	172	265	208	473
2/1/1989	2/3/1989	258	407	666	231	897
Event Average		81	148	229	149	406
Peak Capability MW		679	1235.0	1914.0	522.0	2436.0
Capacity Factor		11.9%	12.0%	12.0%	28.6%	16.7%

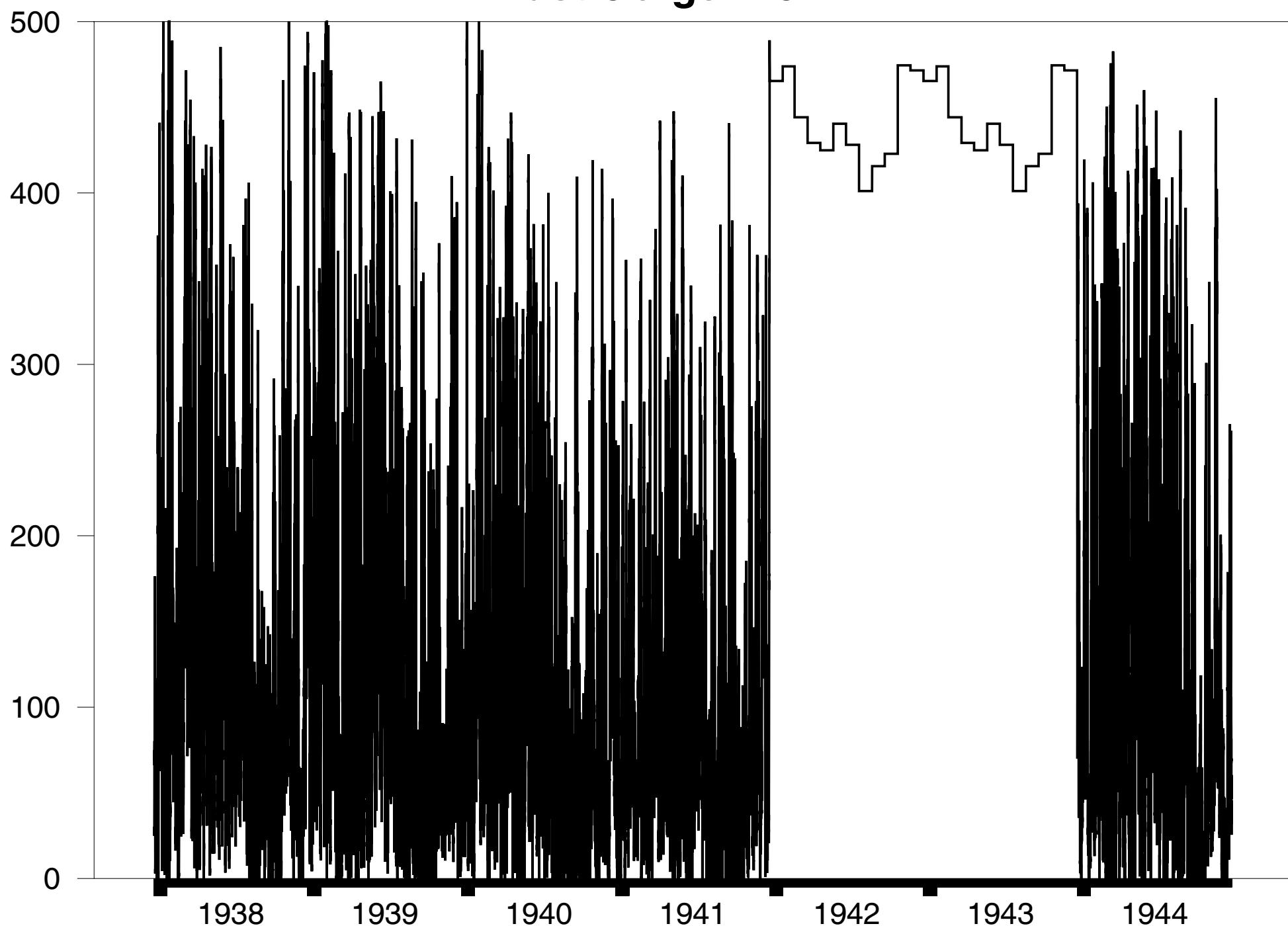
Final Thoughts

- Regional Diversity Matters
- Outside Gorge is Limited Analysis & Highly Individual
- Events can also matter
- Low End of Power Curve is crucial
- Removing negative constraint may move capacity factor down 1-2%
- Capacity while important is usually on average about 20% of total system cost: Energy matter much more
- Higher Ancillary Service still need to balance
-

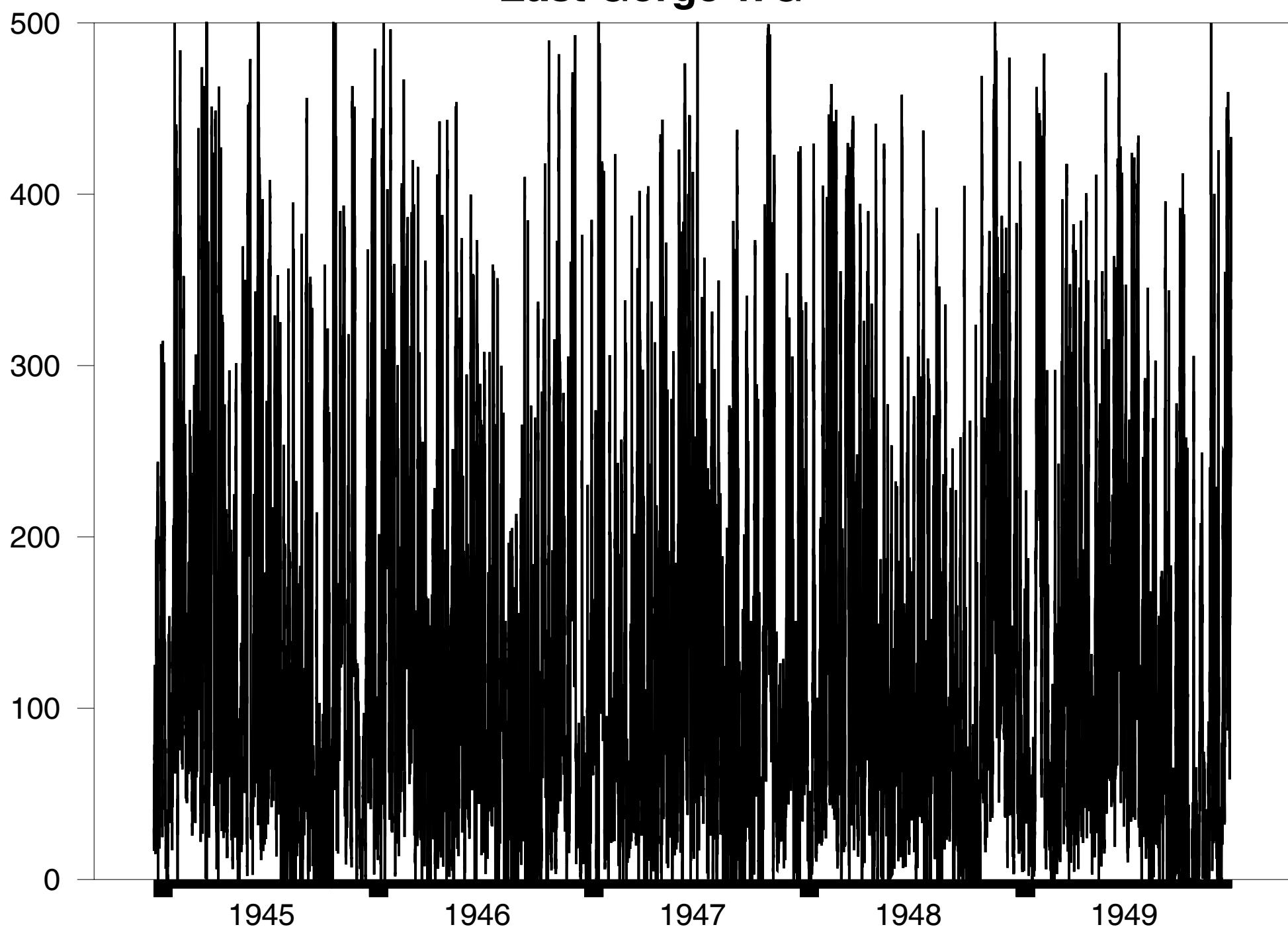
Backcast Graphs

- Graphs labeled WG represent Wind Generation on Y axis in MW for East Gorge Model

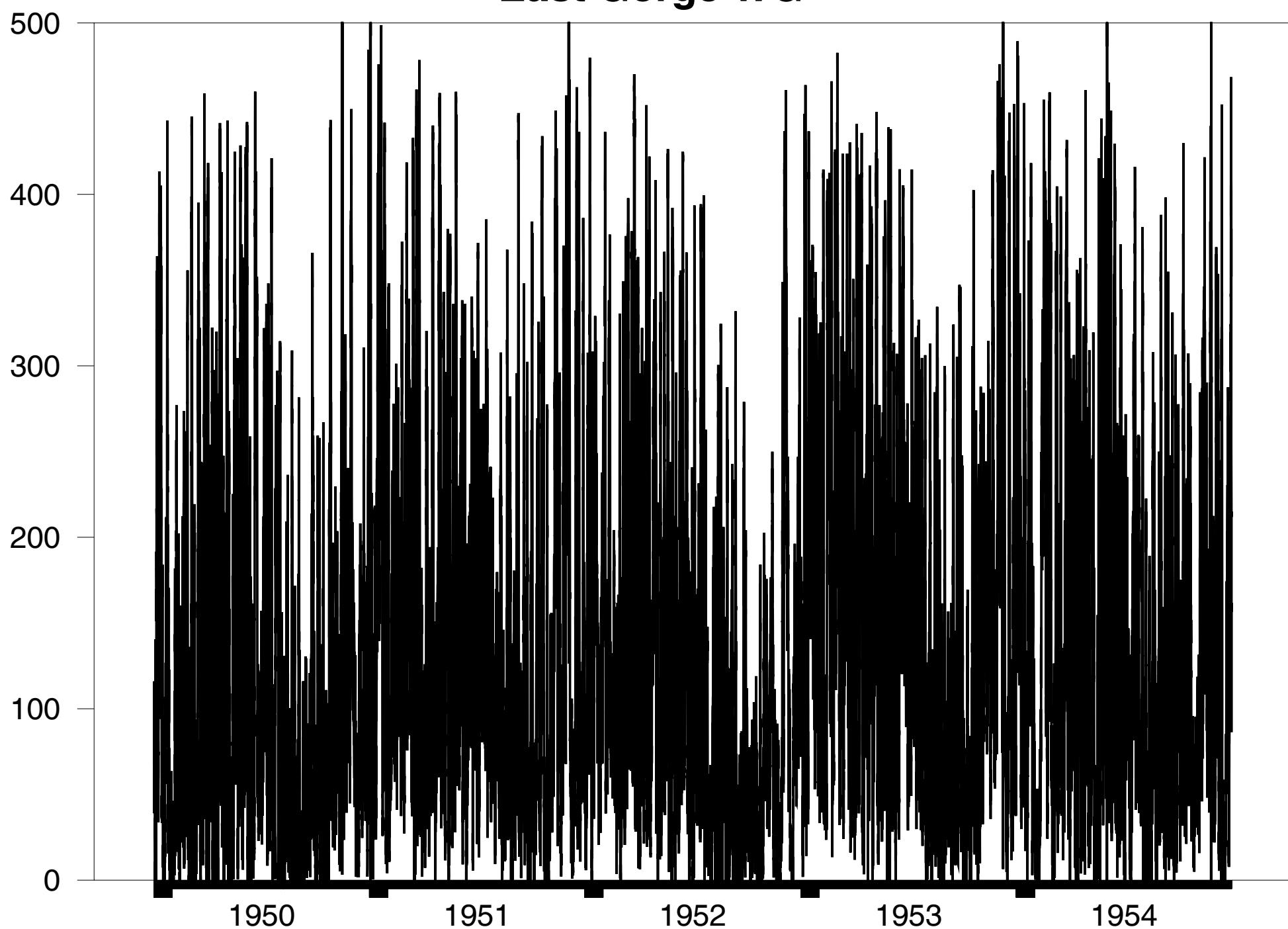
East Gorge WG



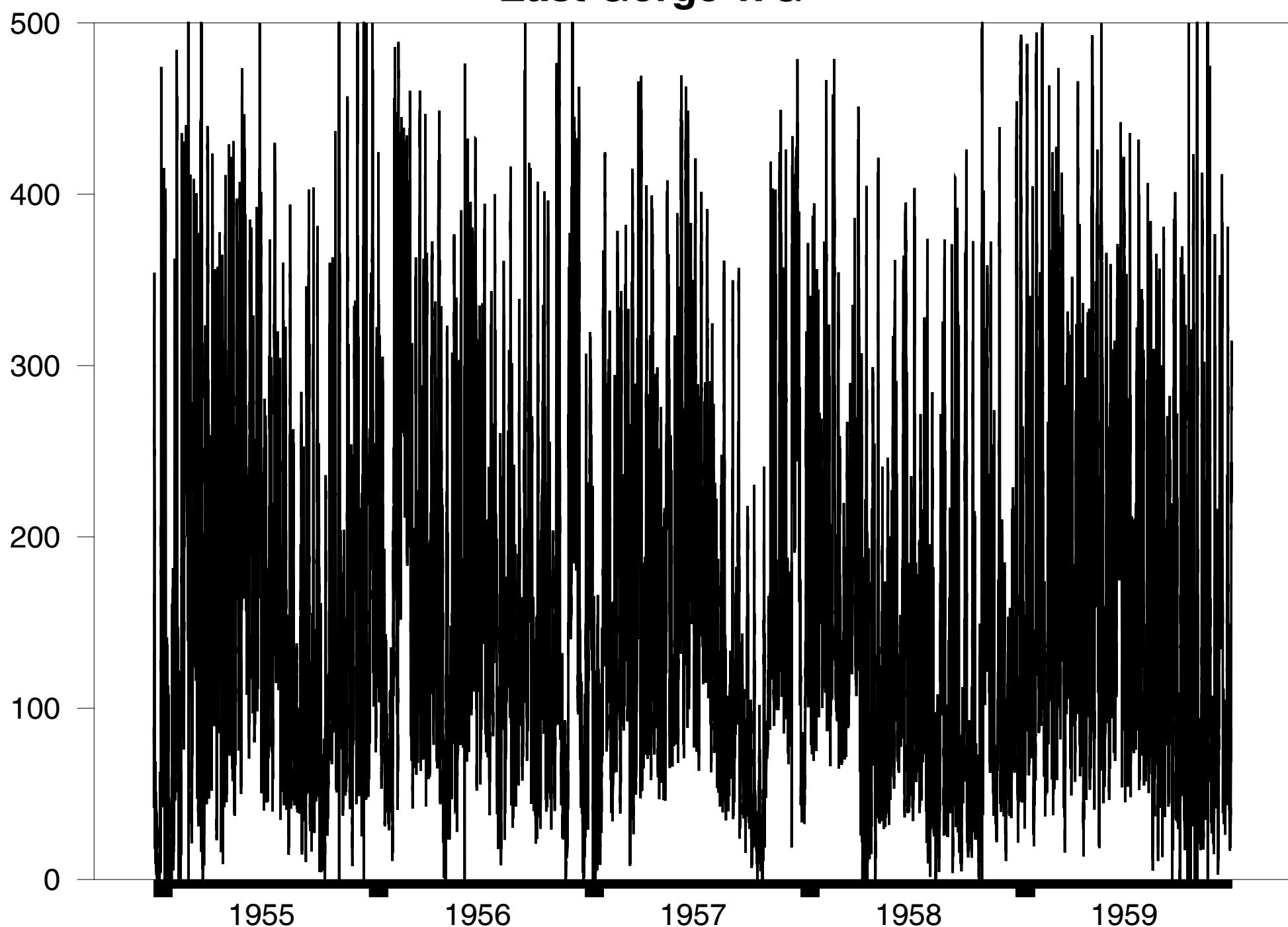
East Gorge WG



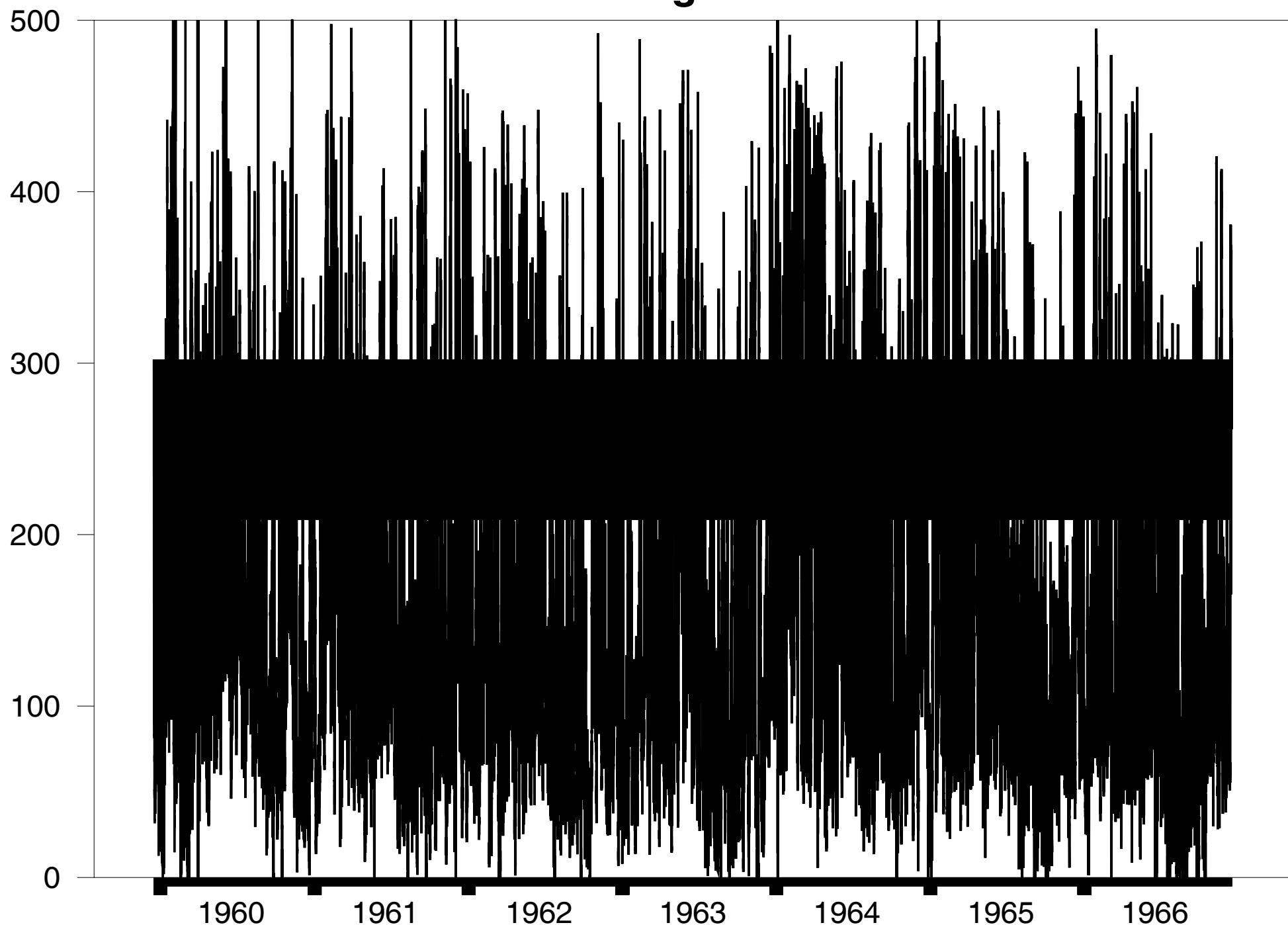
East Gorge WG



East Gorge WG



East Gorge WG



East Gorge WG

