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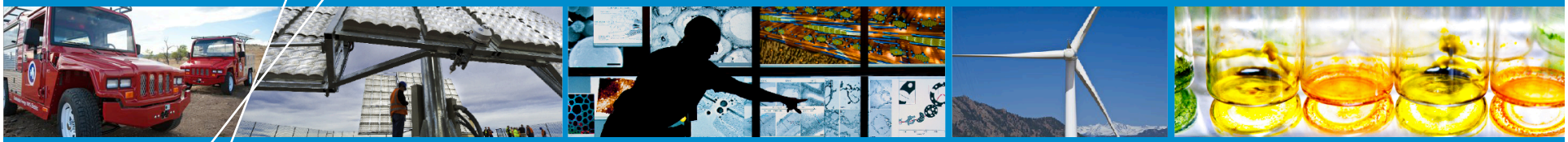
Wind and Solar Forecast Datasets



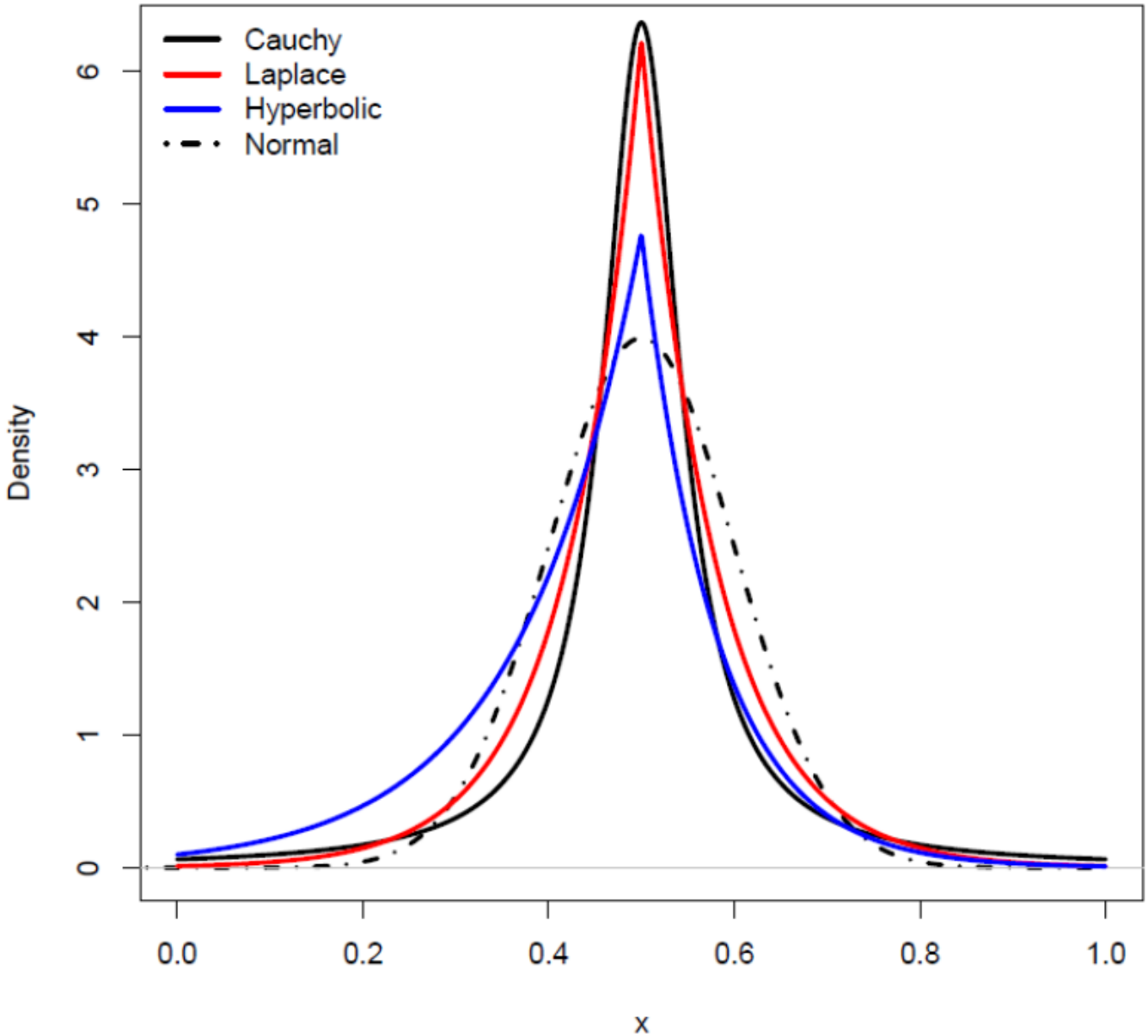
WWSIS 2 TRC Meeting

Bri-Mathias Hodge

April 5th 2012

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Statistical Background



- **Skewness – 3rd Statistical Moment**

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

- **Kurtosis – 4th Statistical Moment**

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

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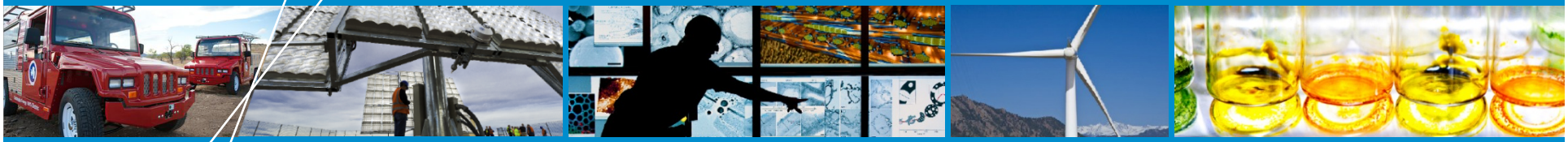


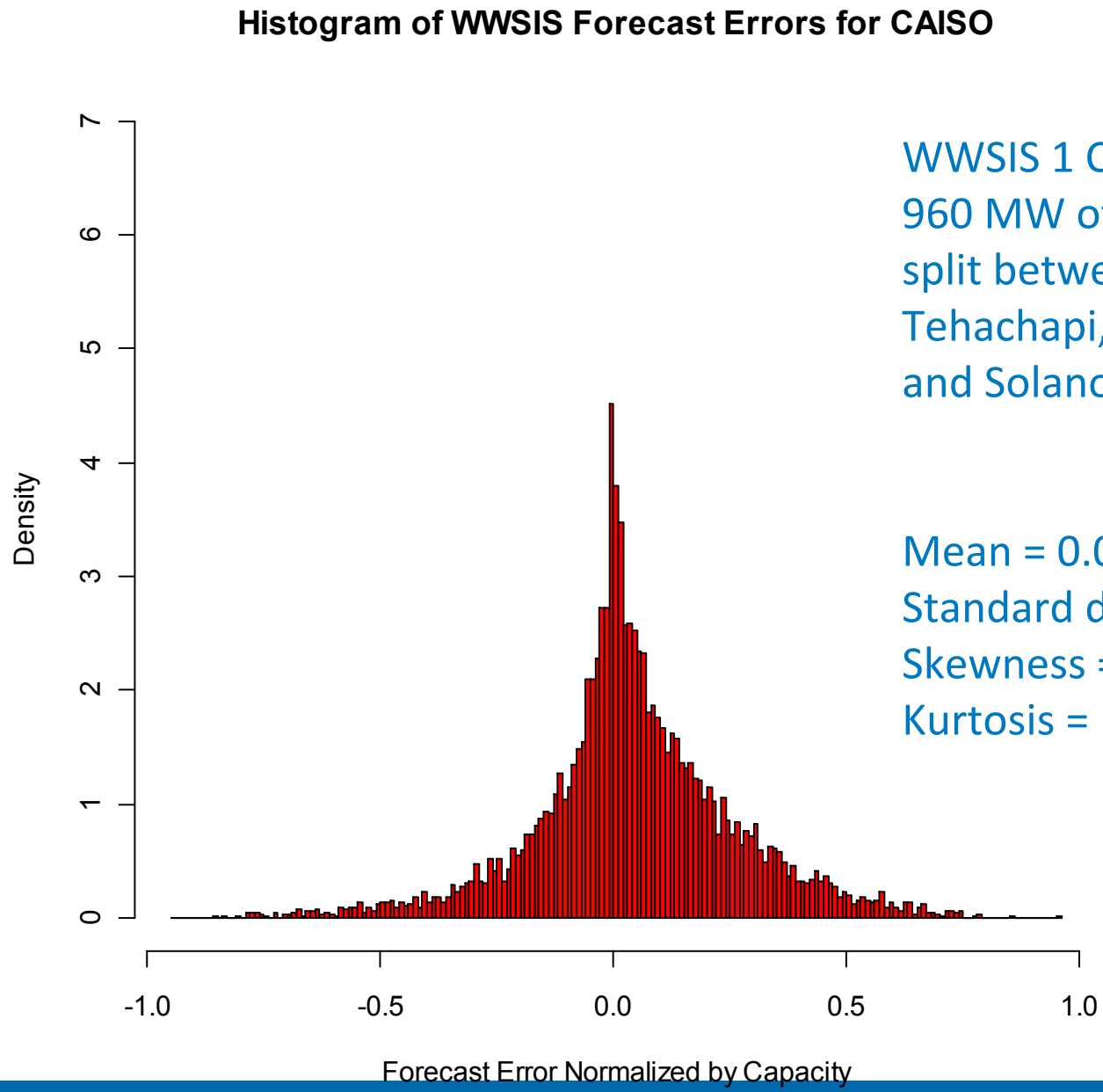
Wind Power Forecasting Errors

Wind Forecasting Error Distributions

- Using forecast errors taken from operational systems
- Aggregated at regions that are ISO-sized
- Map errors from WWSIS 1 through a model error distribution and tweak to generate more realistic error distributions

Balancing Areas

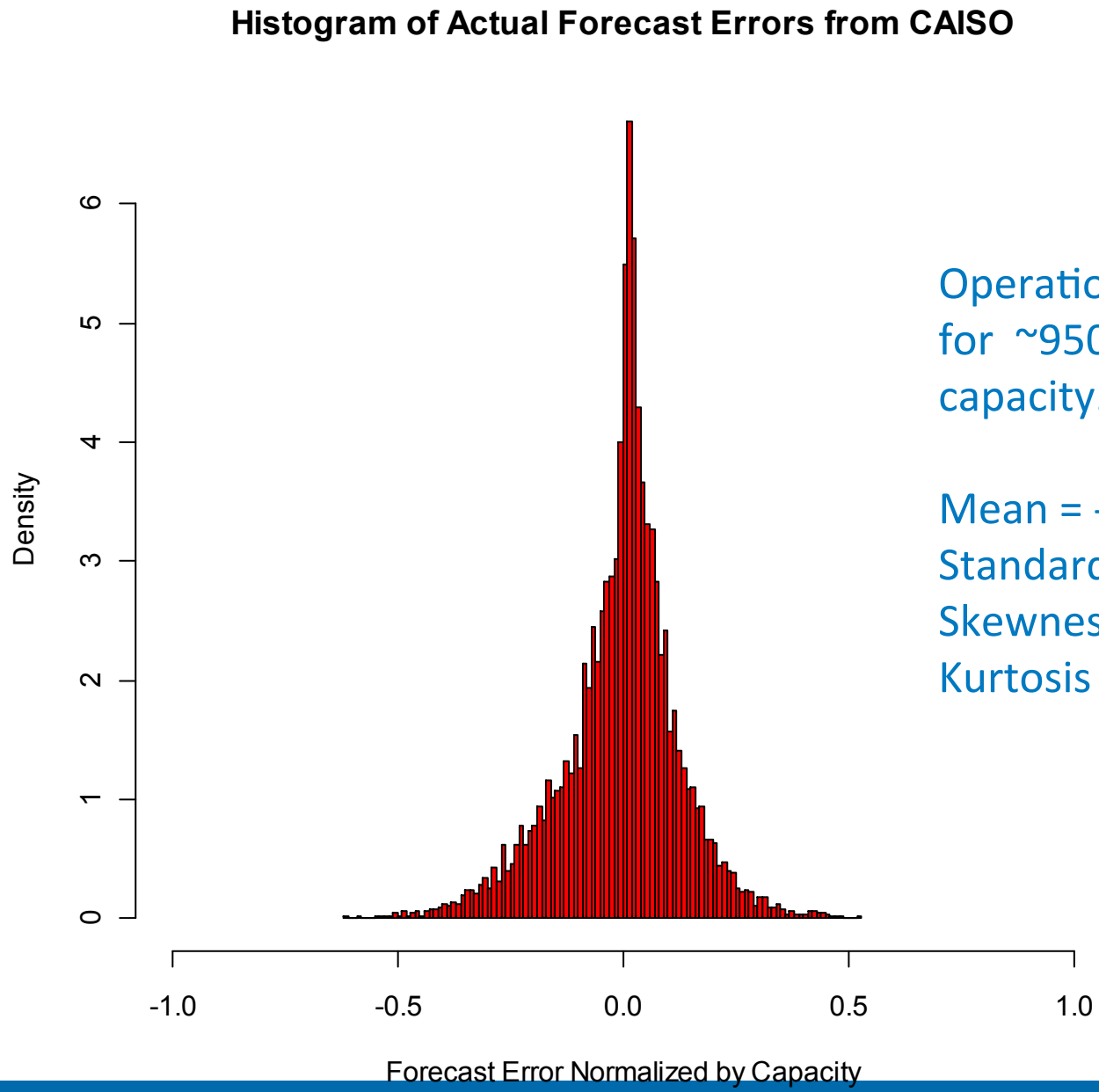
Comparison of Operational and WWSIS Forecasts - CAISO



WWSIS 1 CAISO errors for 960 MW of wind capacity, split between Altamont, Tehachapi, San Gorgonio and Solano sites.

Mean = 0.044
Standard deviation = 0.222
Skewness = -0.061
Kurtosis = 1.680

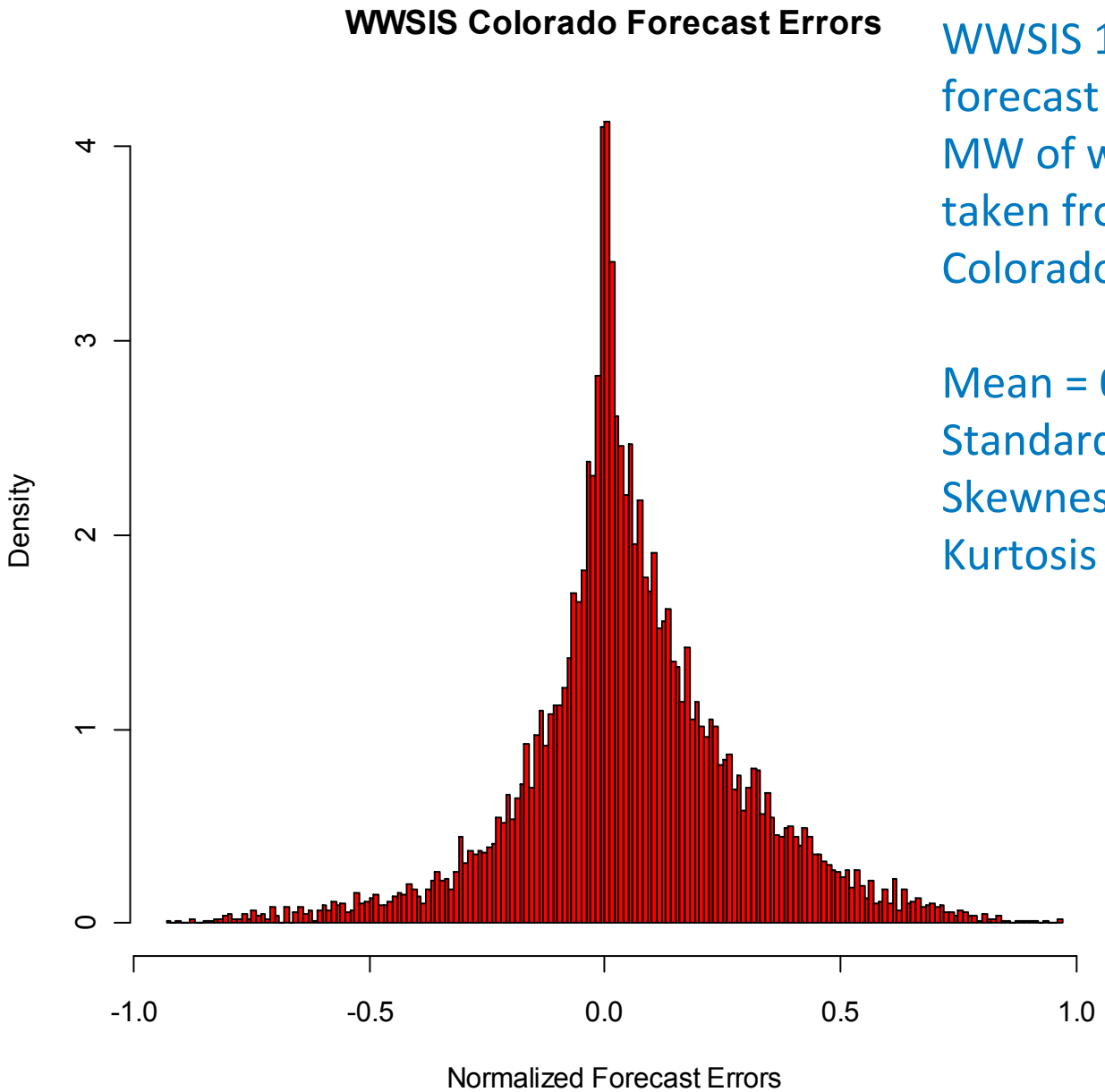
CAISO Day-Ahead Forecast Errors



Operational CAISO errors for ~950 MW of wind capacity.

Mean = -0.004
Standard deviation = 0.130
Skewness = -0.393
Kurtosis = 1.503

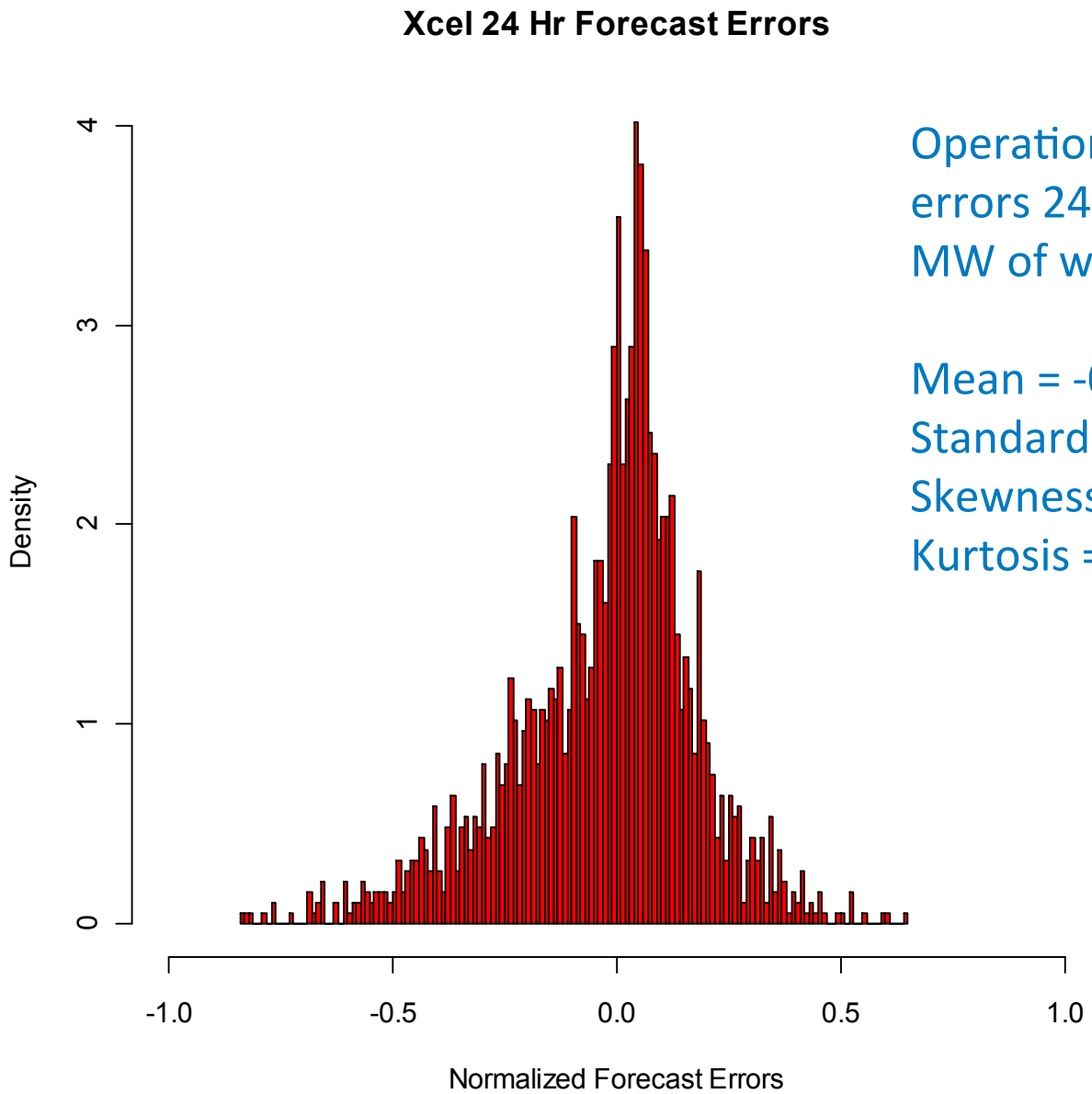
Comparison of Operational and WWSIS Forecasts - Xcel



WWSIS 1 Day-ahead forecast errors for 300 MW of wind capacity, taken from northern Colorado sites.

Mean = 0.056
Standard deviation = 0.232
Skewness = -0.012
Kurtosis = 1.556

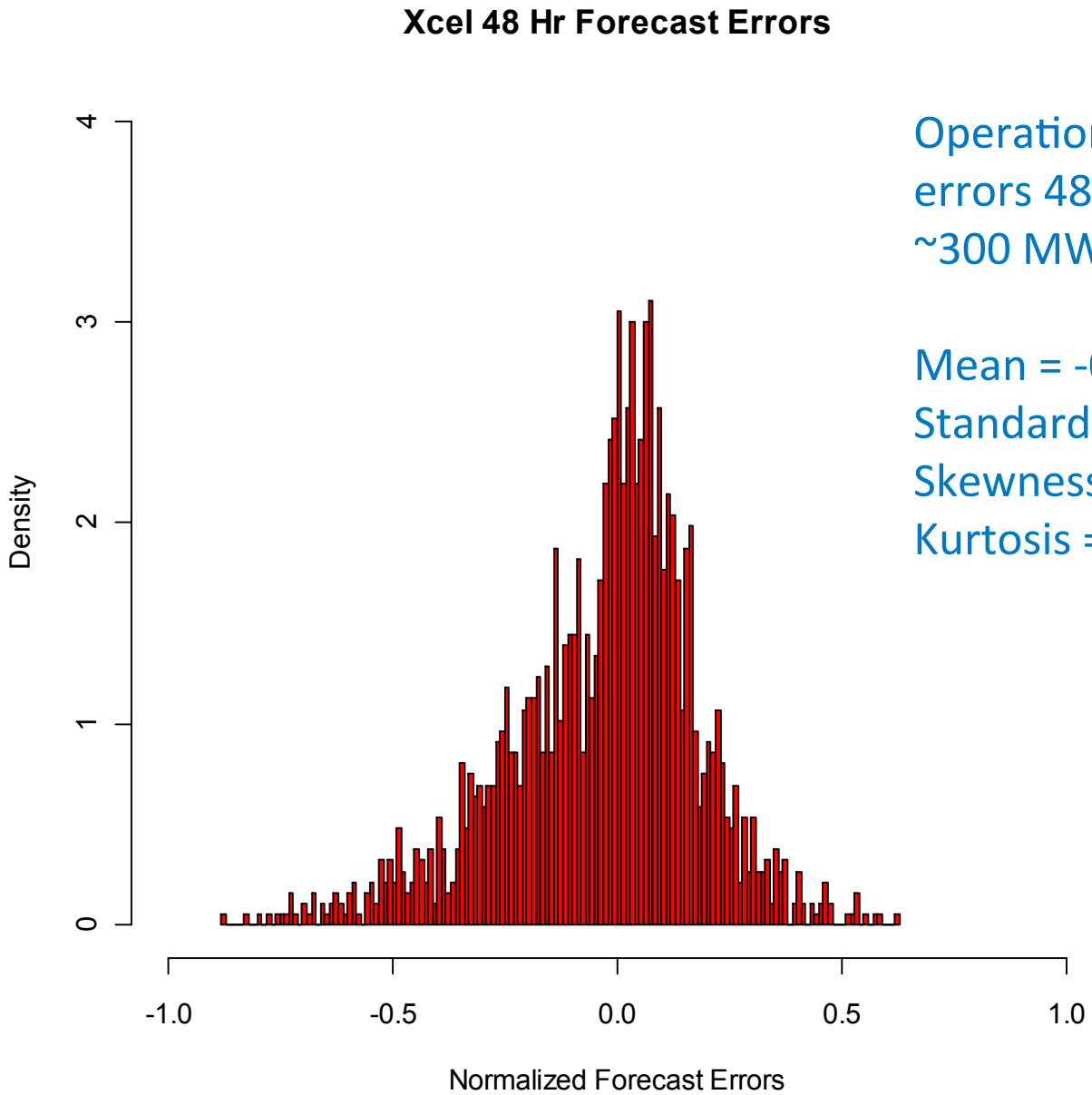
Xcel 24 Hour Forecasts



Operational Xcel forecast errors 24 hrs ahead for ~300 MW of wind capacity.

Mean = -0.024
Standard deviation = 0.205
Skewness = -0.648
Kurtosis = 1.053

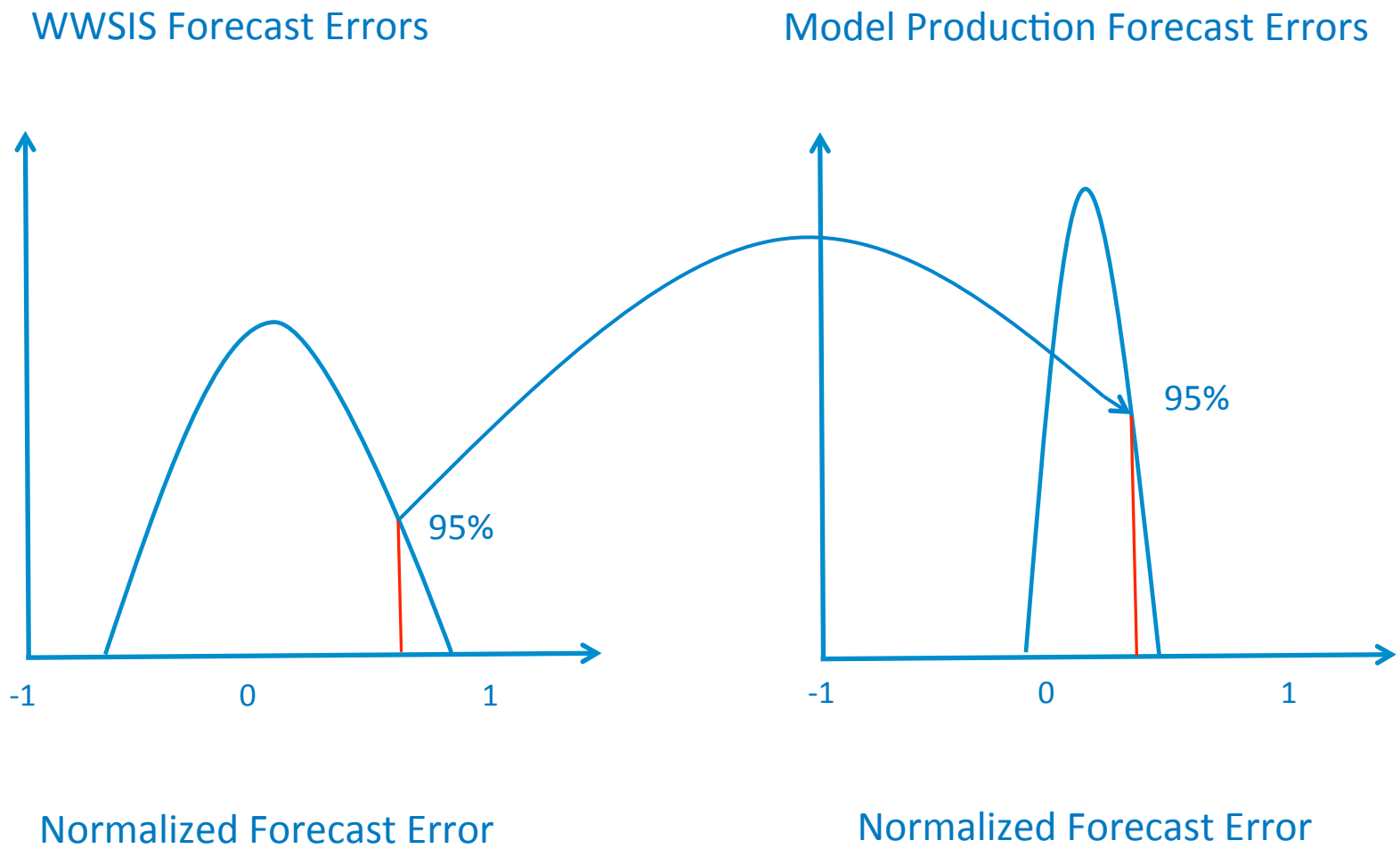
Xcel 48 Hour Errors



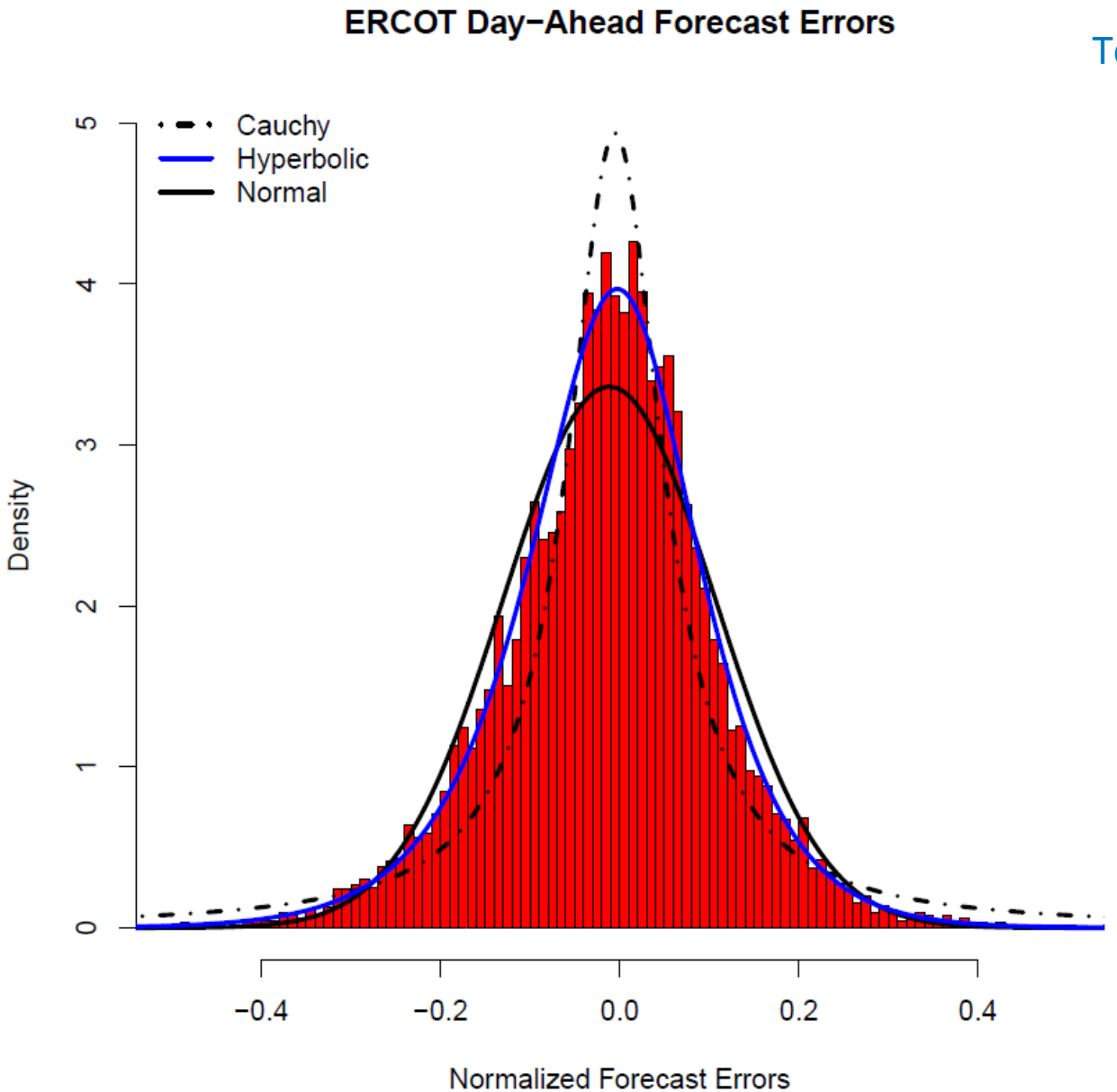
Operational Xcel forecast errors 48 hrs ahead for ~300 MW of wind capacity.

Mean = -0.031
Standard deviation = 0.213
Skewness = -0.618
Kurtosis = 0.853

Mapping Forecast Errors



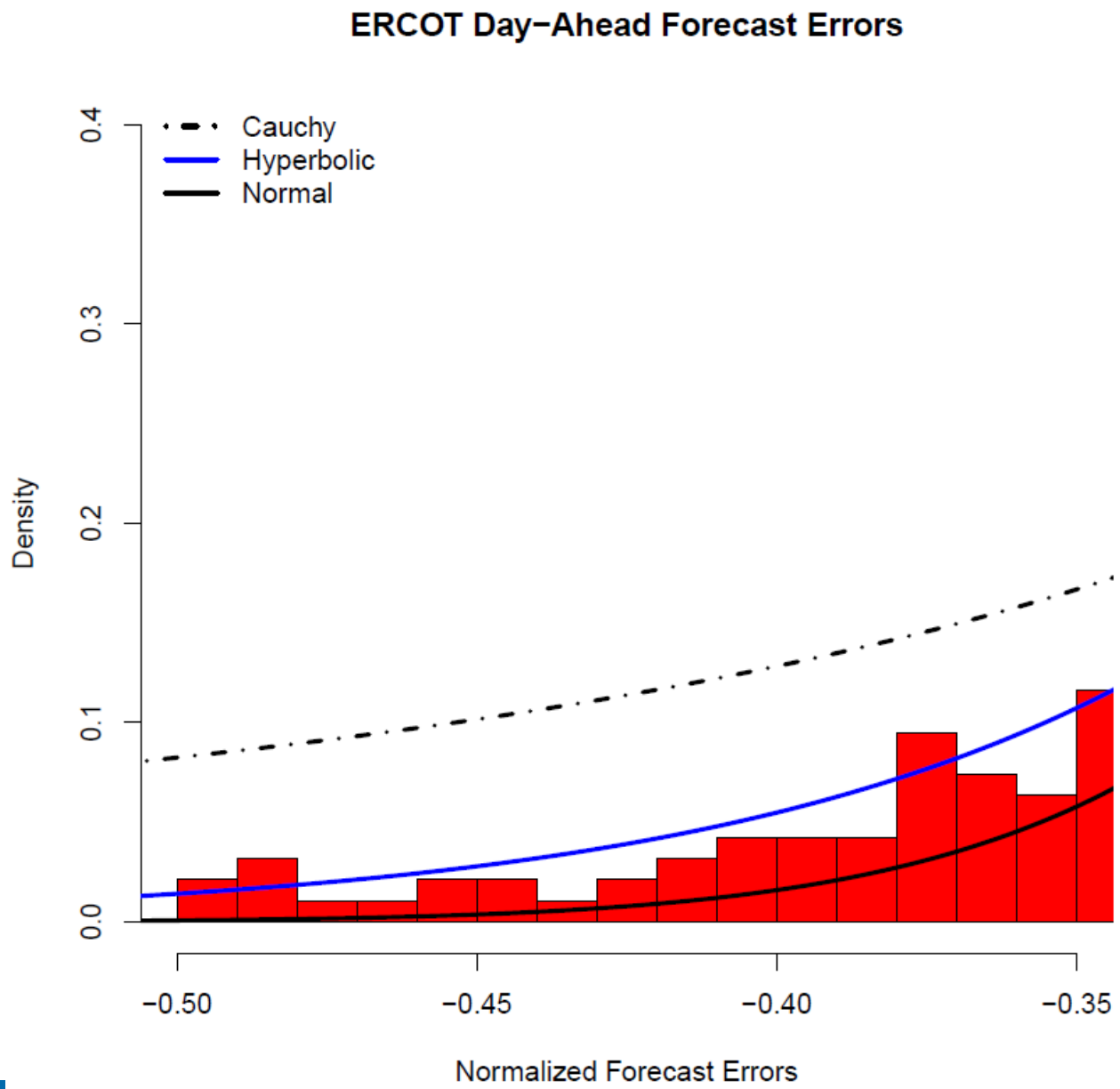
ERCOT Day-Ahead Distribution



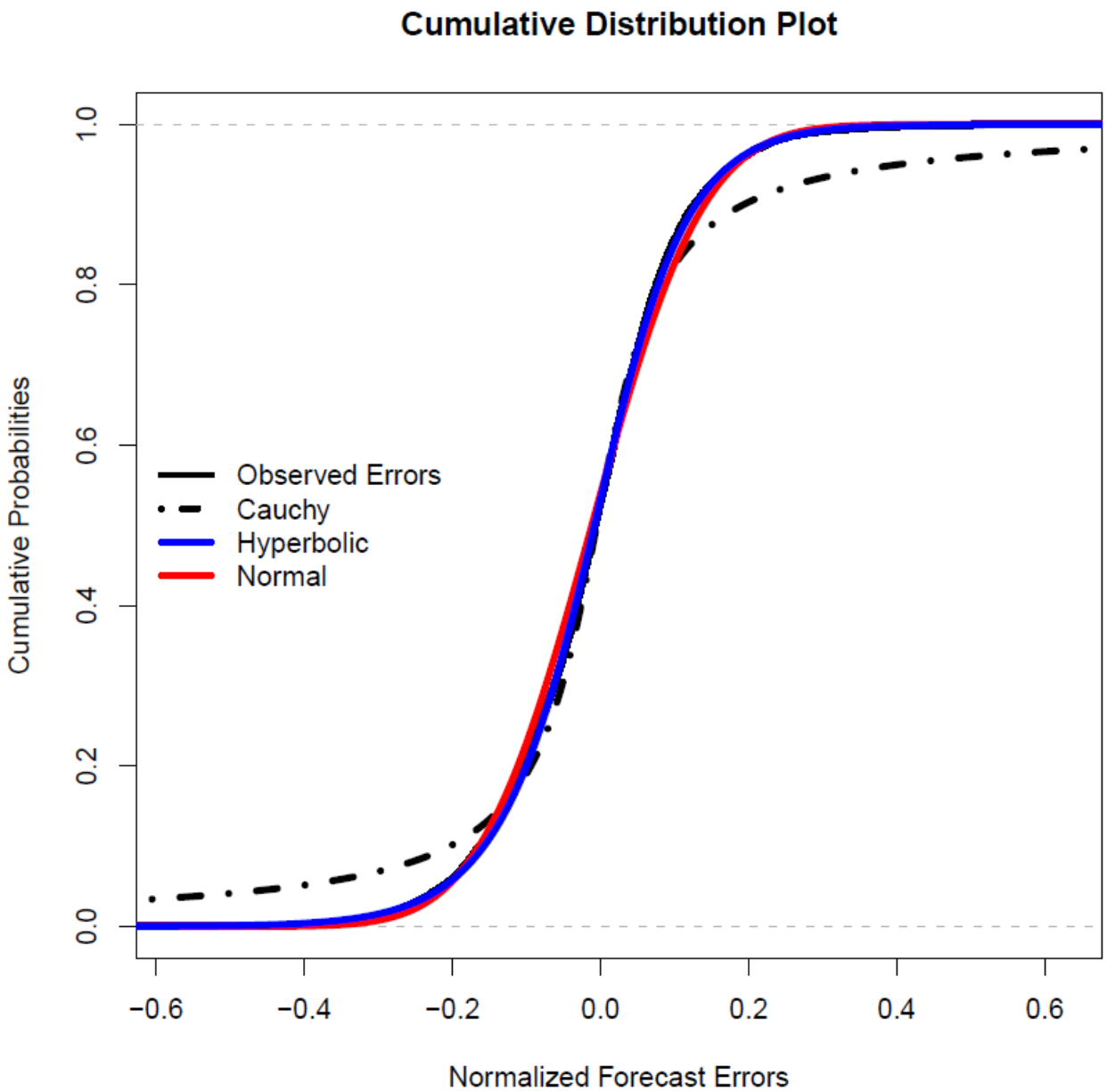
Total Capacity: ~9000 MW

κ = 1.0299
γ= -0.0616

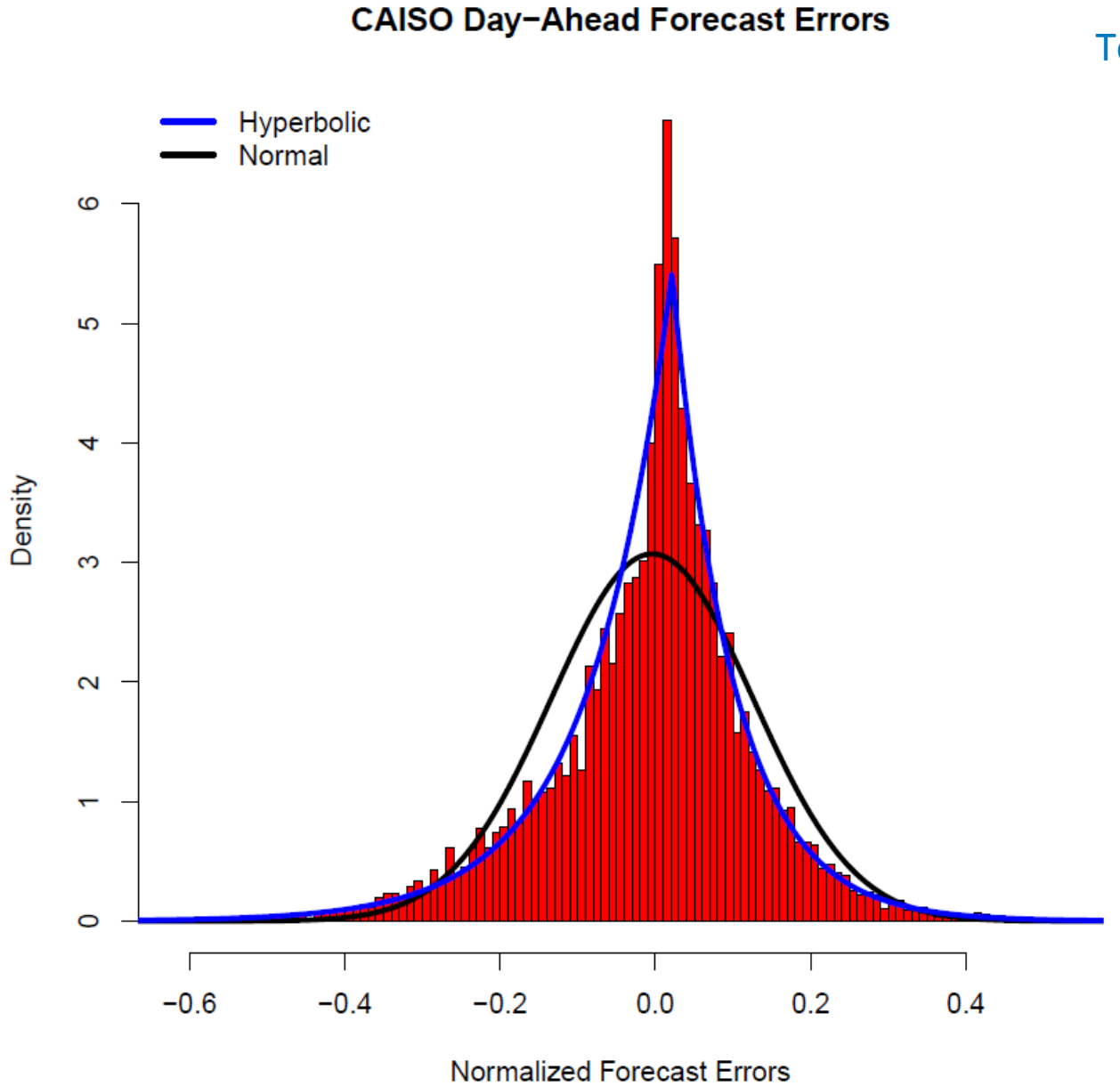
ERCOT Day-Ahead Distribution



ERCOT Day-Ahead Distribution



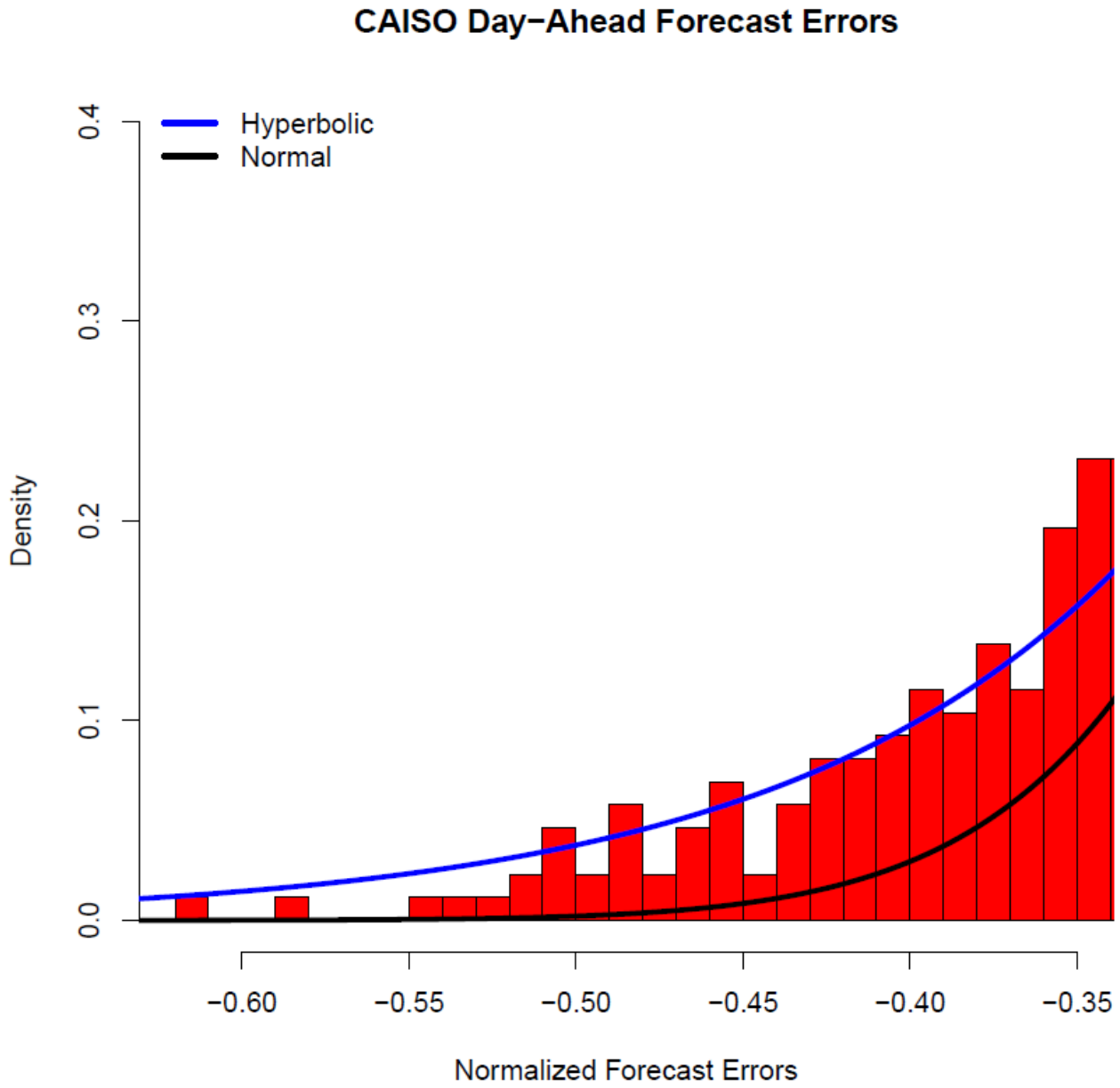
CAISO Day-Ahead Distribution



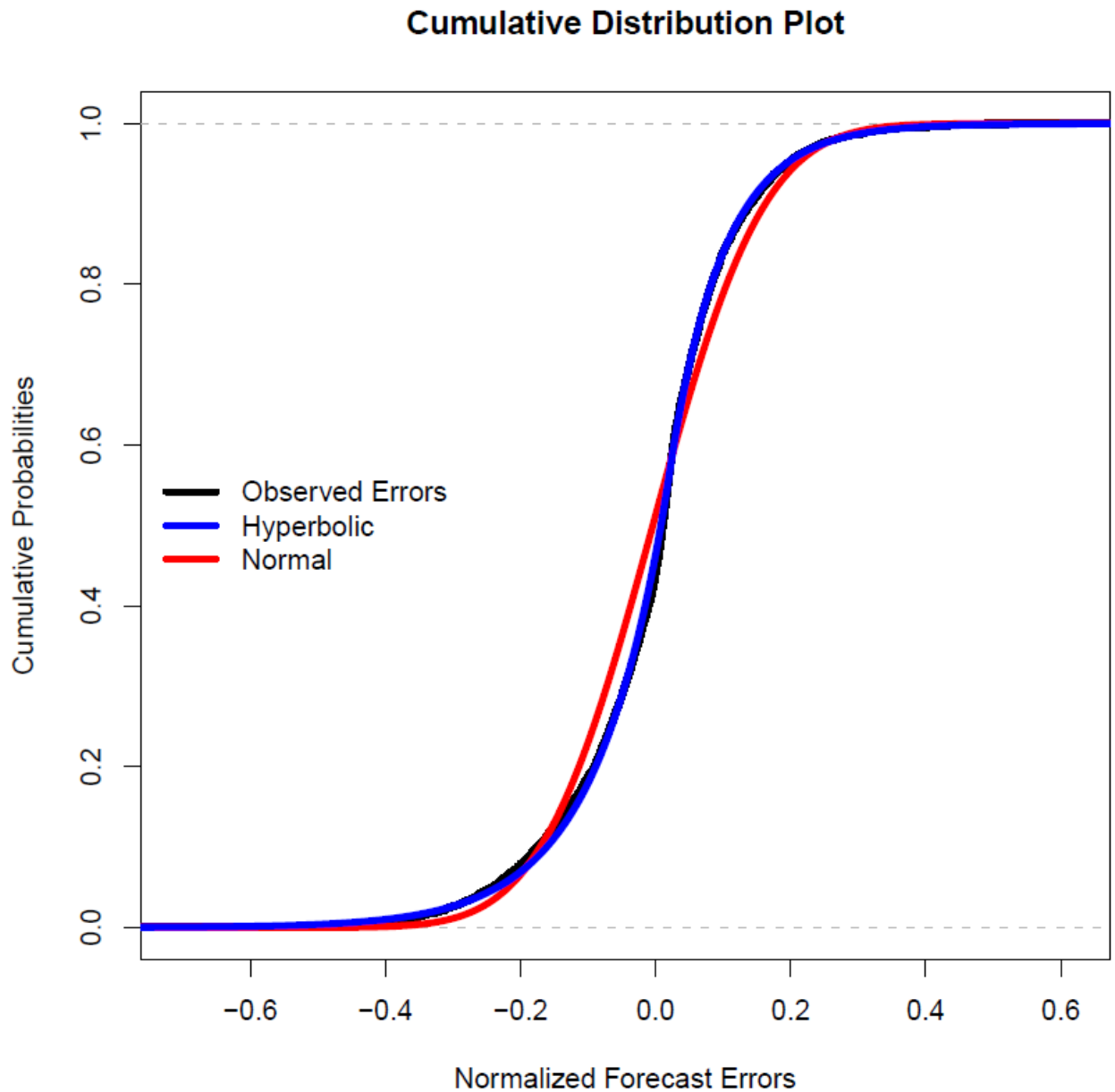
Total Capacity: ~950 MW

κ = 1.5025
γ= -0.393

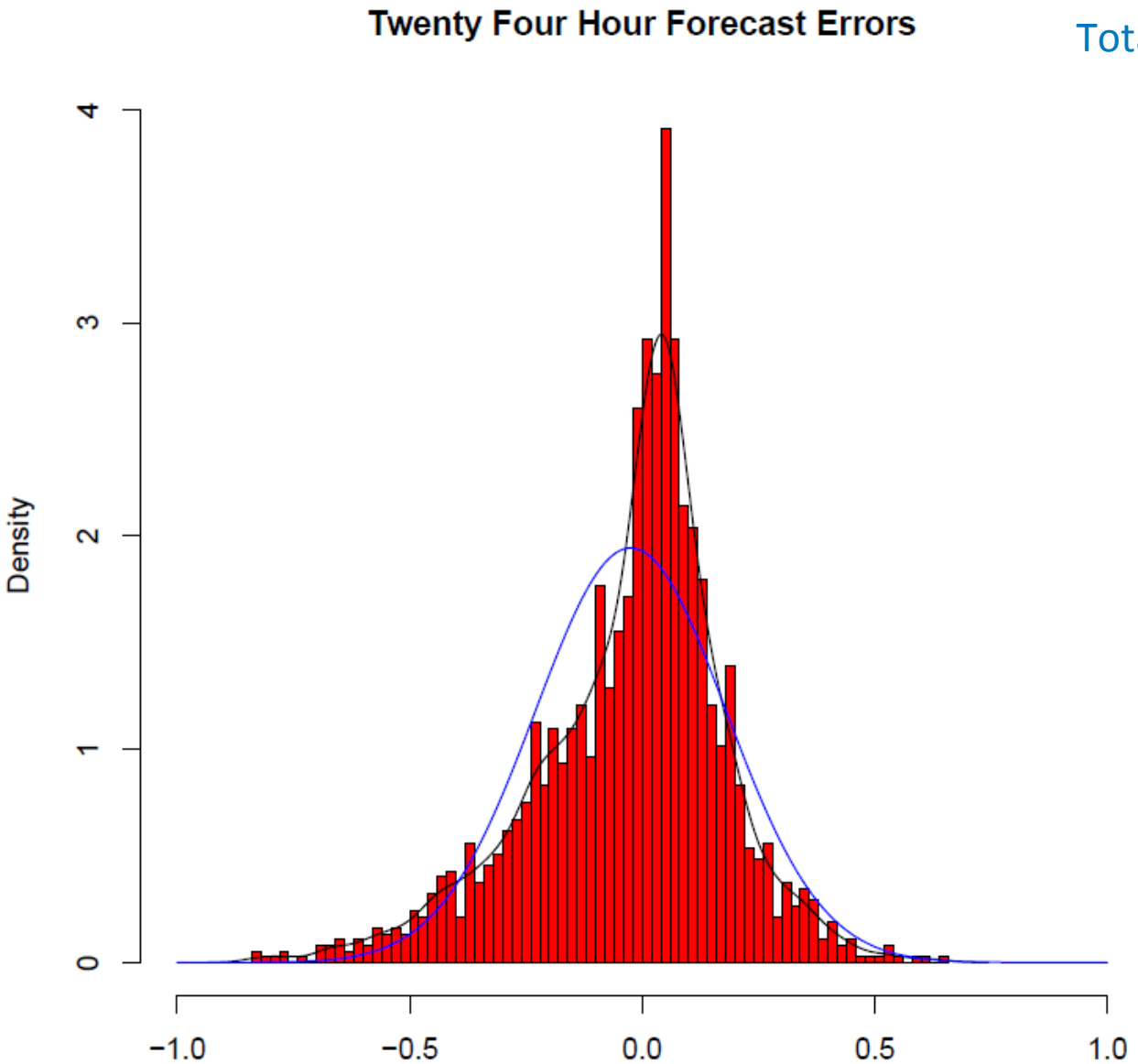
CAISO Day-Ahead Distribution



CAISO Day-Ahead Distribution



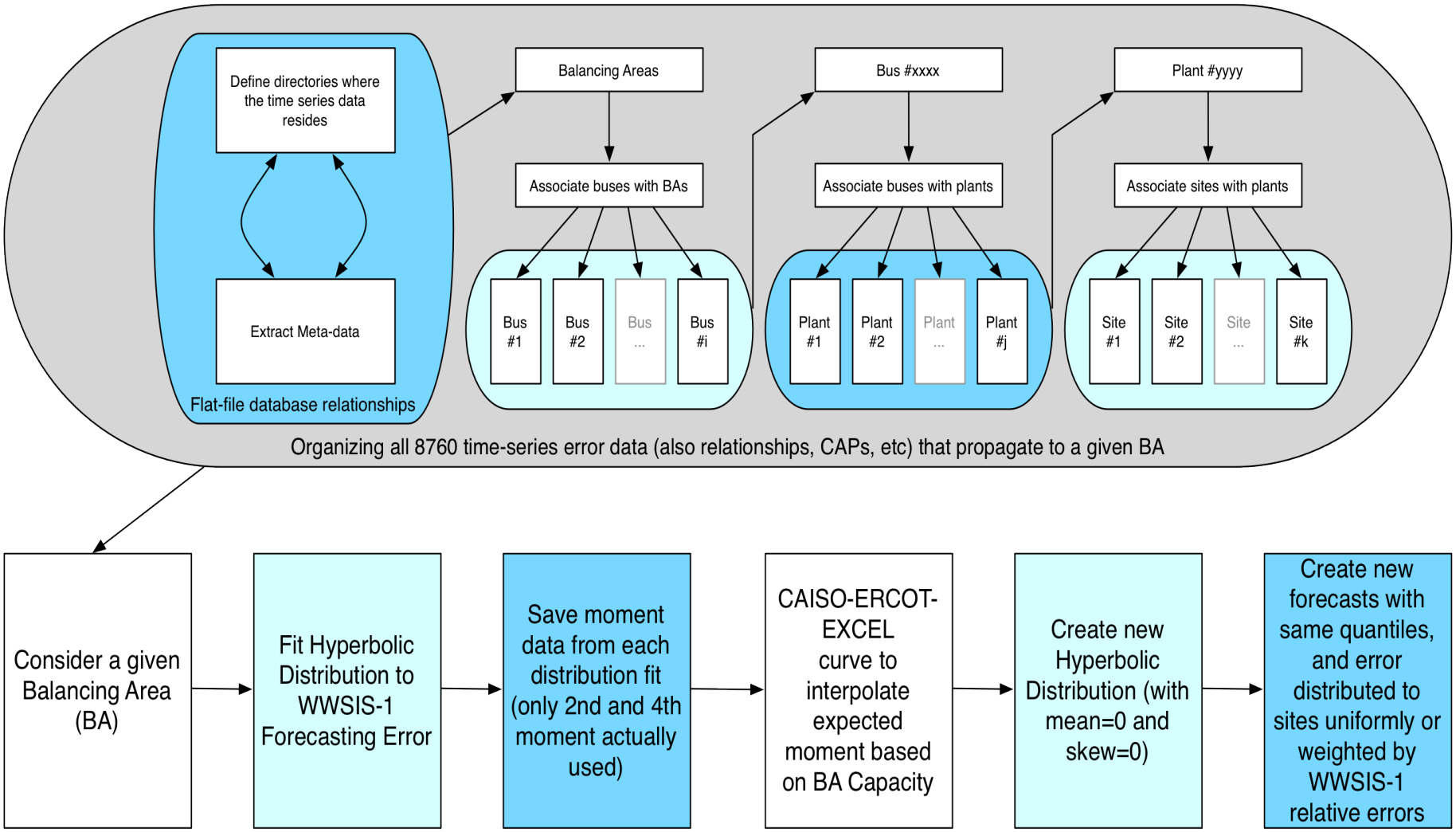
Xcel Wind Plant



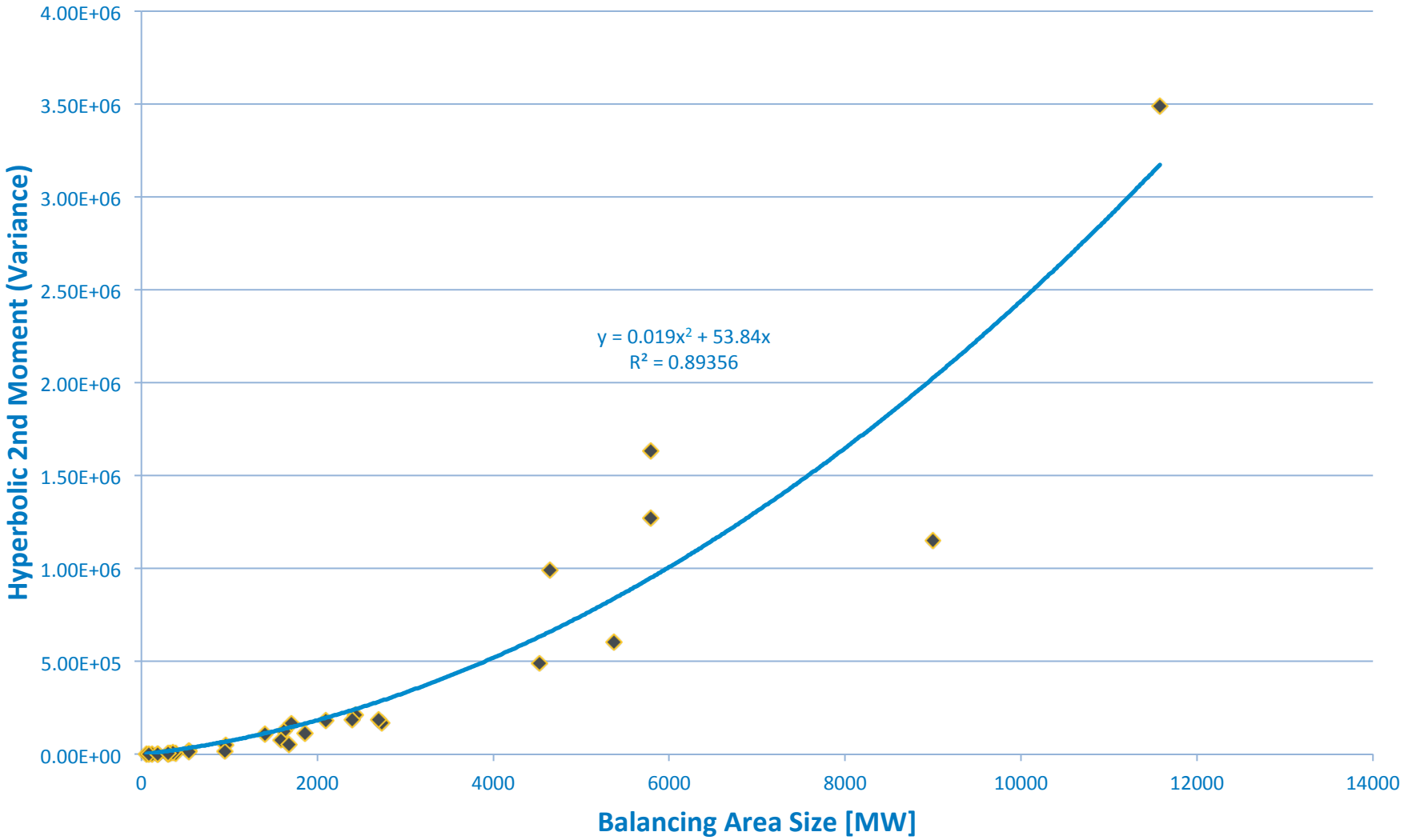
Total Capacity: ~300 MW

κ = 1.05
γ= -0.65

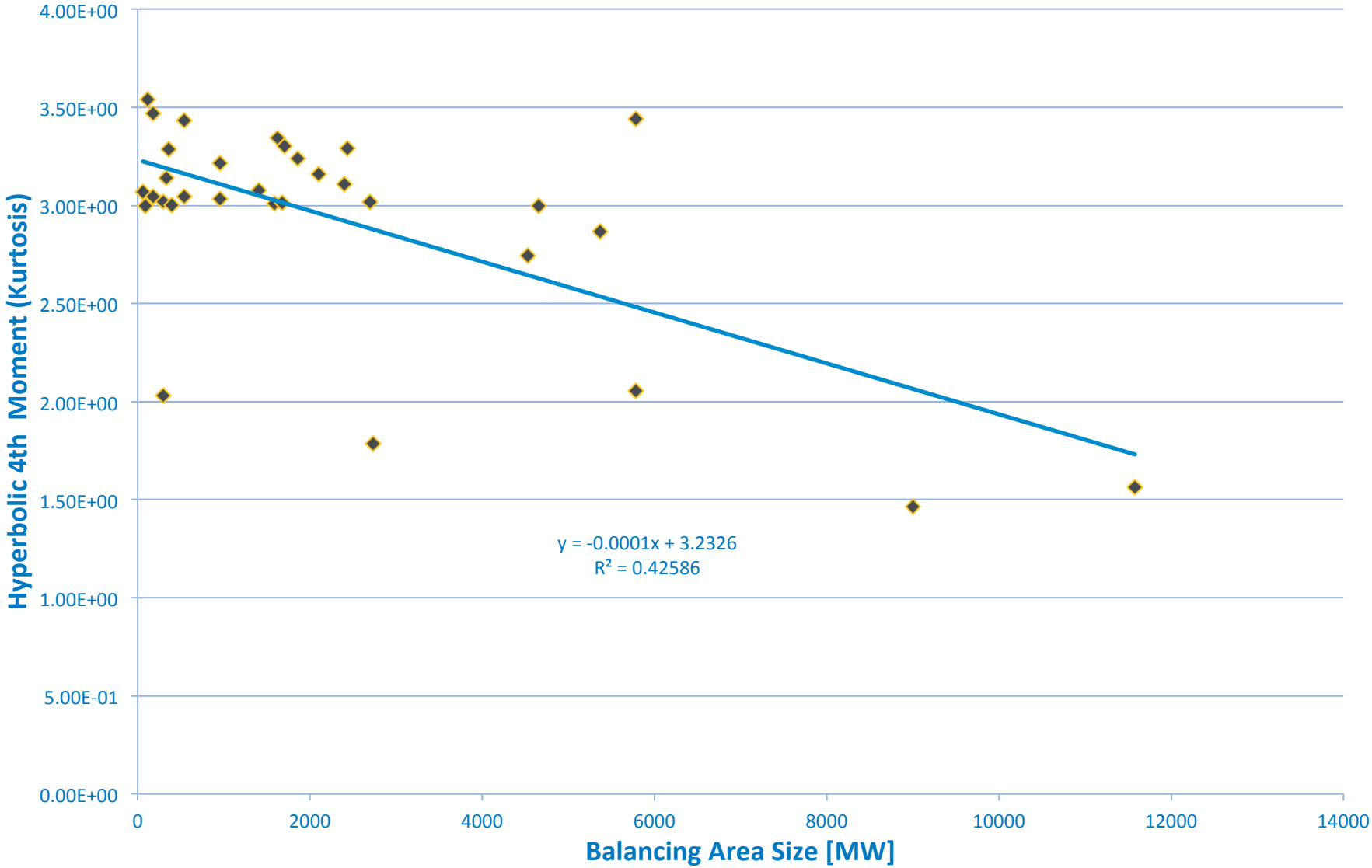
Forecasting Error Distributions Correction



Variance as f(BA Size) "Model Distributions"

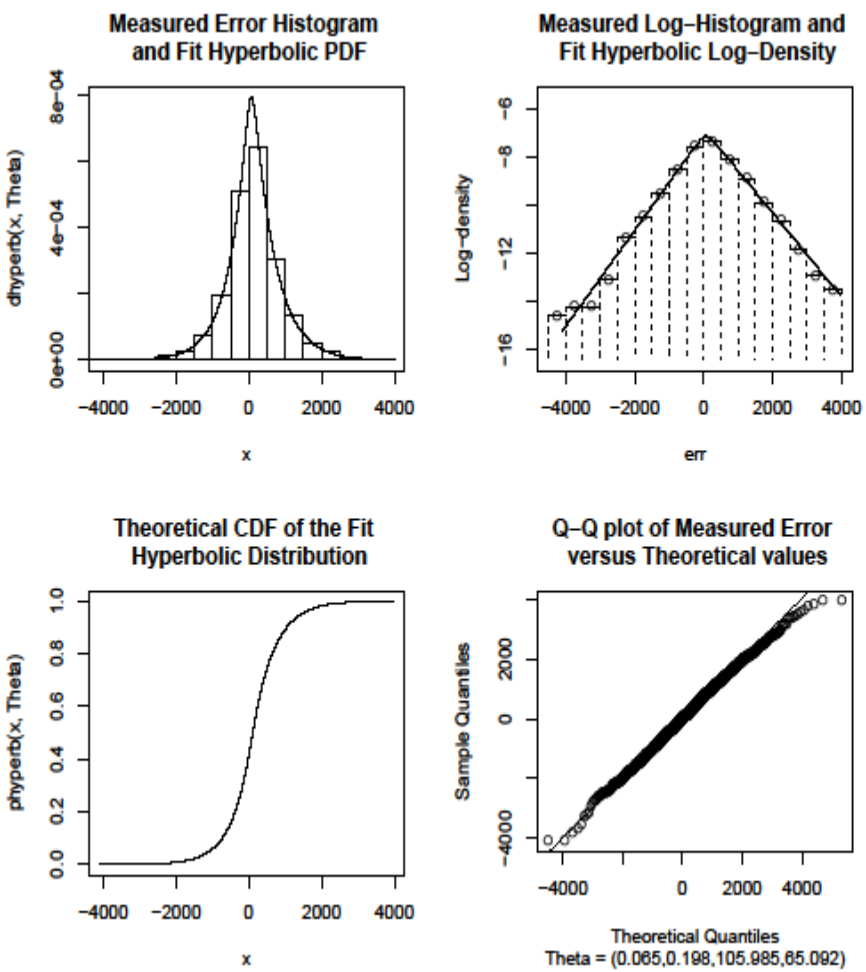


Kurtosis as f(BA Size) "Model Distributions"

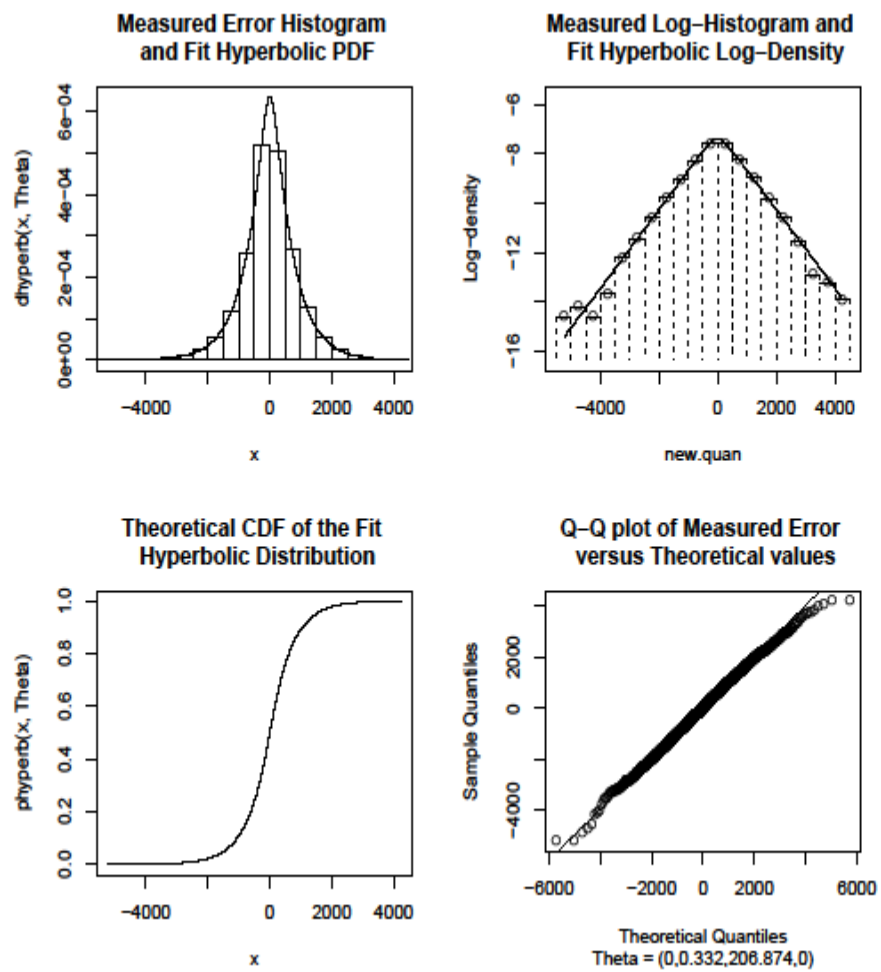


Before and After Correction: BA #9

Original



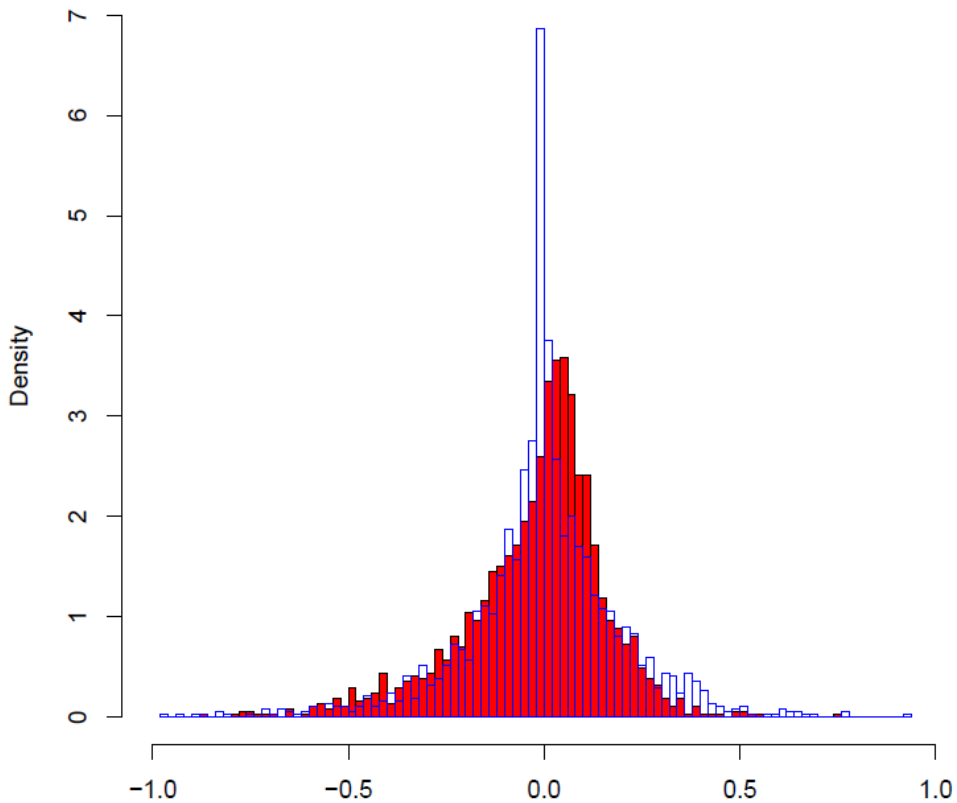
Adjusted



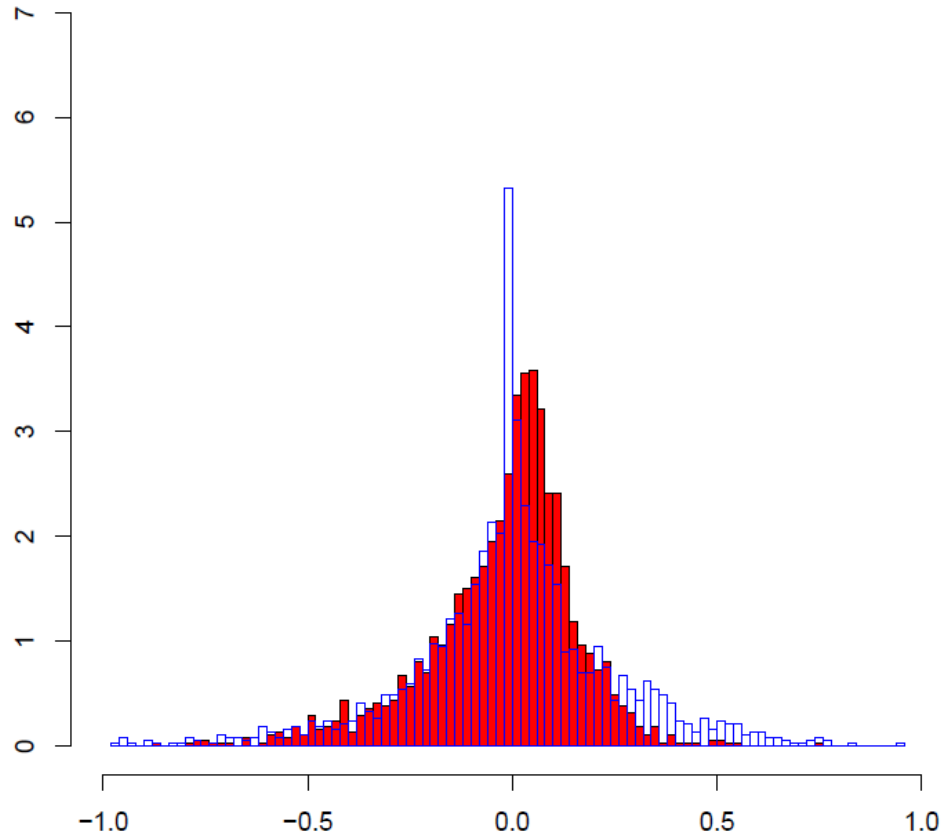
Four-Hour-Ahead Persistence Comparison

4-Hour Ahead forecasts for Xcel are in red

WWSIS 2-Hour-Ahead persistence forecasts in blue



WWSIS 3-Hour-Ahead persistence forecasts in blue



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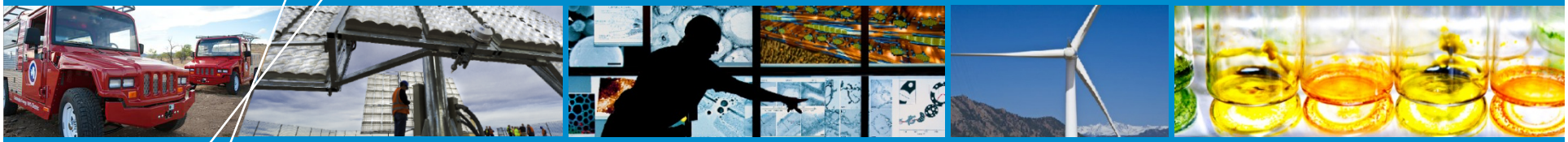


Solar Power Forecasting Errors

WWSIS I Solar Forecasts

Day-Ahead Forecasts for:

- 170 PV sites
- 2,000 CSP sites

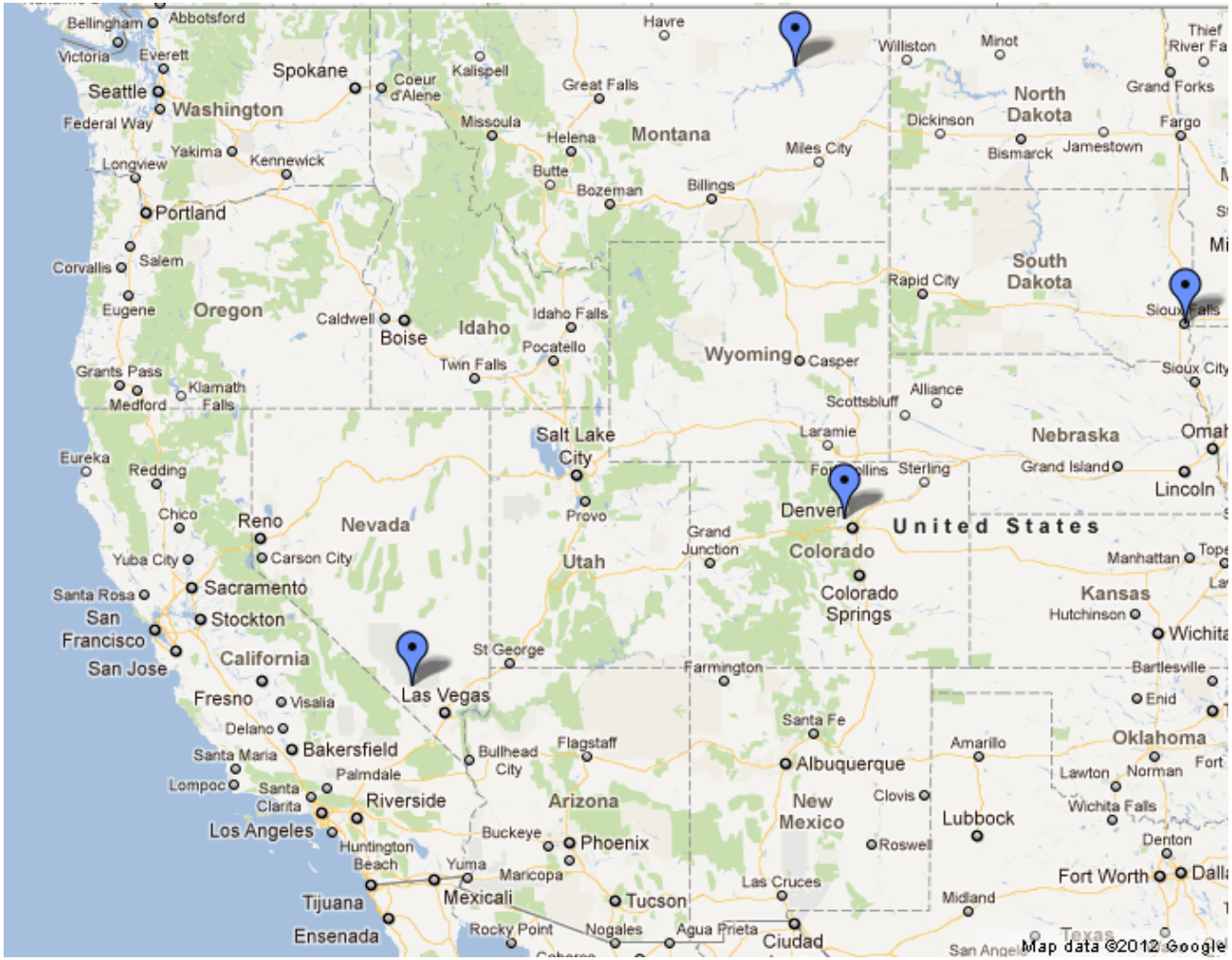
Figure 3.2 All Available Solar Sites in WECC (Each Grey Dot Represents 100 MW)

Solar Forecasting Data

- **Working with SUNY – Albany Atmospheric Science Research Center to get data on solar forecasting errors**
- **Two different forecasting services:**
  - National Digital Forecast Database (NDFD) forecasts produced by the National Weather Service that are utilized as part of SolarAnywhere
  - The Global Environmental Monitoring System (GEMS) forecast produced by the Canadian weather service
- **One year of data for day-ahead forecasts**
  - Four sites:
    - Desert Rock, NV
    - Boulder, CO
    - Fort Peck, MT
    - Sioux Falls, SD

SUNY – Albany Forecast Data

- Four Sites:
  - Boulder, CO
  - Desert Rock, NV
  - Sioux Falls, SD
  - Fort Peck, MT
- Two Forecasts:
  - GEMS
  - NDFD
- Two Forecast Periods:
  - Day-Ahead
  - 2-Day-Ahead



Relevant Timescales

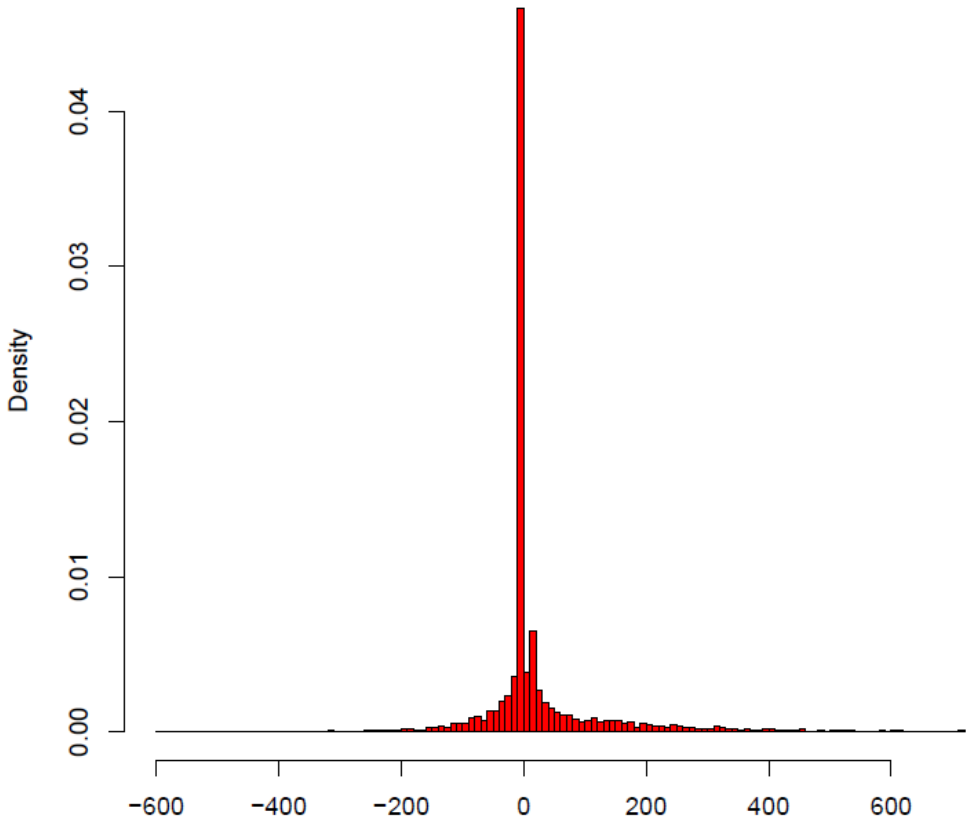
- **Day-Ahead Forecasts**
  - Used for committing thermal units with long start-up times
- **4-Hour-Ahead Forecasts**
  - Can be used to commit combined cycle units
- **1-Hour-Ahead Forecasts**
  - Used to set the dispatch levels of units

Solar Forecasting Methods: Operational Systems

- **Day Ahead (DA)**
  - NWP with statistical post-processing tools such as Model Output Statistics (MOS)
- **Hour Ahead (HA)**
  - Based on forecast of the Clearness Index (CI): The CI is divided into levels or intervals, and for each interval of CI, different probabilistic techniques are applied to solar forecast errors. (Simple, normal distribution; More Complex: regression, machine learning and neural network or the best for each interval)

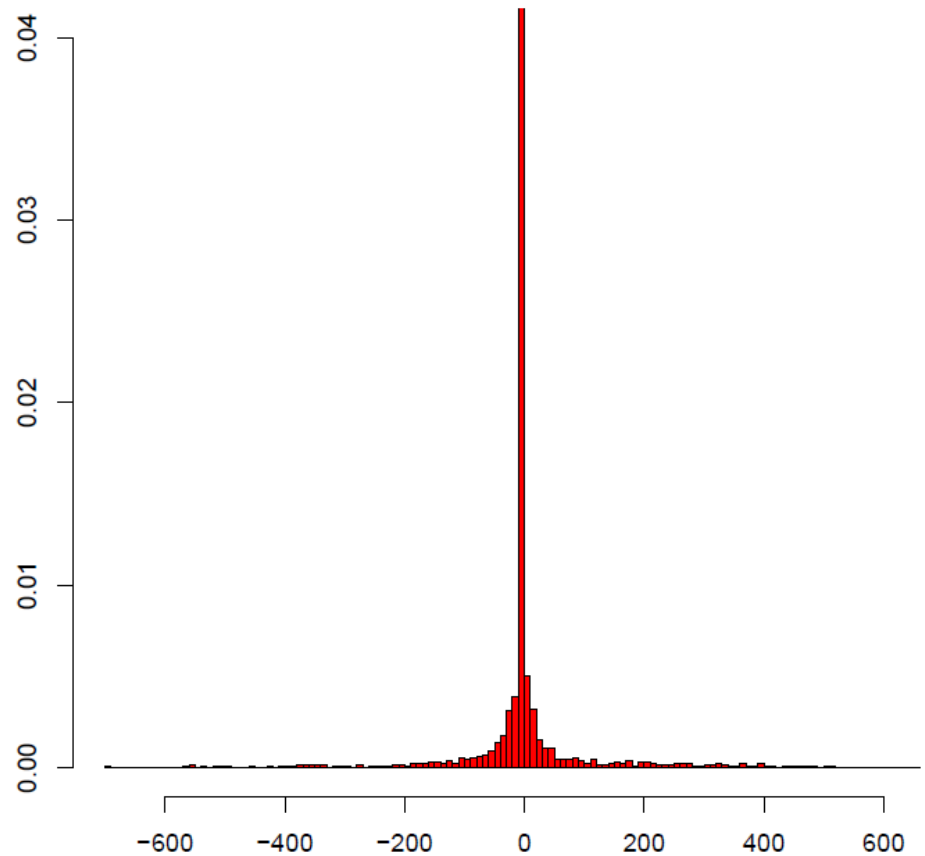
Day-Ahead Solar Forecast Comparison

Boulder – GEM Forecasts



μ = 29.01; σ = 113.72; γ = 1.96; κ = 8.25

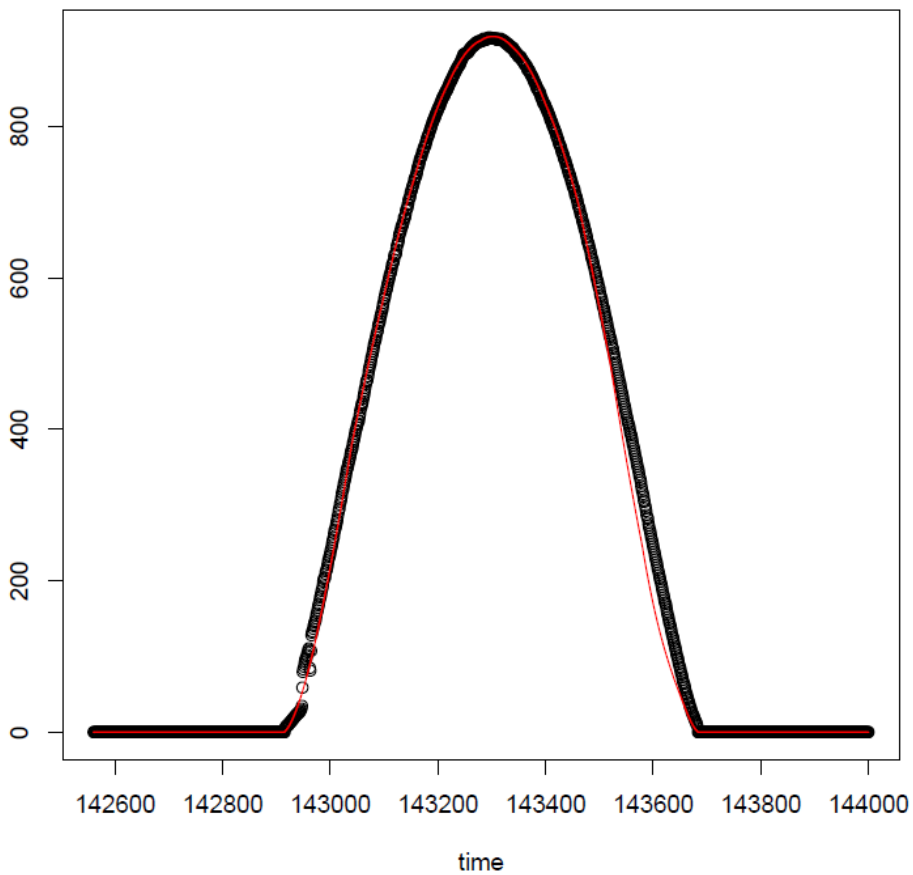
Boulder – WWSIS Site

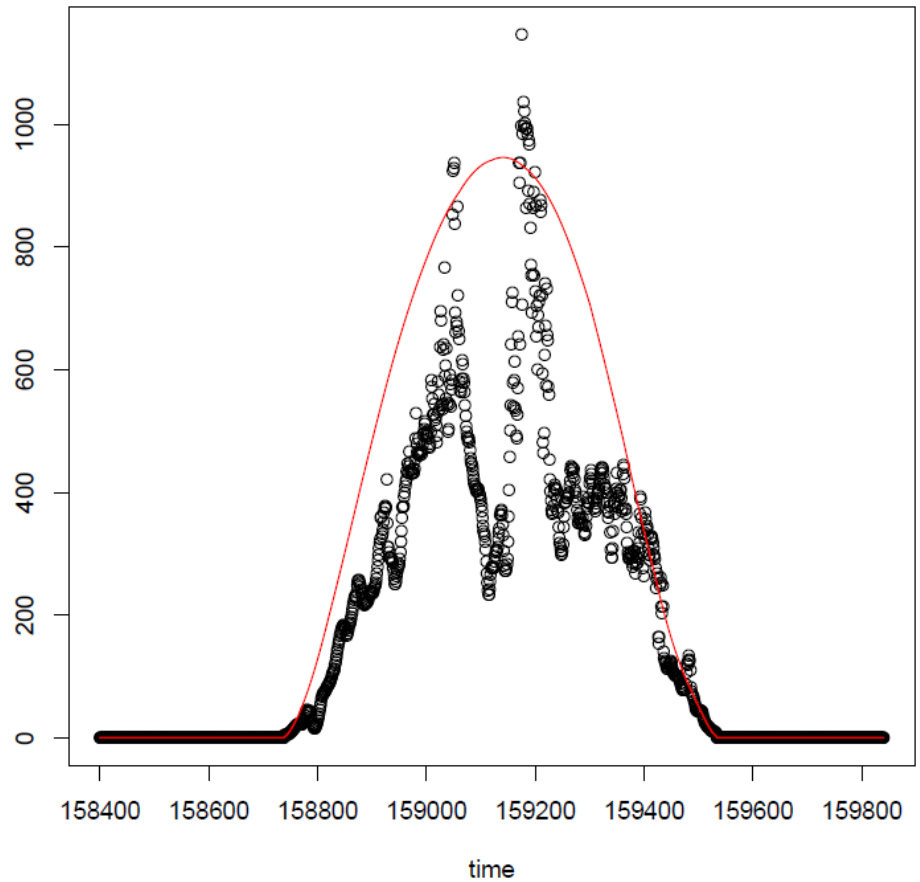


μ = -0.79; σ = 120.05; γ = -0.59; κ = 10.46

Four-Hour-Ahead and One-Hour-Ahead Forecasts

- **Can use persistence of cloudiness:**
  - Actual output from previous hours
  - Clear sky value





Questions?

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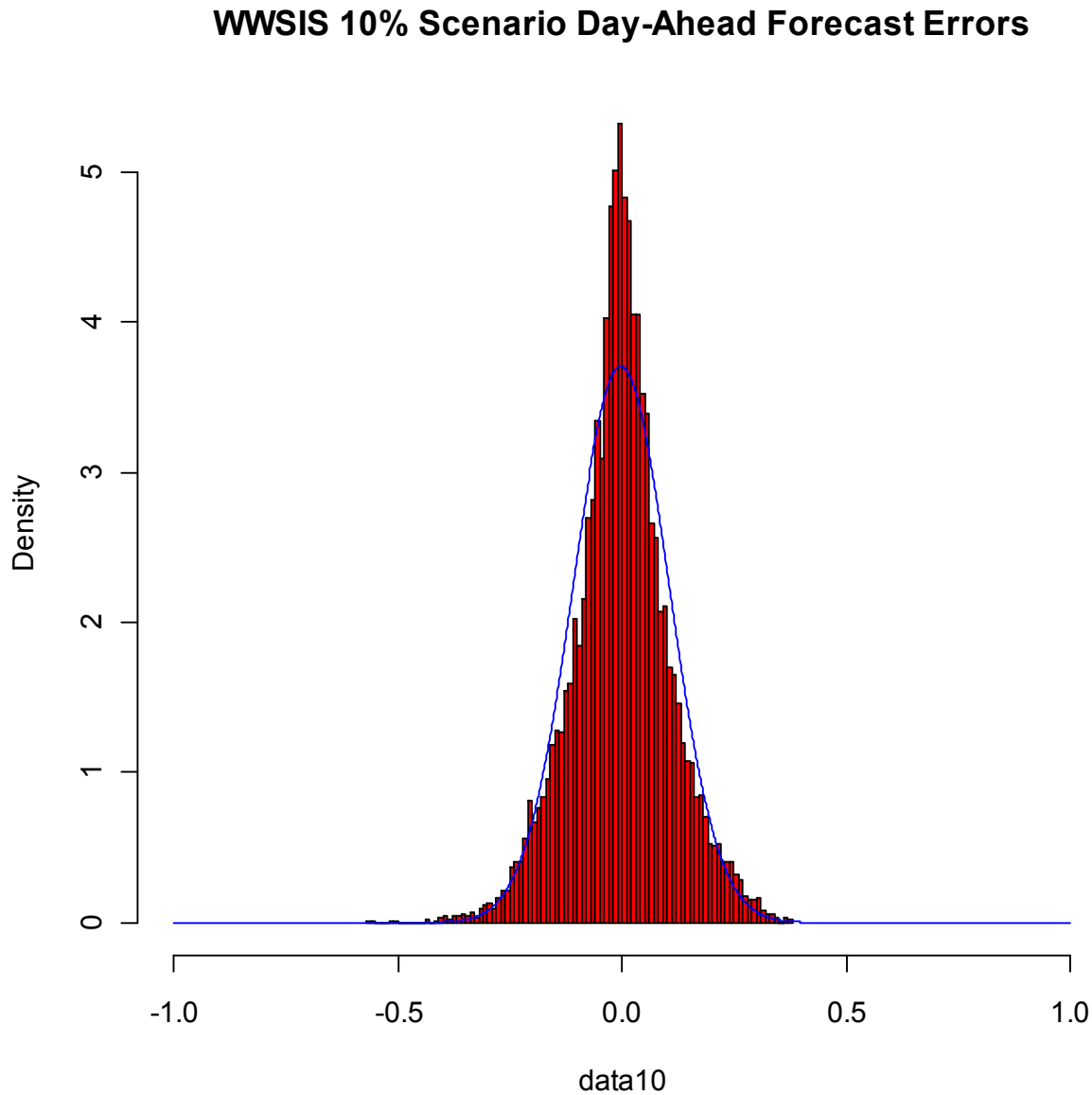
- gregory.brinkman@nrel.gov

- Anthony Florita
- 303-275-4328
- anthony.florita@nrel.gov

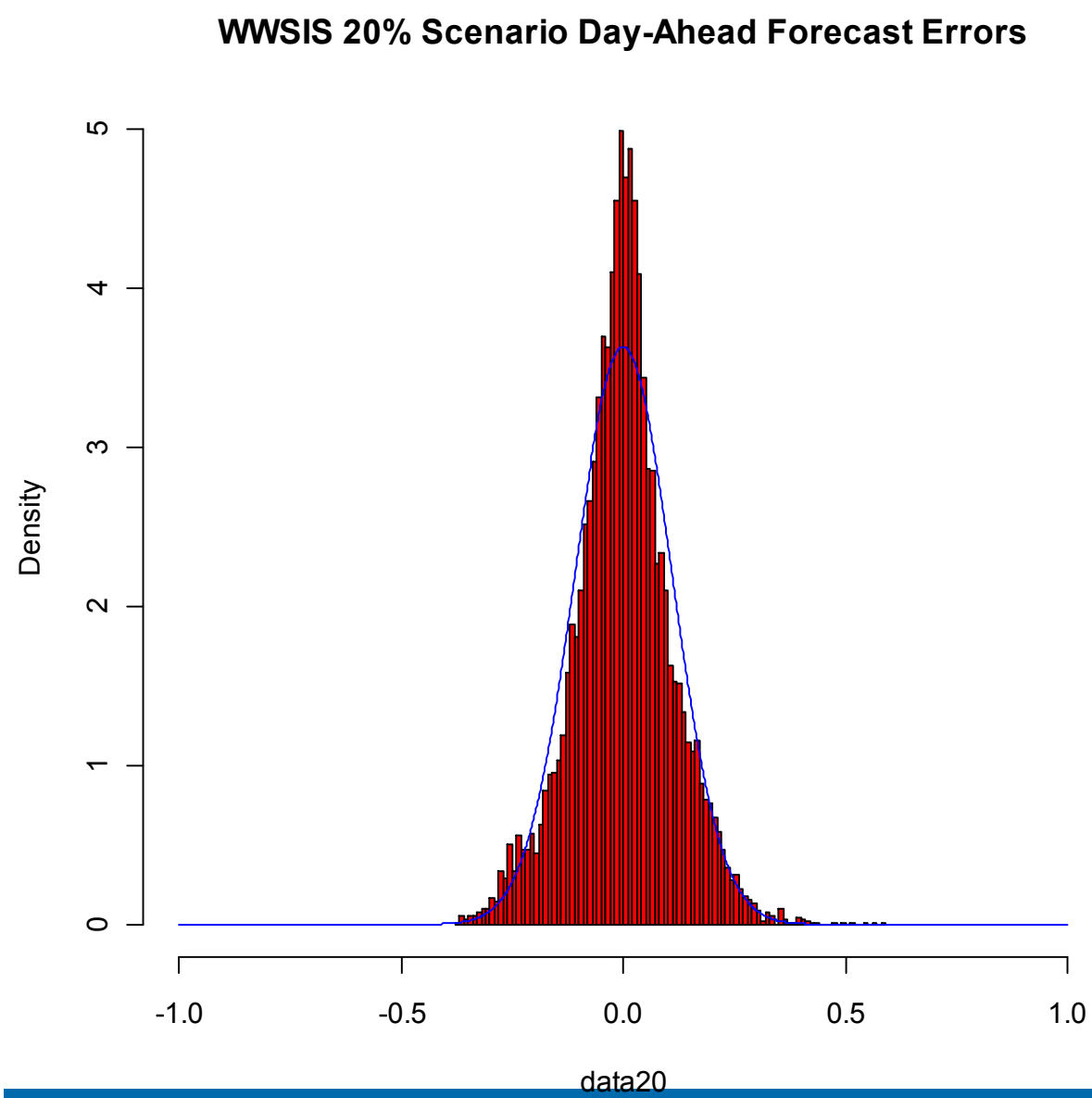
WWSIS I Day-Ahead Forecast Errors



Total Capacity: 9,600 MW

$\kappa = 0.95$
$\gamma = -0.094$

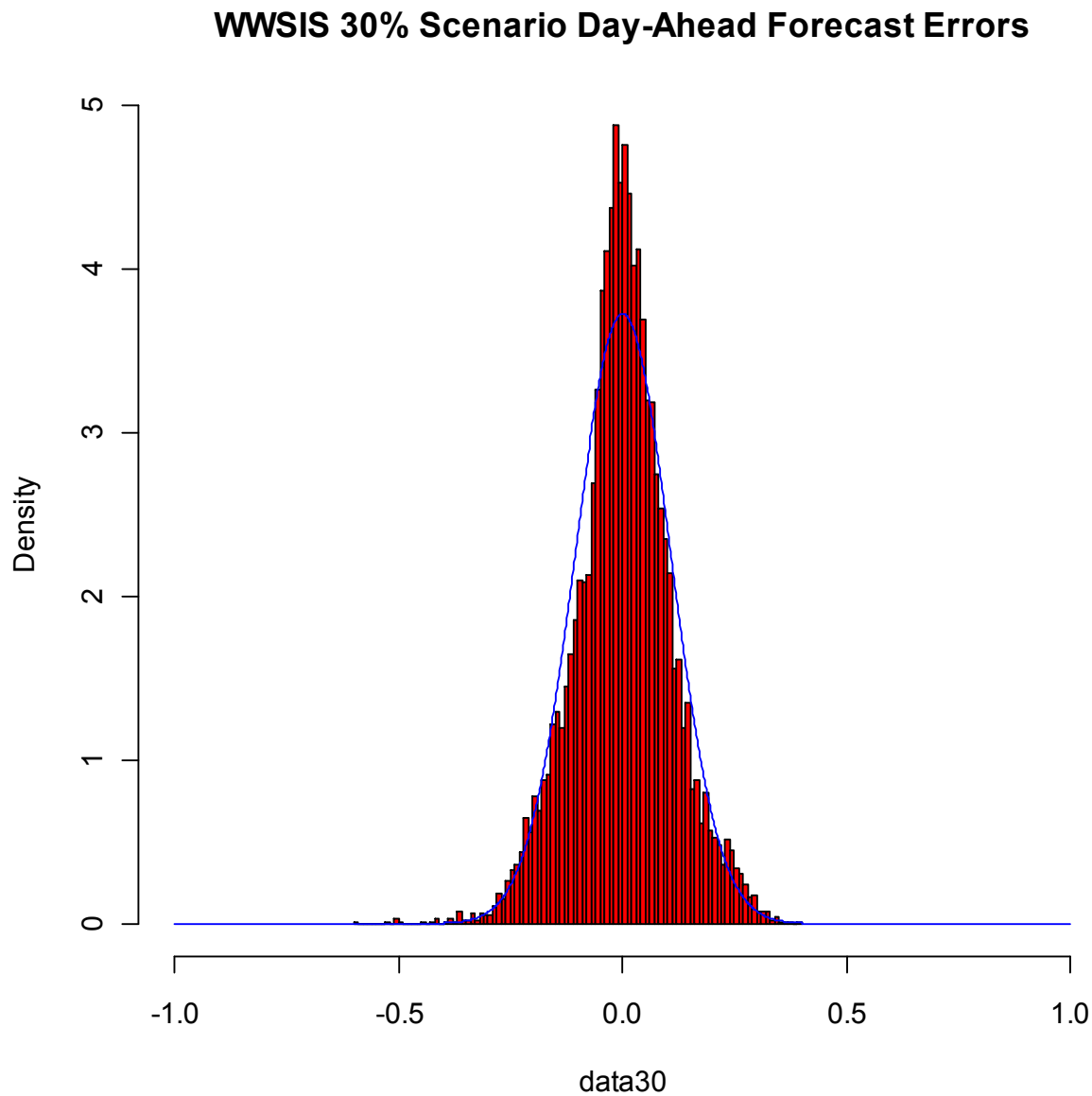
WWSIS I Day-Ahead Forecast Errors



Total Capacity: 18,180 MW

κ = 0.96
γ= 0.082

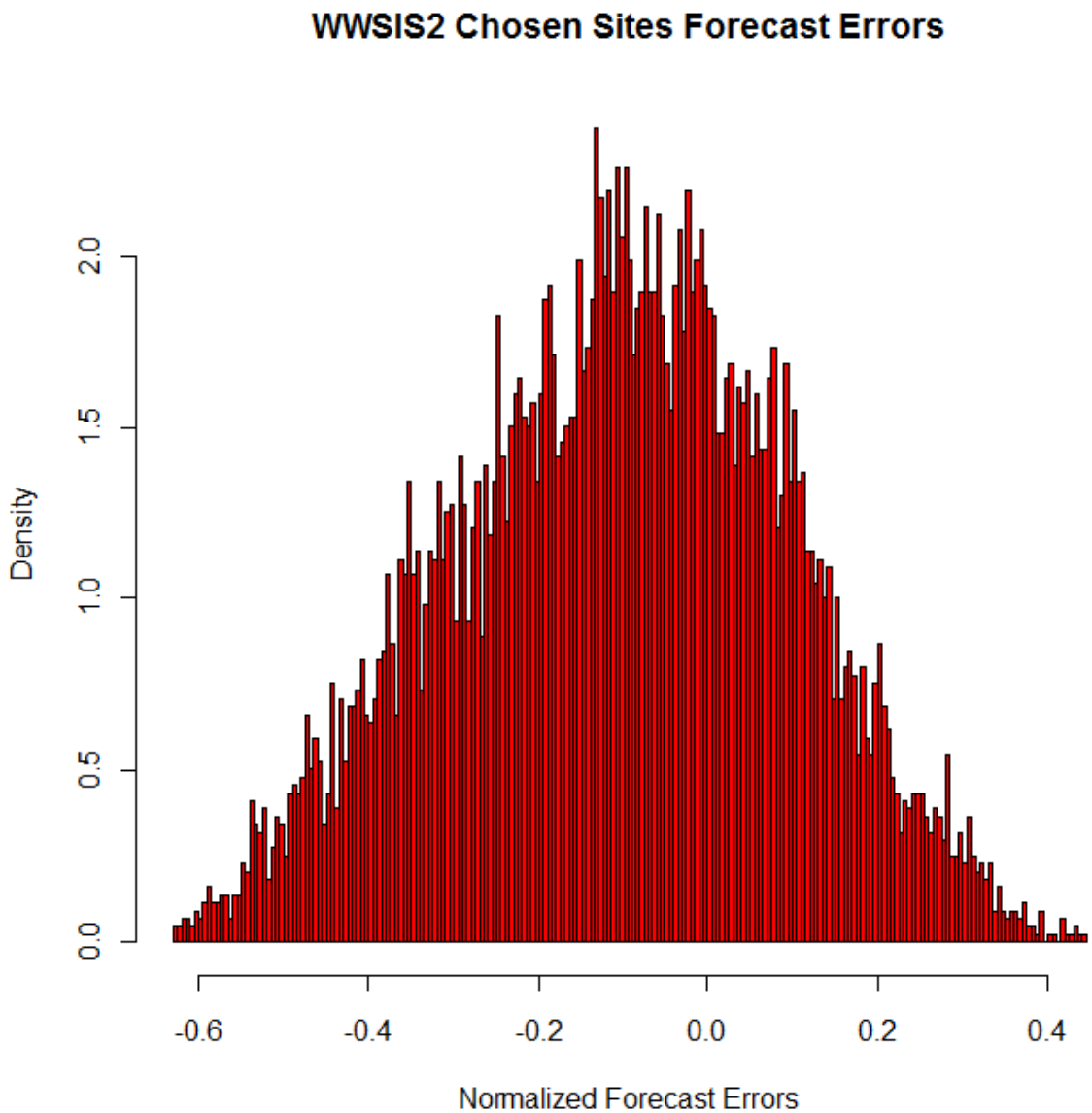
WWSIS I Day-Ahead Forecast Errors



Total Capacity: 26,760 MW

κ = 0.92
γ= -0.103

WWSIS 2 Day-Ahead Forecast Errors



Total Capacity: 69,210 MW

κ = -0.44
γ= -0.089