NREL
NATIONAL RENEWABLE ENERGY LABORATORY

PIX 06588

Wind Power Forecasting Error Distributions over Multiple Timescales

PIX 10926

IEEE Power and Energy Society General Meeting
July 27, 2011

Bri-Mathias Hodge
Michael Milligan
National Renewable Energy Laboratory
Golden, Colorado USA

NREL/PR-5500-52294

Topics

- Statistical background;
- Dataset background;
- Histograms;
- Q-Q plots;
- Kurtosis and skewness;
- Distribution fitting;
- Confidence intervals.

PIX 14820

Statistical Background

- Skewness: measure of the asymmetry of the distribution, the 3rd standardized moment.
- Negative skew – longer tail on left, but more mass on right.
- Positive skew – longer tail on right, but more mass on left.

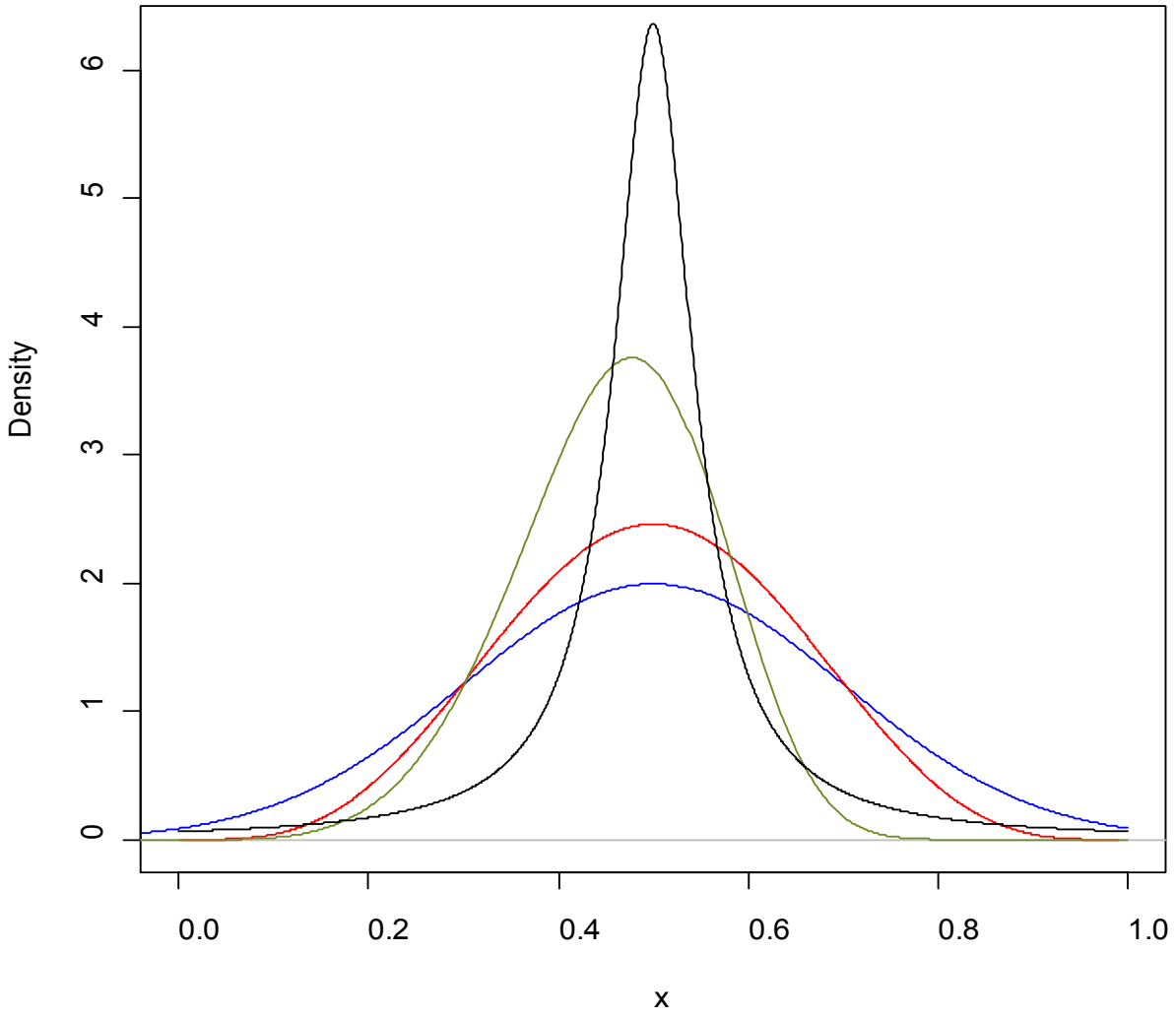
$$\gamma = E\left[\left(\frac{X-\mu}{\sigma}\right)^3\right]$$

- Kurtosis: measure of the peakedness of the distributions, the 4th standardized moment.
- Leptokurtic – more peaked.
- Platykurtic – more flat.

$$\kappa = \frac{E(\varepsilon^4)}{\sigma^4}$$

Parametric Statistical Distributions

- Normal – Blue:
  $\mu = 0.5, \sigma = 0.2$
- Beta – Red:
  $\alpha = \beta = 5$
- Weibull – Green:
  $\kappa = 5, \lambda = 0.5$
- Cauchy – Black:
  $x_0 = 0.5, \gamma = 0.05$



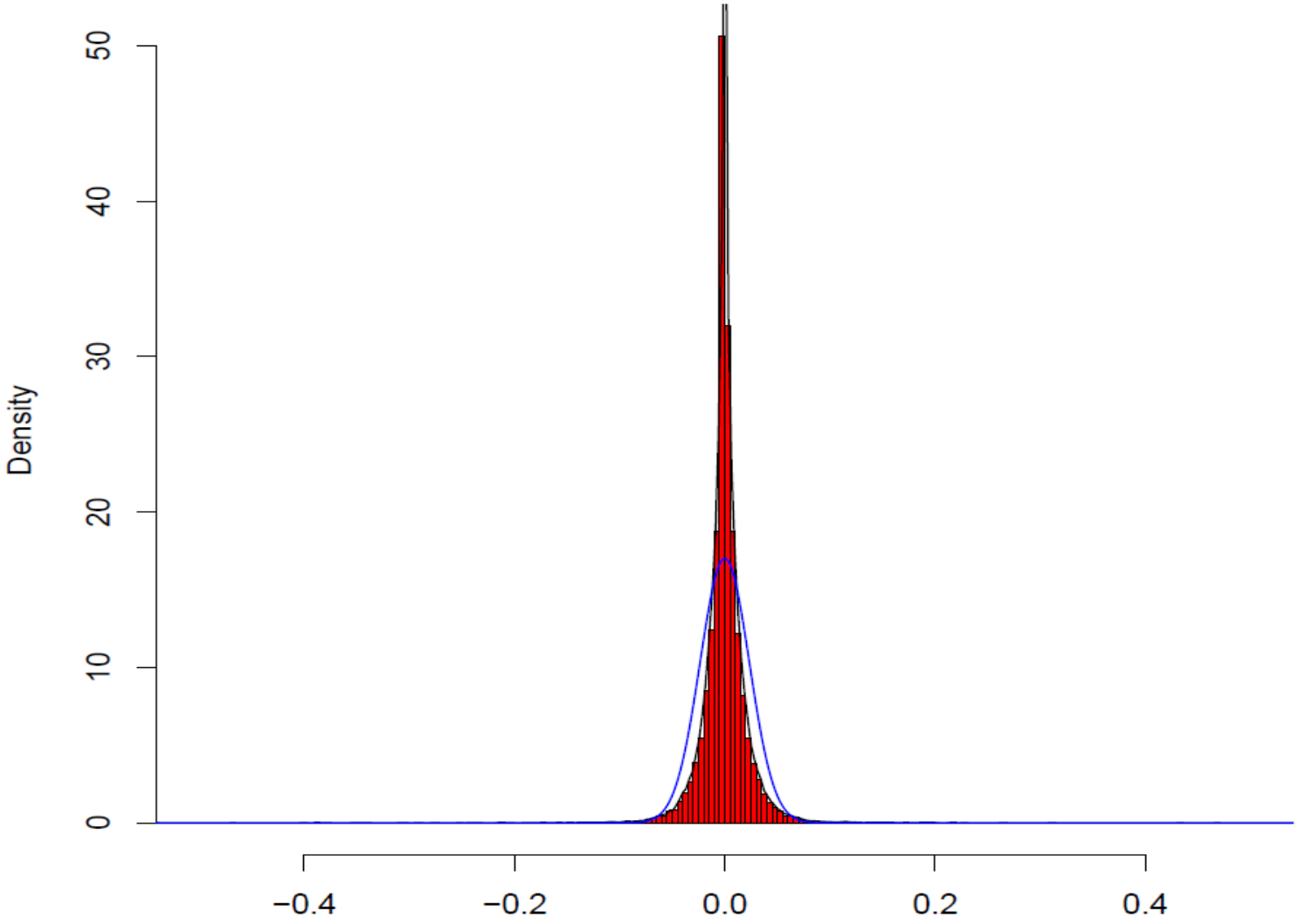
ERCOT Dataset

- One-minute power output data.
- 10 ERCOT plants.
- Range in size from 30 MW to 215 MW.
- Also examined aggregation of all ten wind plants – total capacity ~ 940 MW.
- Two four month periods:
  - Winter (January – April);
  - Summer (June – September).
- Persistence model utilized:

$$\hat{P}(t+k \mid t) = P(t)$$

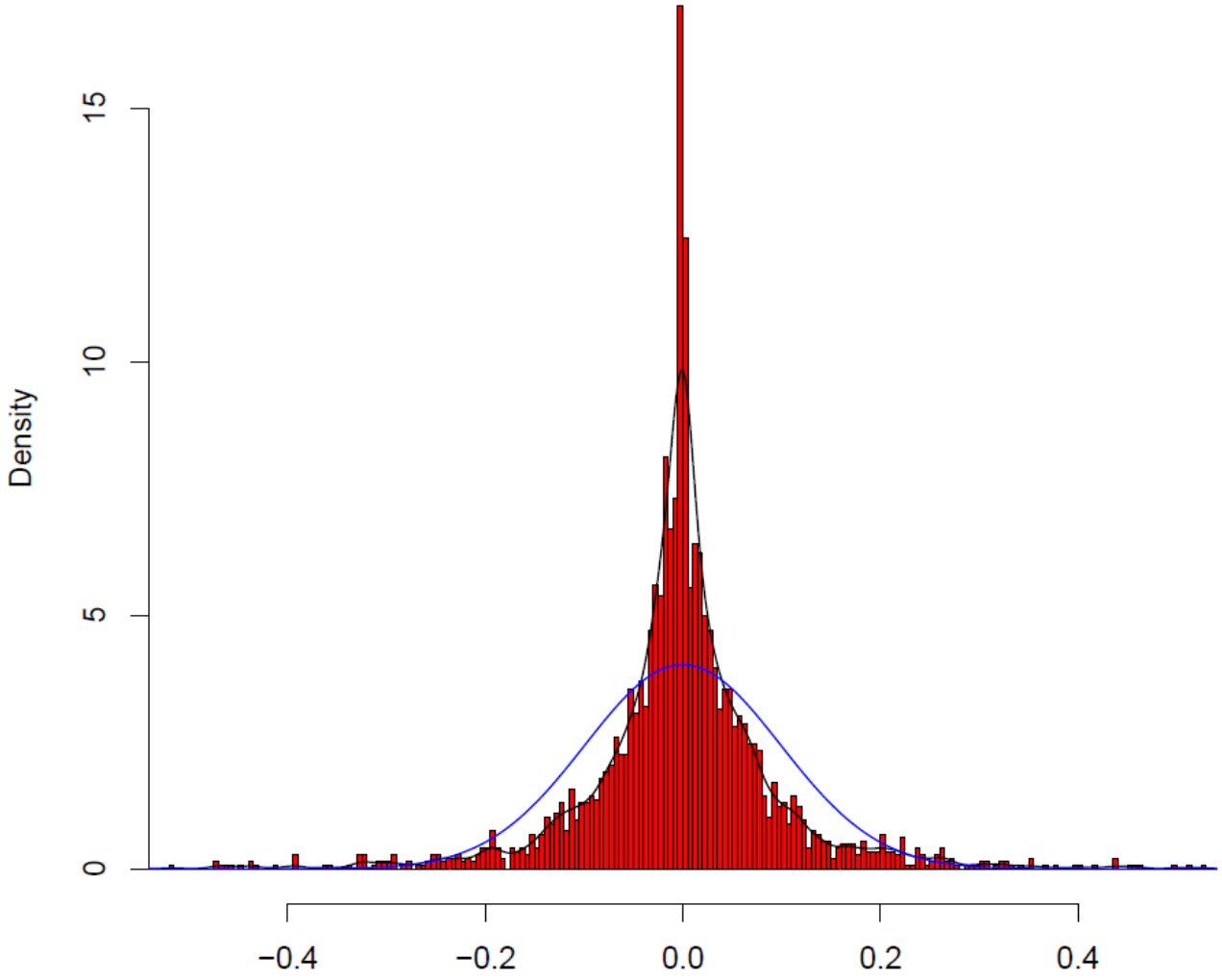
PIX 16112 & 18207

Forecasting Results – Histograms



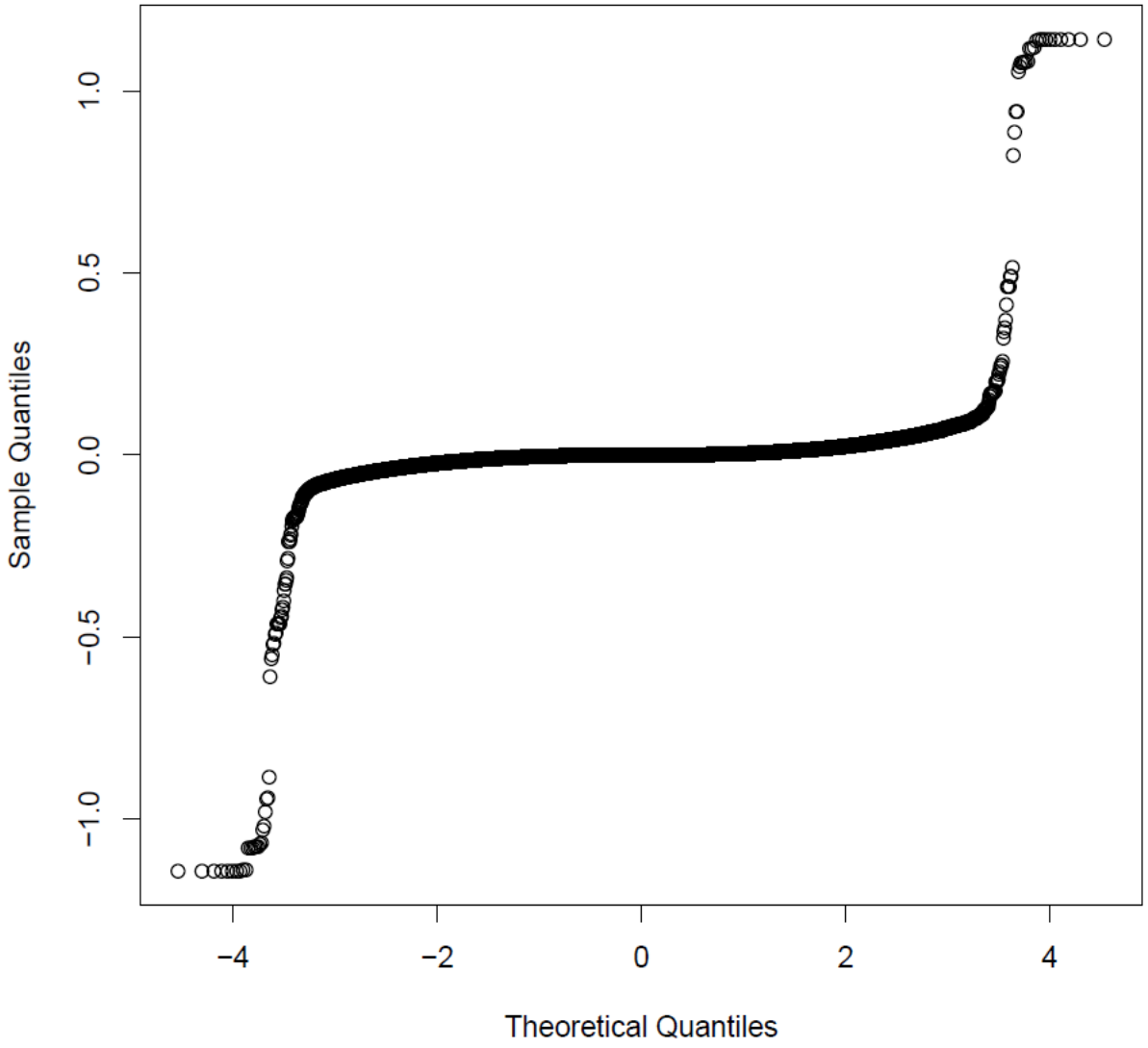
Wind Plant # 3 - 5 minute - Winter : γ = -2.14, κ = 151.25

Wind Plant # 8 – One Hour



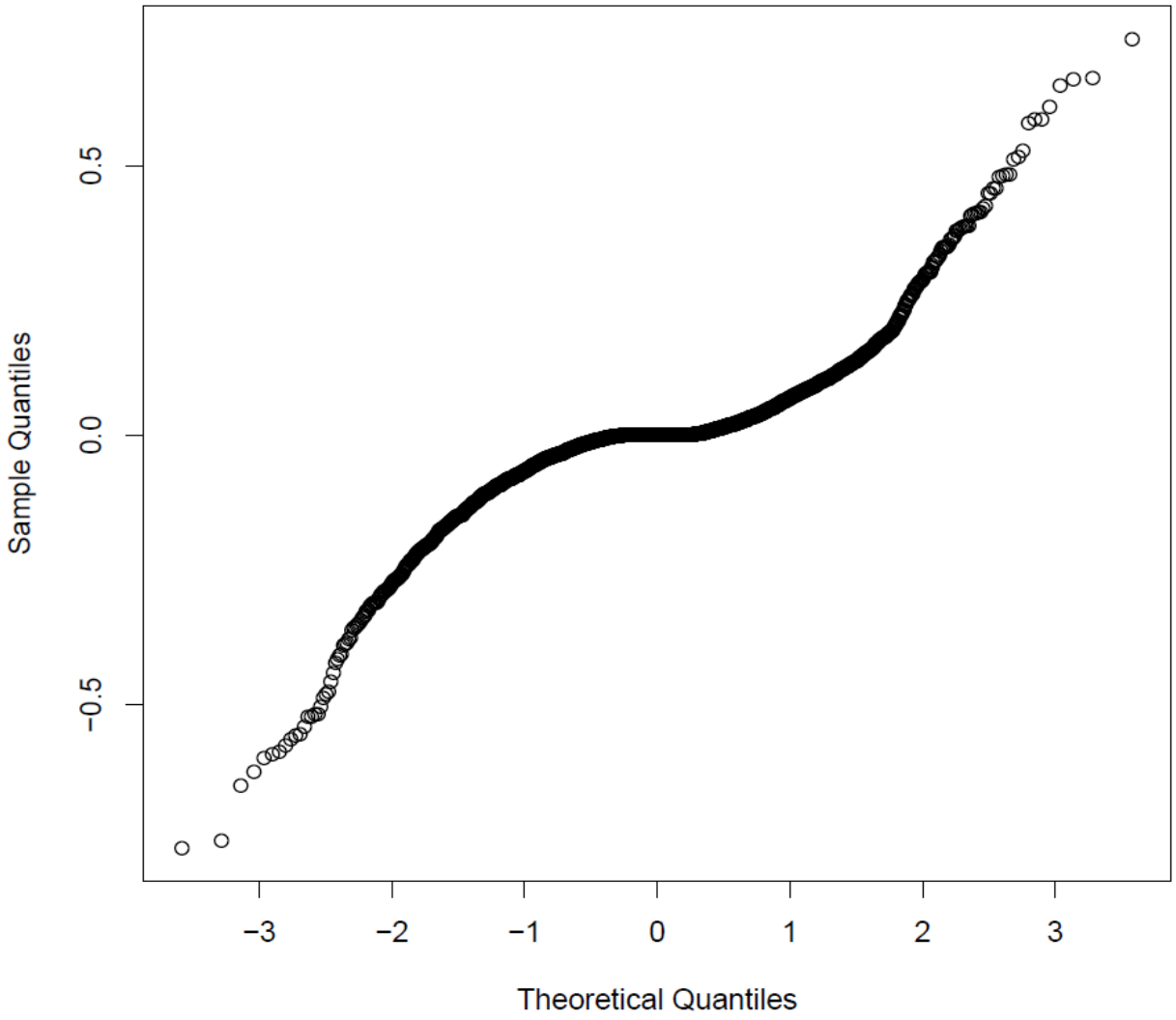
Summer: γ = -0.02, κ = 6.18

Normal Quantile-Quantile Plot – Plant #1



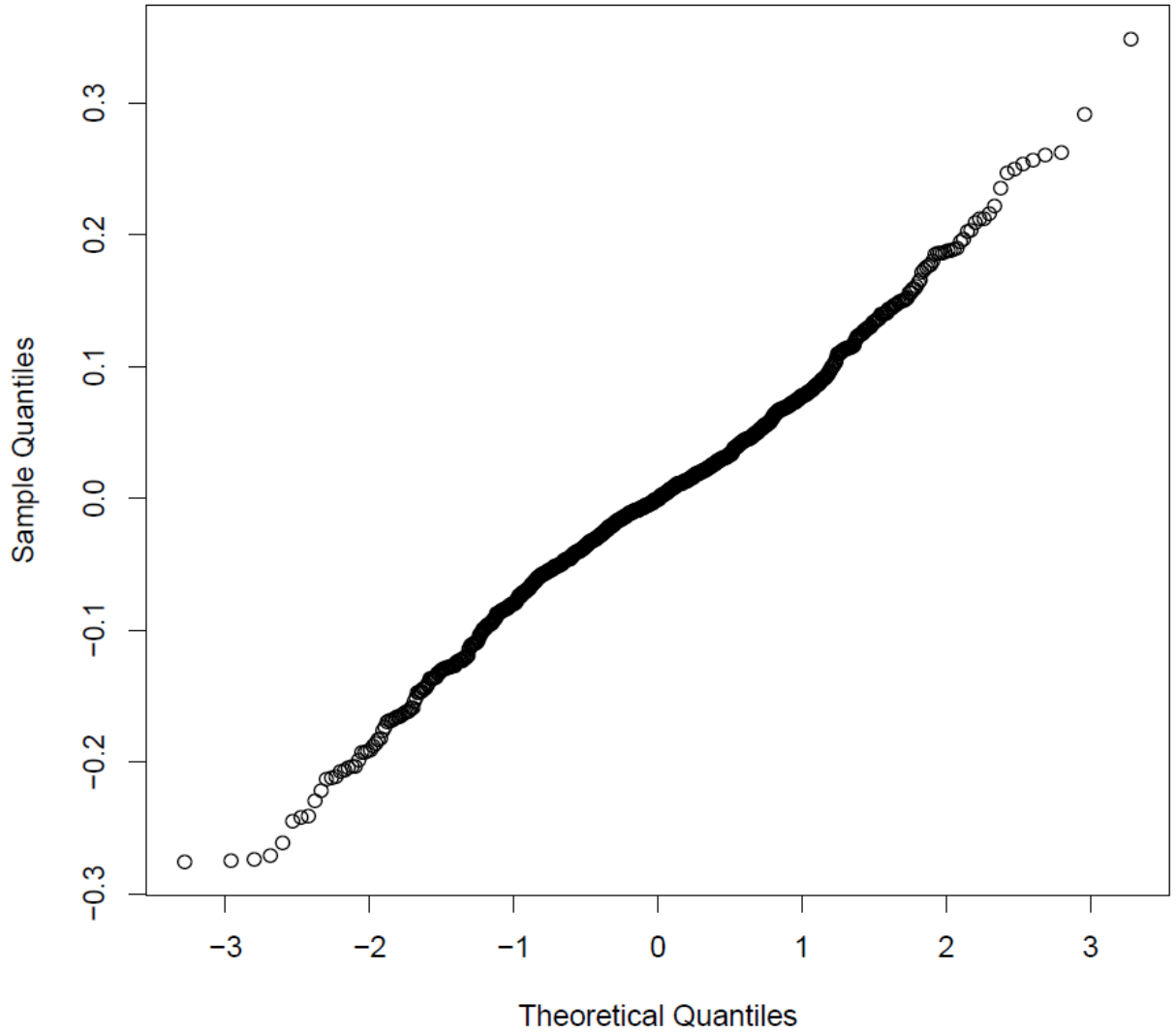
1 minute - Summer : γ = -0.45, κ = 1717.81

Wind Plant # 6 – One Hour



Summer: γ = -0.08, κ = 8.04

Combined ERCOT – Three Hours



Summer: $\gamma = 0.02$, $\kappa = 0.82$

Kurtosis Values

TABLE I

KURTOSIS VALUES FOR PERSISTENCE FORECAST ERROR WITH NO TIME LAG OVER A FOUR MONTH SUMMER PERIOD AT DIFFERENT TIME SCALES

	1 Minute	5 Minute	15 Minute	1 Hour	3 Hour
#1	1,717.89	328.43	163.59	39.50	25.07
#2	210.06	62.61	34.09	8.24	3.42
#3	46.61	42.17	29.05	9.33	2.34
#4	122.11	51.94	30.63	7.61	2.23
#5	595.13	69.88	31.87	9.30	2.65
#6	900.03	137.24	34.84	8.04	2.16
#7	79.91	27.79	19.69	5.16	1.72
#8	50.72	51.31	28.08	6.18	1.13
#9	119.07	37.23	18.41	6.23	1.99
#10	328.18	81.80	38.93	5.14	1.39
ERCOT	149.12	16.32	7.85	2.51	0.82

Skewness Values

TABLE II

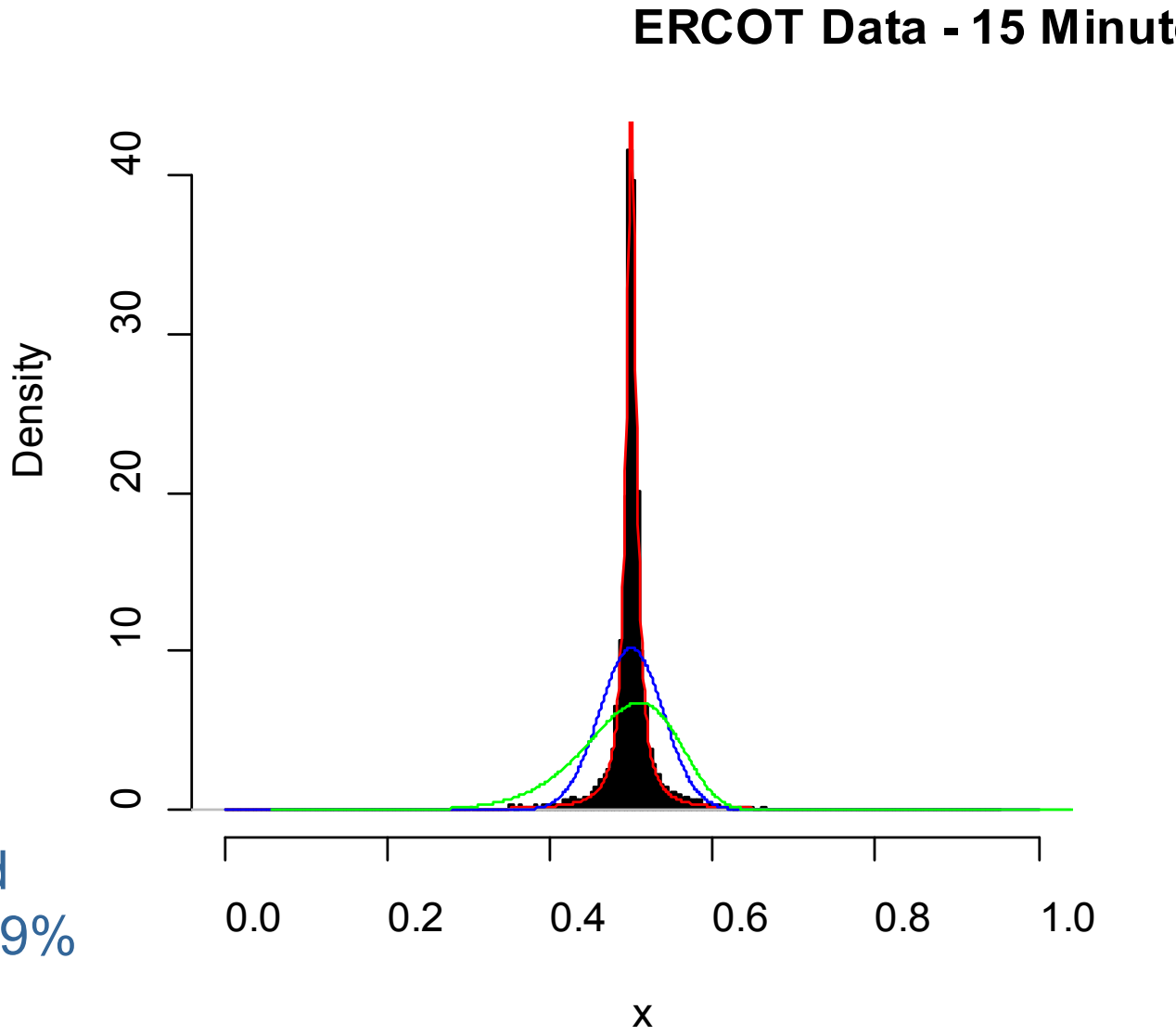
SKEWNESS VALUES FOR PERSISTENCE FORECAST ERROR WITH NO TIME LAG OVER A FOUR MONTH SUMMER PERIOD AT DIFFERENT TIME SCALES

	1 Minute	5 Minute	15 Minute	1 Hour	3 Hour
#1	-0.44	-0.48	-0.11	0.35	1.13
#2	-0.75	-0.08	0.94	0.63	0.44
#3	0.00	-0.40	0.06	0.06	0.16
#4	-0.40	1.56	1.48	0.56	0.18
#5	4.21	1.67	1.03	0.50	0.00
#6	-4.26	-0.92	0.06	-0.08	-0.12
#7	-0.15	0.48	0.61	0.13	-0.03
#8	0.14	-0.06	-0.48	-0.02	0.02
#9	-0.25	-0.20	0.07	-0.08	-0.17
#10	-1.07	0.10	0.26	-0.24	0.00
ERCOT	0.25	0.01	-0.07	0.05	0.02

Distribution Fitting

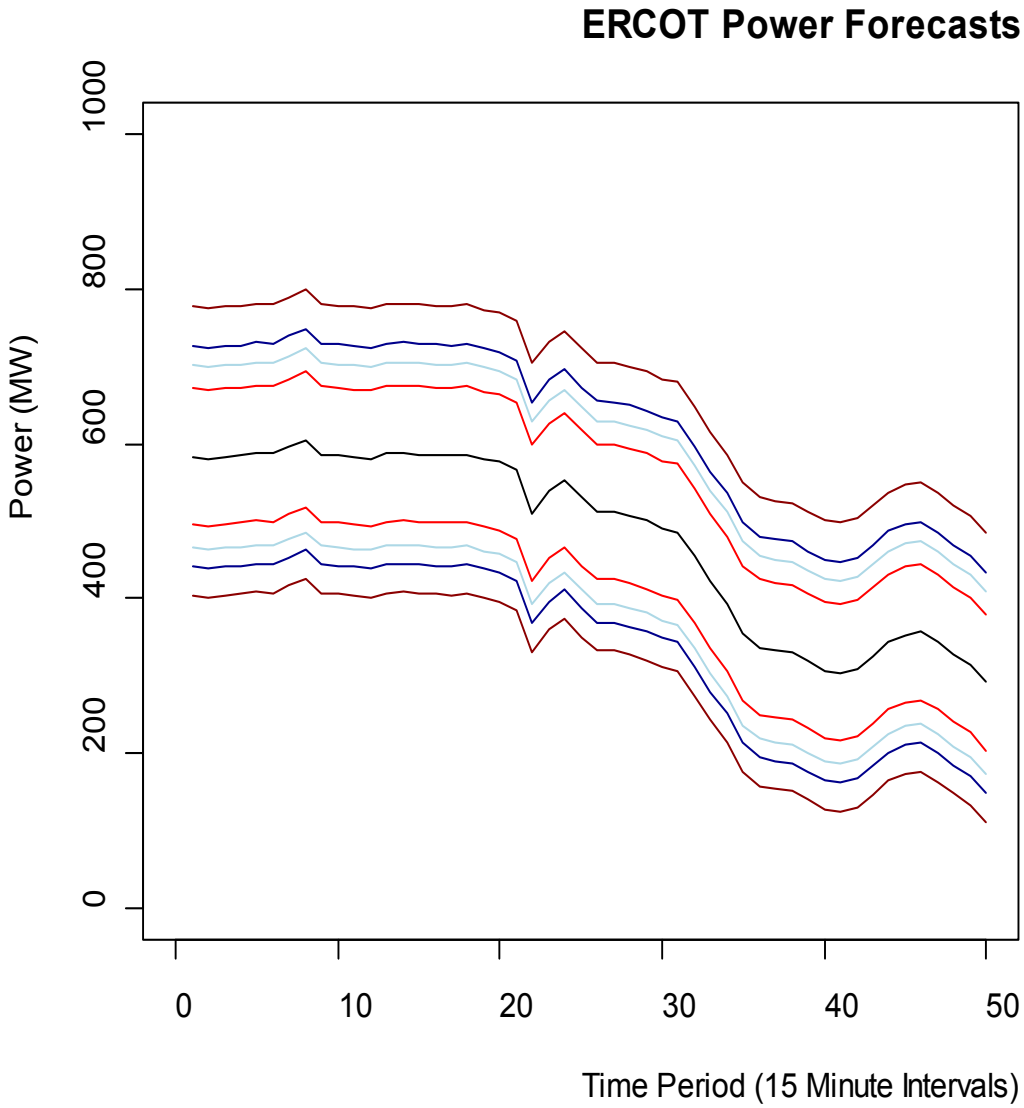
- Beta – Blue:
  $\alpha = 82.08$
  $\beta = 82.14$
- Weibull – Green:
  $k = 9.44$
  $\lambda = 0.52$
- Cauchy – Red:
  $x_o = 0.4999$
  $\gamma = 0.0069$

Cauchy produces more accurate log-likelihood values than the beta and Weibull distributions in 89% and 95% of the cases.



Comparison of Confidence Intervals

- Black – Point forecast.
- Blue – Normal distribution.
- Red – Cauchy distribution.
- Lighter shade:
  - 90% confidence interval.
- Darker shade:
  - 95% confidence interval.



Questions?

PIX 17731 & 16105