How and When to Use the Monte Carlo Method to Compute Normalized Annual Peak Demand Statistics

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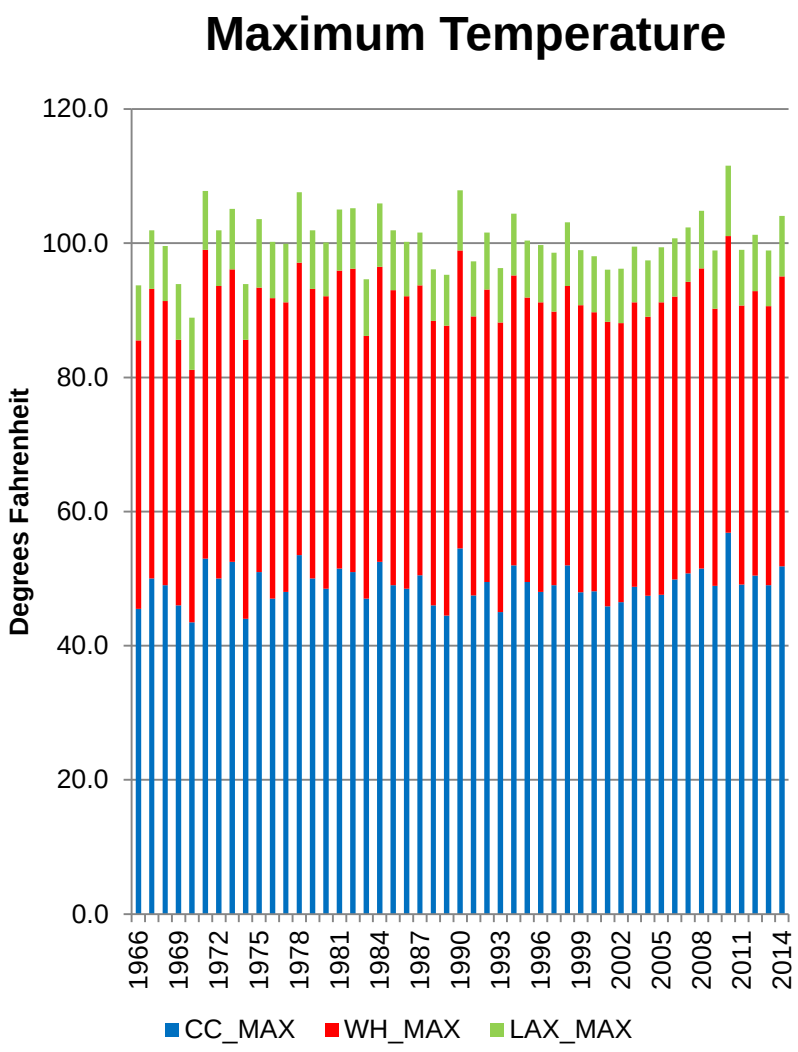
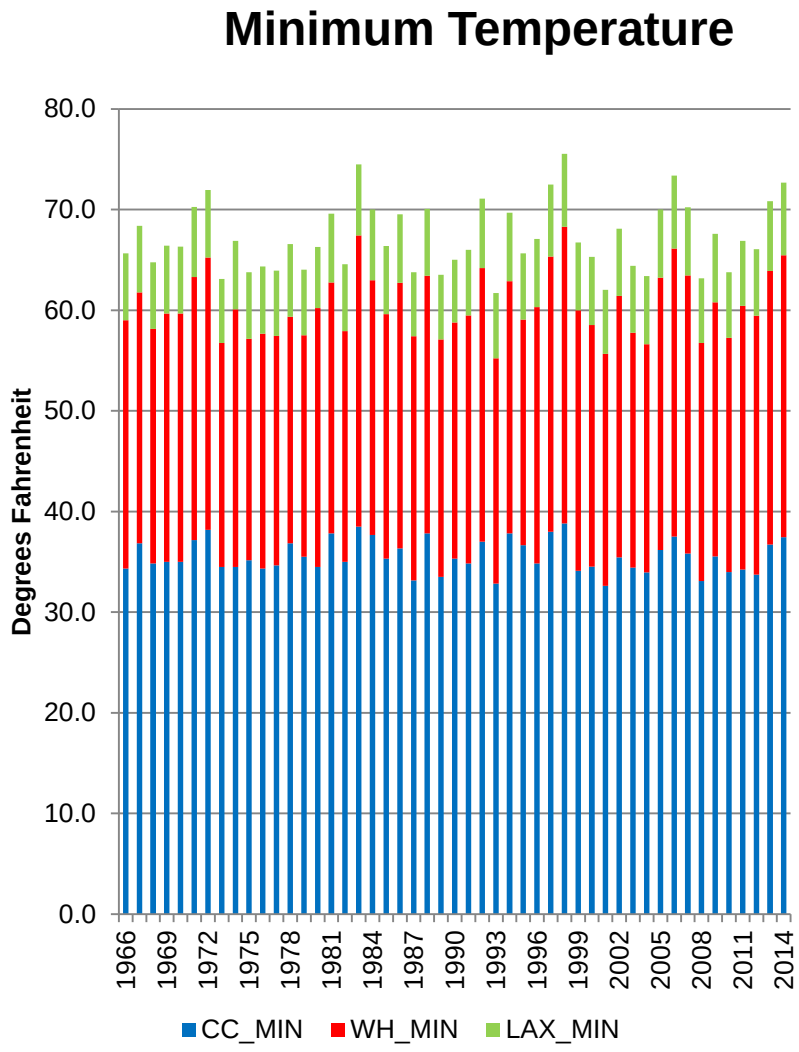
Monte Carlo Method

- Define a domain of possible inputs.
- Perform a deterministic computation on the inputs.
- Generate inputs randomly from a probability distribution over the domain.
- Aggregate the results.

Define a Domain



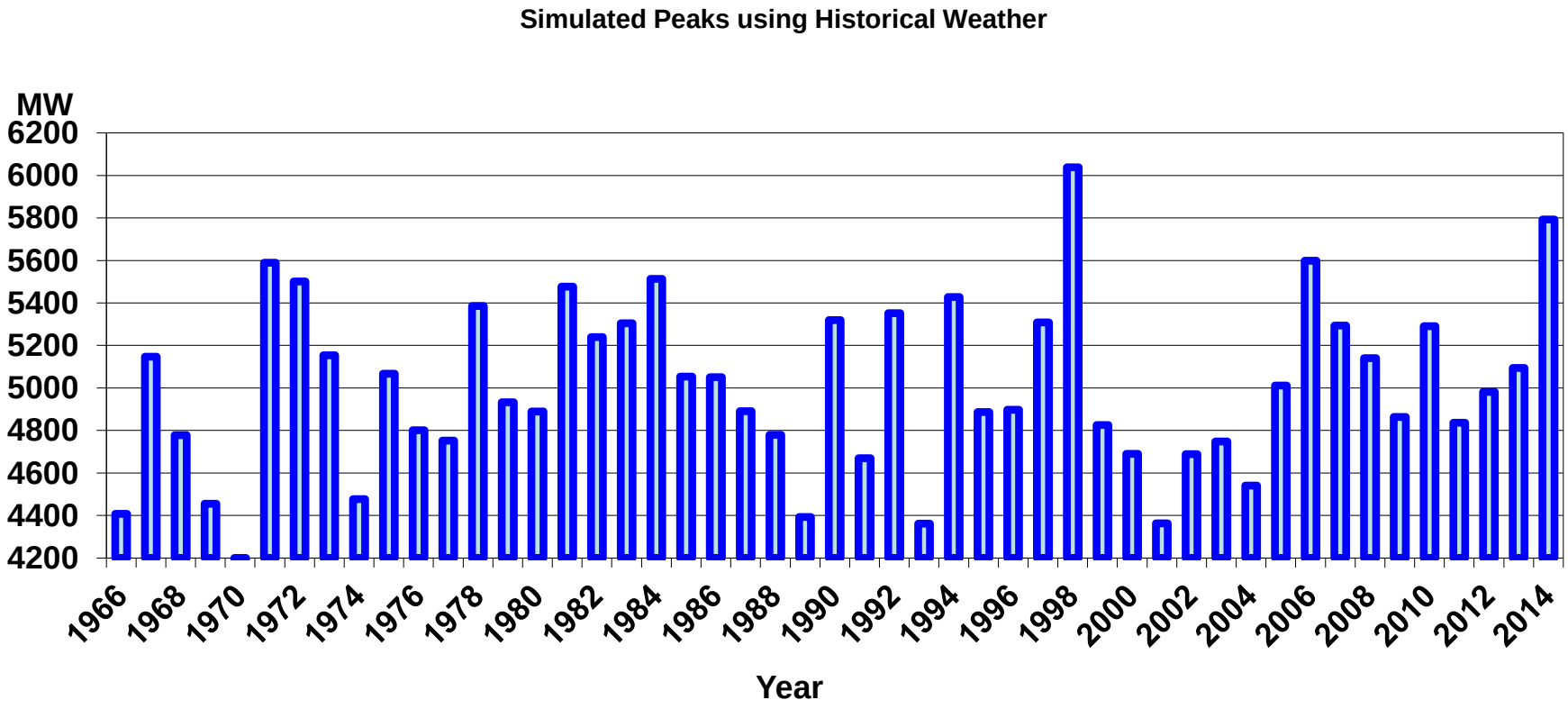


Perform a deterministic computation

- Temperature Response Model using Splines
- Temperatures Variables
  - Maximum Weighted Temperature – Measures Intensity
  - 3 Day Moving Average Minimum Temperature – Measures Duration

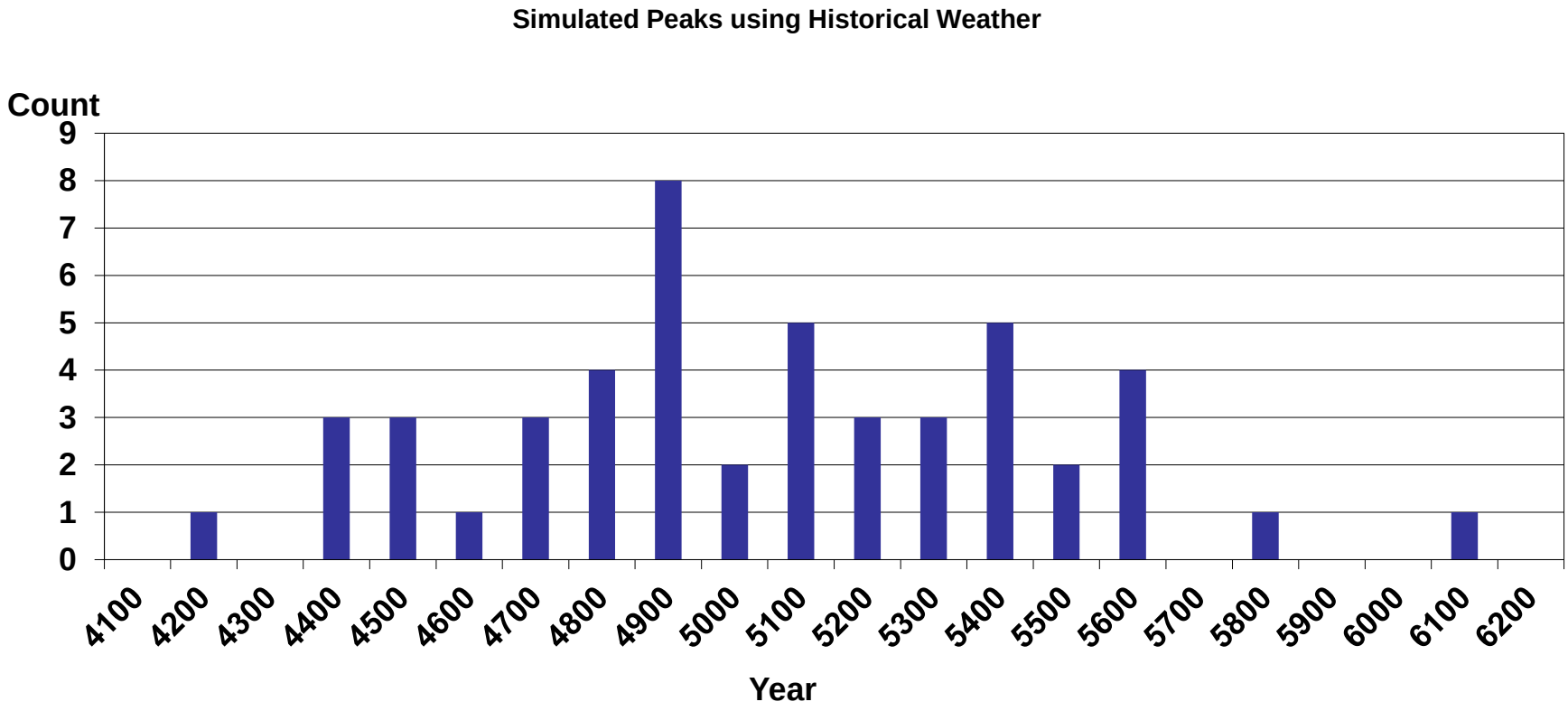
Coefficient MW	Variable
3000	Constant
51	MaxTemp75
59	MaxTemp80
63	MaxTemp85
61	MaxTemp90
73	MaxTemp95
88	MaxTemp100
20	MaxTemp105
57	MinTemp60
47	MinTemp65
142	MinTemp70

1 in X Calculation Methodology



1 in X Calculation Methodology

When the sample size n is relatively large, the distribution of the sample mean will still be approximately normal by the central limit theorem.



1 in X Calculation Methodology

- Mean = 5004 MW
- Standard Deviation = 402 MW
- 1 in X Calculation using Excel function
  - 1 in 2 = NORMINV(.5,5595,364.37) = 5004 MW
  - 1 in 10 = NORMINV(.9,5595,364.37) = 5520 MW
  - 1 in 40 = NORMINV(.975,5595,364.37) = 5793 MW

Generate Inputs Randomly from a Probability Distribution over the Domain

- Two Step process in R using functions cov.wt and mvrnorm
- Function cov.wt (Domain, Weight) Default is equal-weighted
- Function mvrnorm (n, array of means, covariance matrix)

Means from Cov.wt

Weather Inputs	Equal Weighted	Trend Weighted
CC_Min	71.10816	70.95535
CC_MAX	98.38776	98.92408
WH_MIN	62.40000	63.20531
WH_MAX	106.75510	106.79429
LAX_MIN	67.06531	67.26098
LAX_MAX	85.79592	85.71918

Generate Inputs Randomly from a Probability Distribution over the Domain

Equal Weight Covariance Matrix

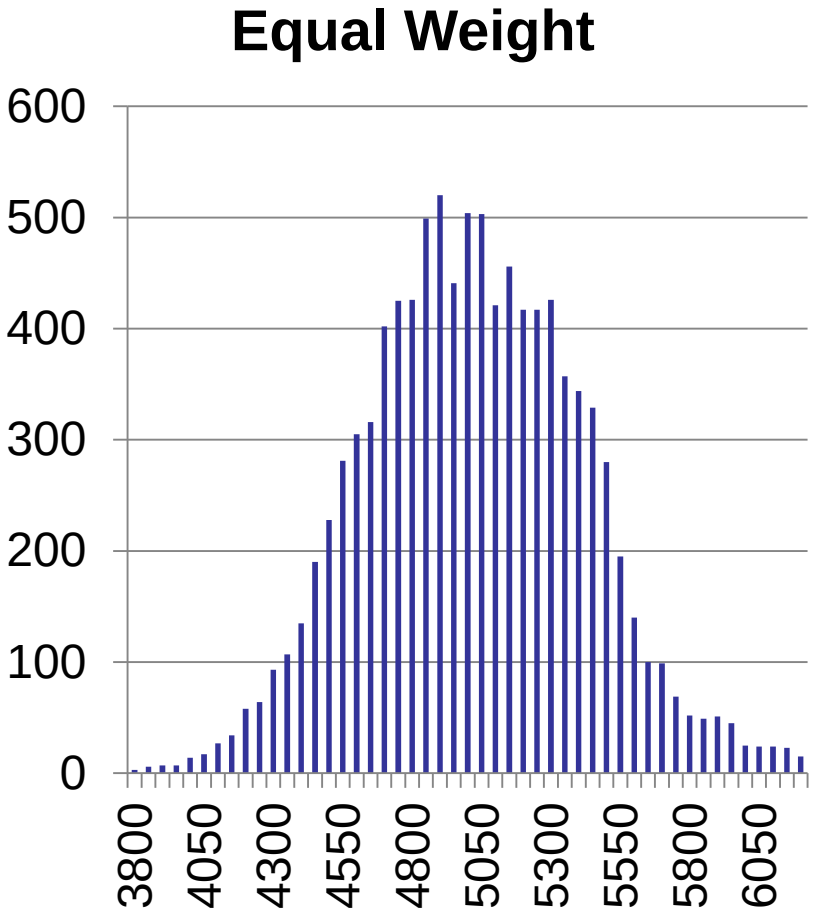
	CC Min	CC Max	WH Min	WH Max	LAX Min	LAX Max
CC Min	10.62	5.28	9.62	-0.40	6.06	6.23
CC MAX	5.28	30.82	-0.42	12.65	1.81	26.76
WH MIN	9.62	-0.42	23.42	-4.28	7.51	-4.86
WH MAX	-0.40	12.65	-4.28	15.43	-1.81	7.74
LAX MIN	6.06	1.81	7.51	-1.81	6.92	5.48
LAX MAX	6.23	26.76	-4.86	7.74	5.48	40.08

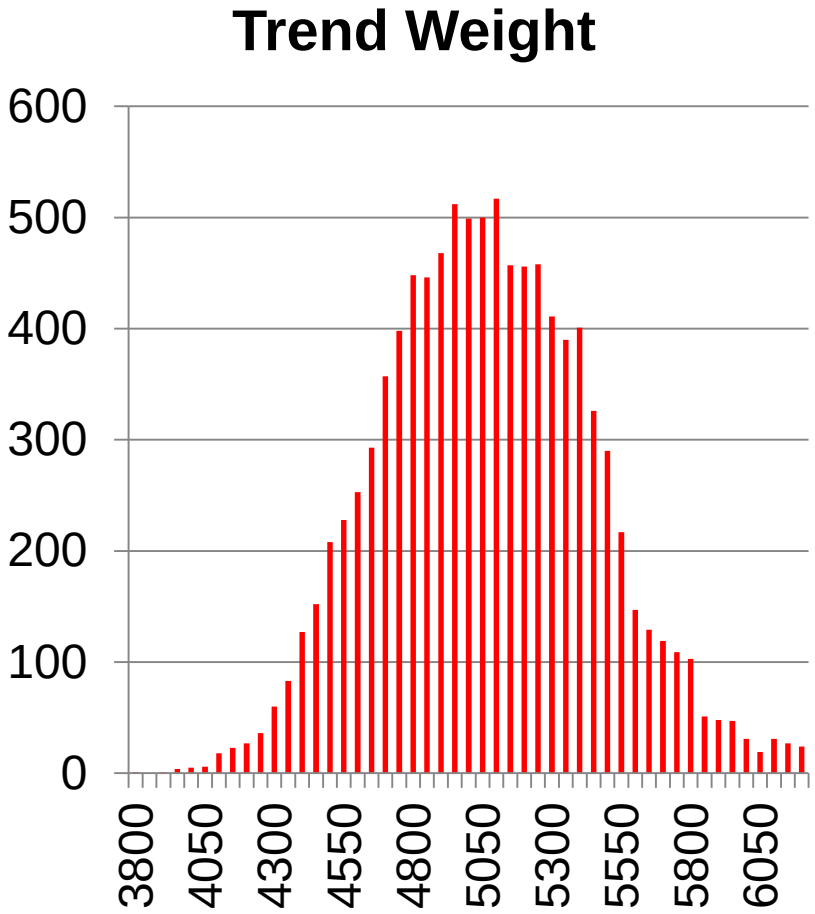
Trend Weight Covariance Matrix

	CC Min	CC Max	WH Min	WH Max	LAX Min	LAX Max
CC Min	11.58	3.78	11.26	-2.05	7.17	5.86
CC MAX	3.78	28.64	0.96	8.12	1.77	27.19
WH MIN	11.26	0.96	25.30	-4.71	9.23	-2.07
WH MAX	-2.05	8.12	-4.71	9.94	-2.42	5.61
LAX MIN	7.17	1.77	9.23	-2.42	7.55	5.06
LAX MAX	5.86	27.19	-2.07	5.61	5.06	38.90

Aggregate Your Results

- Create Frequency table
- 10000 draws from the multivariate normal distribution.
- Calculate peaks based on the weather response function.





Aggregate Your Results

- When computing normalized annual peak demand statistics from simulations use percentiles.

	Historical Normal	Equal Weight Simulation	Trend Weight Simulation
1 in 2	5004	4988	5034
1 in 10	5520	5486	5530
1 in 40	5793	5834	5864

When to Use Monte Carlo Simulation

- You suspect the underlying distribution of your weather response function has a fat tail.
  - Normal distribution estimates cut off fat tails.
- You have a hypothesis that your domain is non-stationary. (Climate Change?)
- You have an ill-mannered weather response function (Deterministic computation).
- Credibility with your Planners. More and more stochastic processes are being used in Generation, Transmission and Distribution.