



## Synthetic Wind

B. Kujala

Outline

The Goal

Cross-  
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Conclusions

# Historic Temperature Correlated Synthetic Wind Generation Record

Ben Kujala

[bkkujala@bpa.gov](mailto:bkkujala@bpa.gov)

Bonneville Power Administration

July 29, 2009



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# Context

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- GENESYS needs a long-term wind generation record, the characteristics of the record should be as close to the observed time series record as possible.
- Backcasting based on the OSU anemometer measurements was not feasible.
- Temperature-correlated synthetic wind retains important statistical attributes of wind generation.
- Methodology is currently undergoing peer review.
  - A synthetic study using the methodology in cross-correlated time series was presented to a joint conference of the Western North American Region of the Biometric Society and the Institute of Mathematical Statistics.
  - A paper on using the method for wind fleet capacity factor data was submitted to the Power and Energy Society of IEEE.
  - Additional papers and presentations will be pursued.



# The Goal of the Historic Temperature Correlated Synthetic Wind Generation Data

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It has been well established that temperatures affect load where extreme high or low temperatures translate into high loads.

- The synthetic wind power generation data recreates certain statistical characteristics of the original or observed wind power generation data set. The characteristics identified to focus on were:
  - Distribution/Density
  - Lag Structure or Persistence
  - Cross-Correlation
- The data is integrated into the existing resource adequacy studies using the GENESYS system.



# Why Cross-Correlation with Historic Temperatures?

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More data are used to answer questions about extreme historical temperature events.

- To what extent does wind generation contribute to meeting peak loads? What about sustained periods of high loads such as in cold snap or heat wave events?
- Does integrating wind change the hydro system's capability to meet peak loads or sustained periods of high loads?



# Cross-Correlations in the Observed Record

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As an initial examination of the cross-correlation in the observed record, the six peak hours of the day during the cold snap season were examined.

**Table:** Correlation matrix for the six peak load hours of the day in the cold snap season, November to February.

	Average Temp	Capacity	Regional Load
Average Temp	1.0000	0.3061	-0.8196
Capacity	0.3061	1.0000	-0.1792
Regional Load	-0.8196	-0.1792	1.0000



# Confidence Intervals for Cross-Correlations

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Asymptotic confidence intervals show highly significant cross-correlation:

- Correlation 95% CI between the average load center temperature and the wind fleet capacity factor: (.3043, .3057)
- Correlation 95% CI between the regional load and the wind fleet capacity factor:  $(-0.1799, -0.1784)$



# Why Correlation?

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Correlation is linear, why not talk about the distribution? The Kolmogorov-Smirnov test is a standard nonparametric statistical test for this question. For example, the probability that the wind fleet capacity factors during the cold snaps events have the same distribution as the capacity factors from the cold snap season observations that were not during cold snap events, is less than  $2.2 \times 10^{-16}$ .



# Synthetic Record During Historical Cold Snaps

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One of the main goals of this synthetic record is to align extreme temperature events in the historical record with observed output from the wind fleet. For evaluation, graphs of the synthetic record during historic cold snaps are given in the following slides.



# Cold Snap 1989

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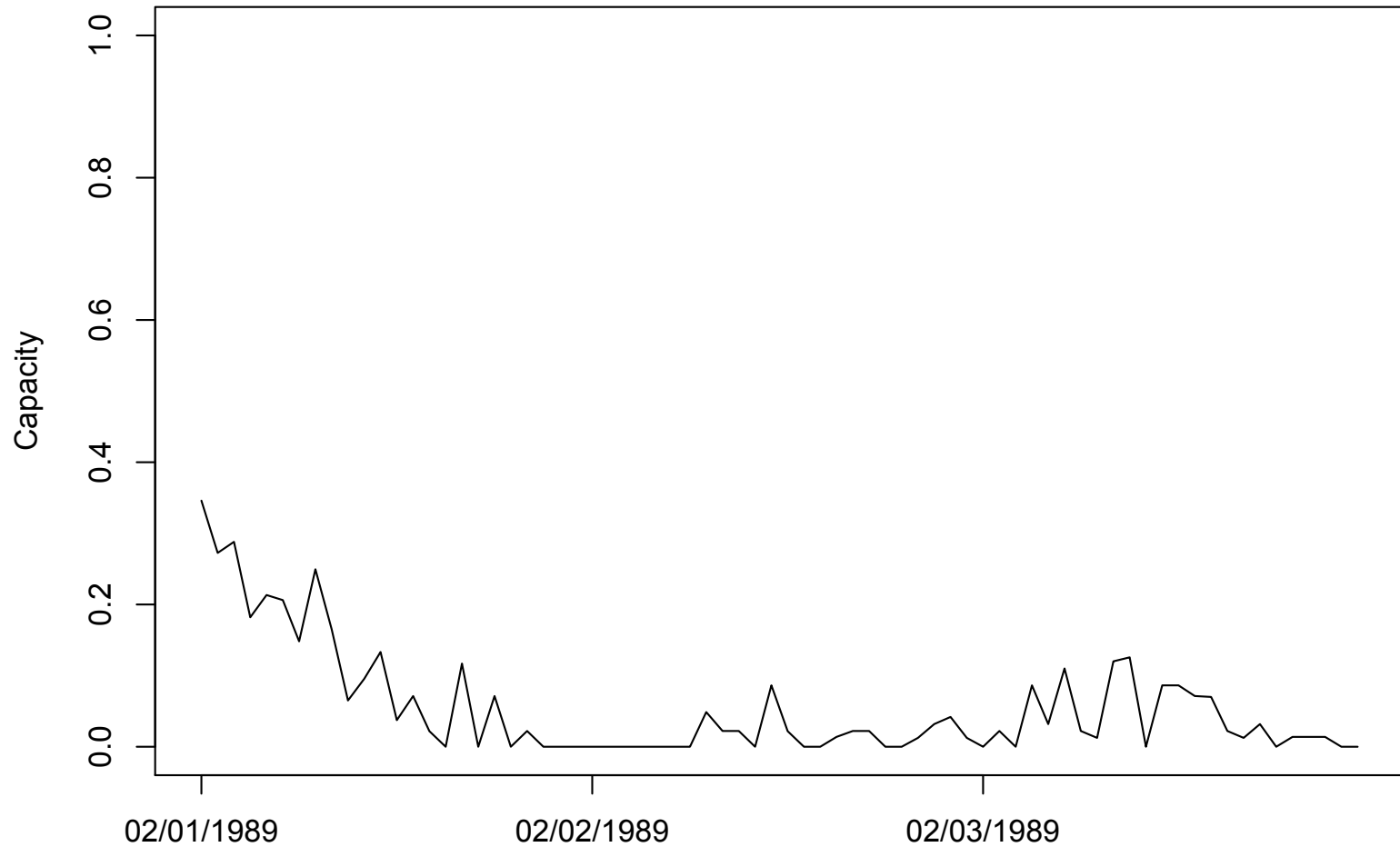
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**Synthetic Time Series from 02/01/1989 to 02/03/1989**









# Cold Snap 1998

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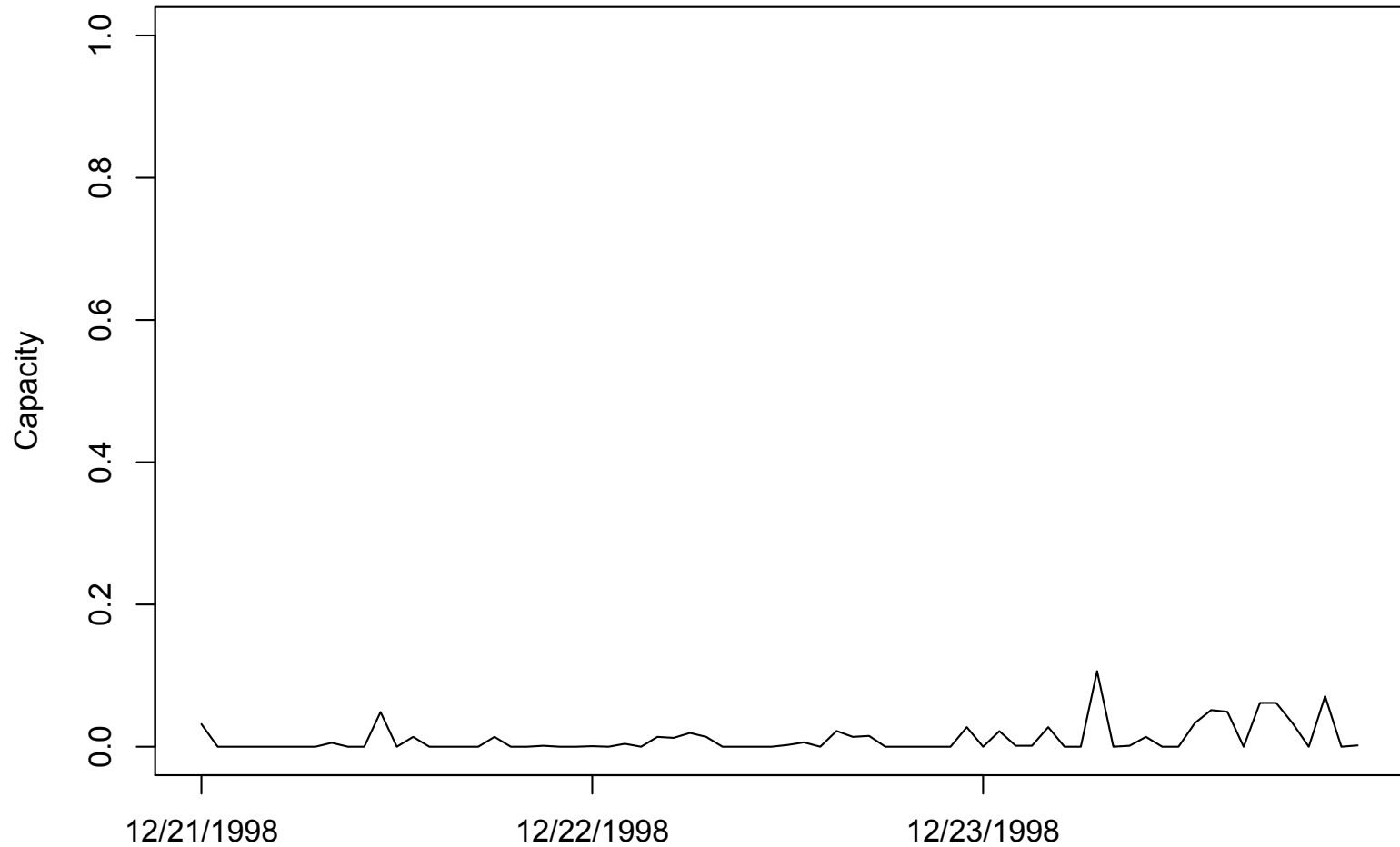
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**Synthetic Time Series from 12/21/1998 to 12/23/1998**





# Cold Snap 2000

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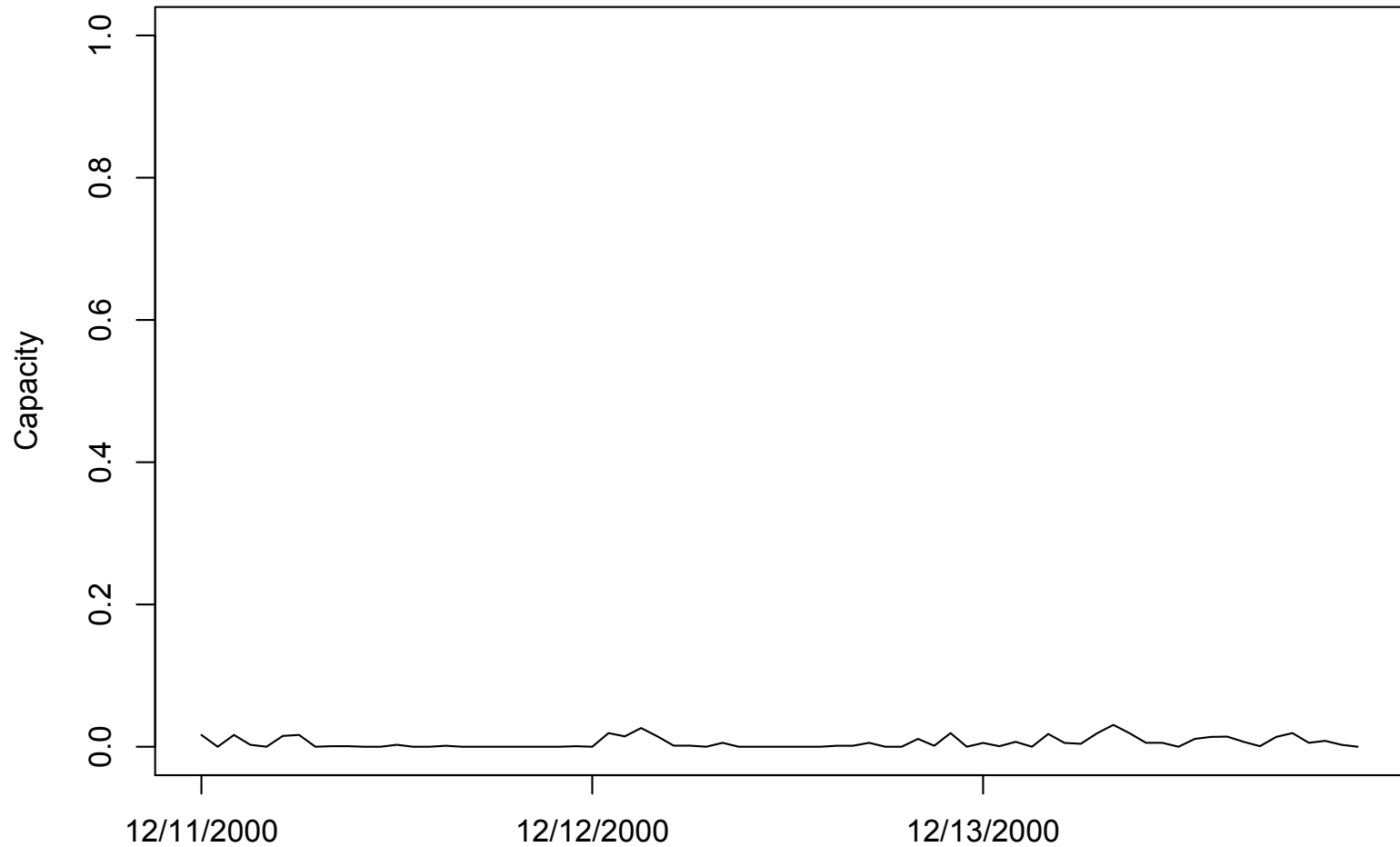
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**Synthetic Time Series from 12/11/2000 to 12/13/2000**





# Cold Snap 2004

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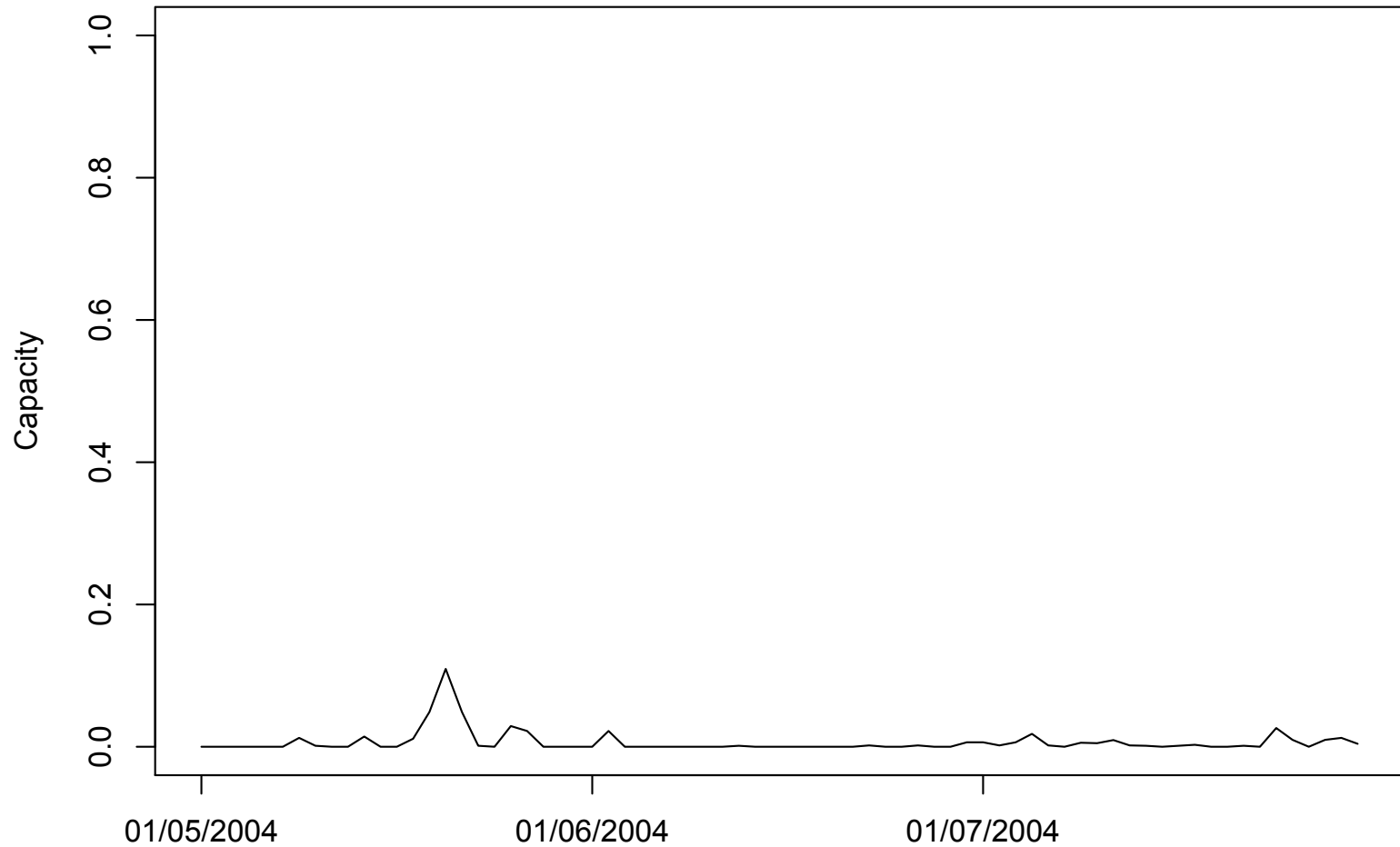
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**Synthetic Time Series from 01/05/2004 to 01/07/2004**





# Cold Snap 2005

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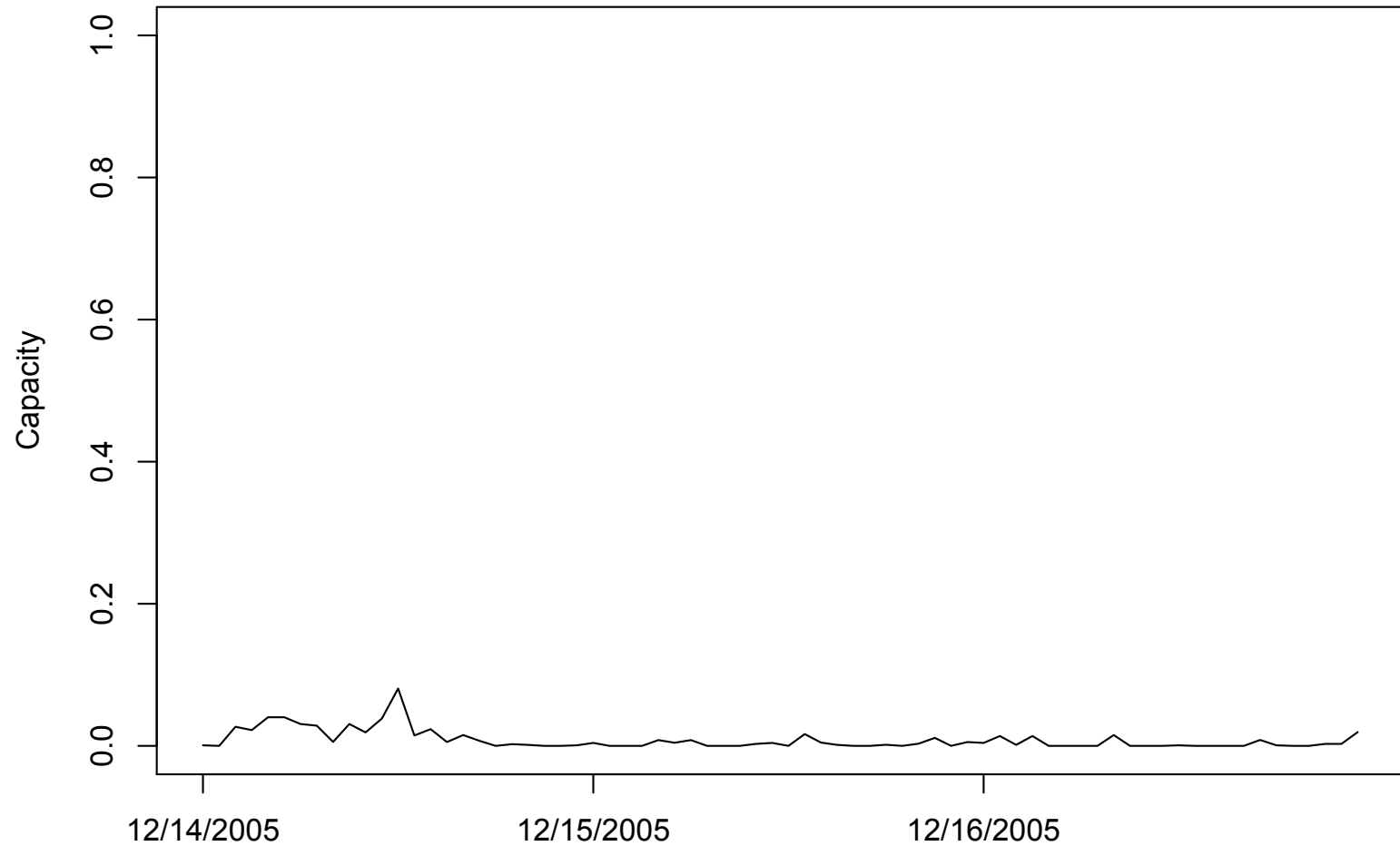
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**Synthetic Time Series from 12/14/2005 to 12/16/2005**





# Trial GENESYS Run

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In GENESYS each of the 70 water years were run against the load years from 1975 forward (70 water years  $\times$  32 load years = 2240 games). The wind year was either in lockstep with the load year or randomly selected. Three scenarios were run: a base case of the existing GENESYS setup for BPA (minimal wind included), an additional 5000 MW of wind with no other changes, and an additional 5000 MW of wind with a 5% increase in load.



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Run Type	Games	Game%	# Events	Hours	Time%	SumMag	EUE
Base Random	875	39.1%	37213	1800598	9.2%	1850214673	94.3
Base Lockstep	878	39.2%	37419	1807936	9.2%	1855848508	94.6
5000 Random	341	15.2%	19948	246458	1.3%	250938906	12.8
5000 Lockstep	357	15.9%	8154	277363	1.4%	315950504	16.1
5000 & 5% Random	466	20.8%	11624	398003	2.0%	459927355	23.4
5000 & 5% Lockstep	474	21.2%	12046	433259	2.2%	538234012	27.4



# Conclusions & Recommendations

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- While there was not much of a difference between lockstep and random for the base case with the current BPA resource mix in GENESYS, adding in 5000 MW of wind showed a more distinct impact. This initial result indicates there are other interesting ramifications as far as the number of events and the magnitude of the events. Considering these initial results it is recommended that an analysis on the regional level should be pursued.
- If possible, the historical temperature record should be expanded to allow for a longer lockstep analysis.
- A final report detailing the methodology, issues of interest, and results from the regional GENESYS model should be prepared as a final outcome.
  - What are the issues of interest or fundamental questions?
  - What metrics are we going to use? Is LOLP the best measure to determine the outcome of any study?