Extreme Weather and the Grid of the Future

Justin Sharp, Ph.D.
Collaborators:
Josh Novacheck, Marty Schwarz, Zack Tzavelis, Grant Buster, Michael Rossol (NREL)

Your assumptions are your windows on the world. Scrub them off every once in a while, or the light won't come in.

Alan Alda, actor, writer and director

Klondike Wind Farm. Photo © Justin Sharp

Sharply Focused
Understanding Renewable Resources

☎ 503-709-9781
justin@sharply-focused.com

Meteorology and Market Design For Grid Services Workshop Online COVID Edition, June 18, 2020

Disclaimer

- Purpose of Presentation
  - To obtain external technical review on methods and analysis and promote robust technical discussion within ESIG community
  - Not to convey findings or conclusions to take away or inform activities
  - Not posted in presentation repository for the meeting
- State of Content Presented
  - Data, results, conclusions, and interpretations presented have received limited review by technical experts outside NREL
  - Does not constitute a comprehensive treatment of the issues discussed or specific advice to inform decisions
- Request to Audience
  - Provide review feedback during or after the session
  - Not for public use - do not distribute, quote, or cite

Material includes unpublished preliminary data and analysis that is subject to change

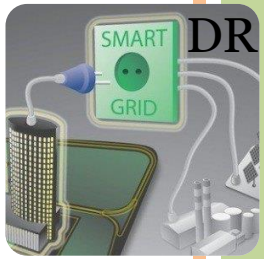
Objectives

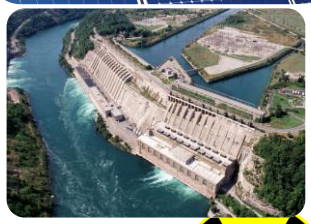
- Context: Meteorology and the energy transition
- Provide guidance on important ways the impact of meteorology will change for the grid of the future through referencing a subset of preliminary results from the NREL Tail Events project.

Sharply Focused
Understanding Renewable Resources

☎ 503-709-9781
justin@sharply-focused.com

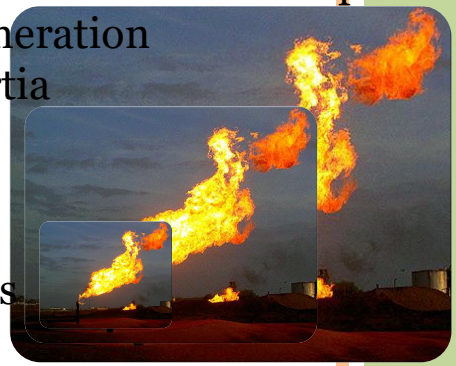
The Renewable Energy Transition

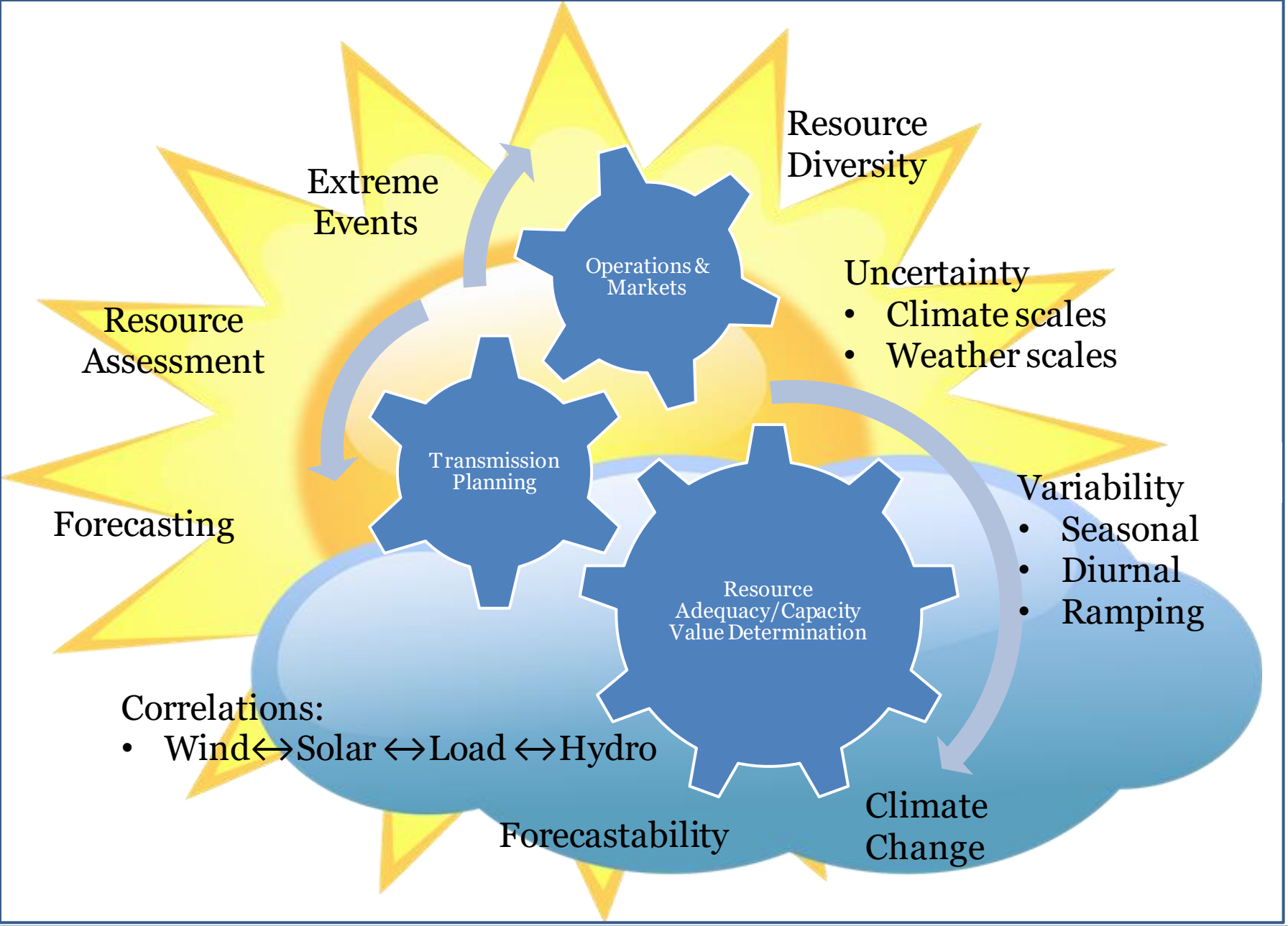




Weather modulated load and generation
Largely thermal
Dispatchable
Centralized
N-1 contingency
Lots of inertia but little storage
Slow to moderate ramping rates

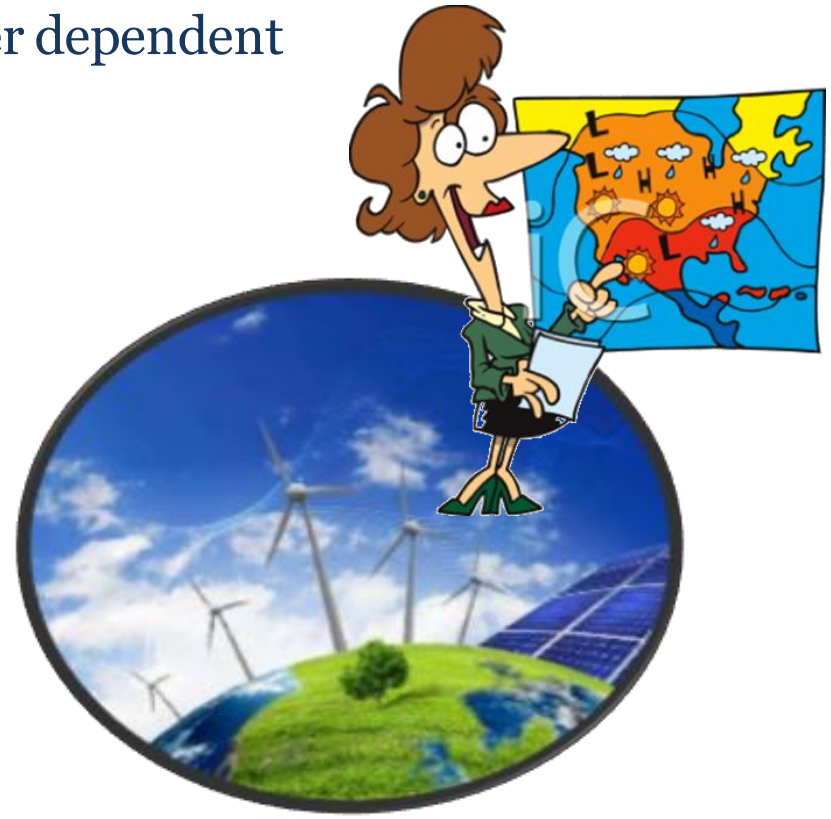
Strong correlation between weather generation
Weather modulated load and Wx driven response
Mostly weather driven generation
More storage but less inertia
Fast ramping rates
More distributed
RE penetration and thus gas use ultimately depends on generation planning.




Resource Diversity
Extreme Events
Operations & Markets
Uncertainty
• Climate scales
• Weather scales
Resource Assessment
Transmission Planning
Forecasting
Resource Adequacy/Capacity Value Determination
Variability
• Seasonal
• Diurnal
• Ramping
Correlations:
• Wind↔Solar ↔Load ↔Hydro
Forecastability
Climate Change

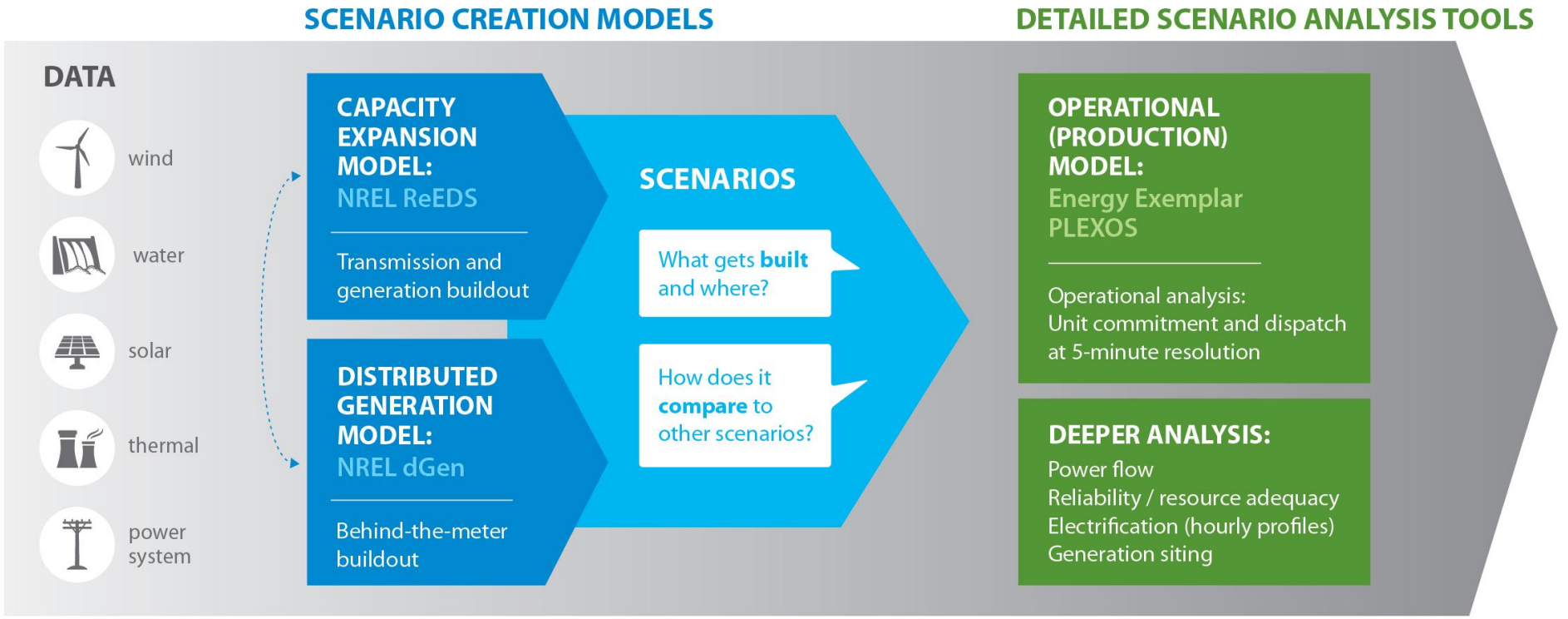
Geologist is to Oil and Gas as…?

- Uncertainty and variability are a function of footprint and weather
- Wind, solar, load and to some extent hydro are all interdependent
- Even imports and exports are weather dependent

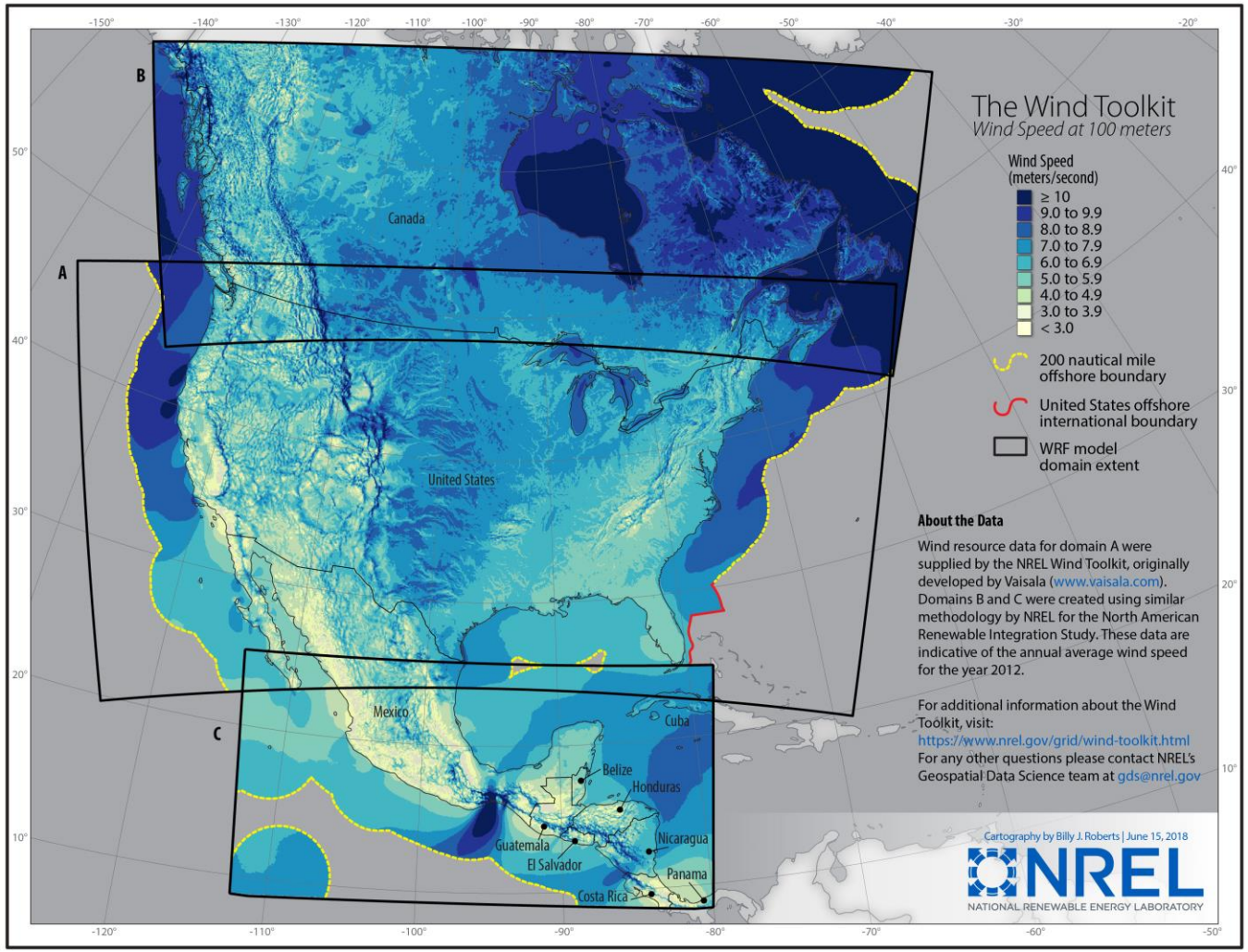


Impact of Weather Tails on High-Penetration Renewables

- Identify days where weather events occurred throughout the US that had a major impact on load, system operation, and VER generation
- Objectively analyze the impact of tail weather events on future scenarios of renewable energy build out.
- Funded by DOE



Concurrent Wind, Solar, and Weather Datasets (2007-2013)



WIND Toolkit

Domain A

- Vaisala Wind Toolkit
- 2007-2013
- Continuous United States

Domain B

- NREL created using similar method
- 2010-2013
- Canada

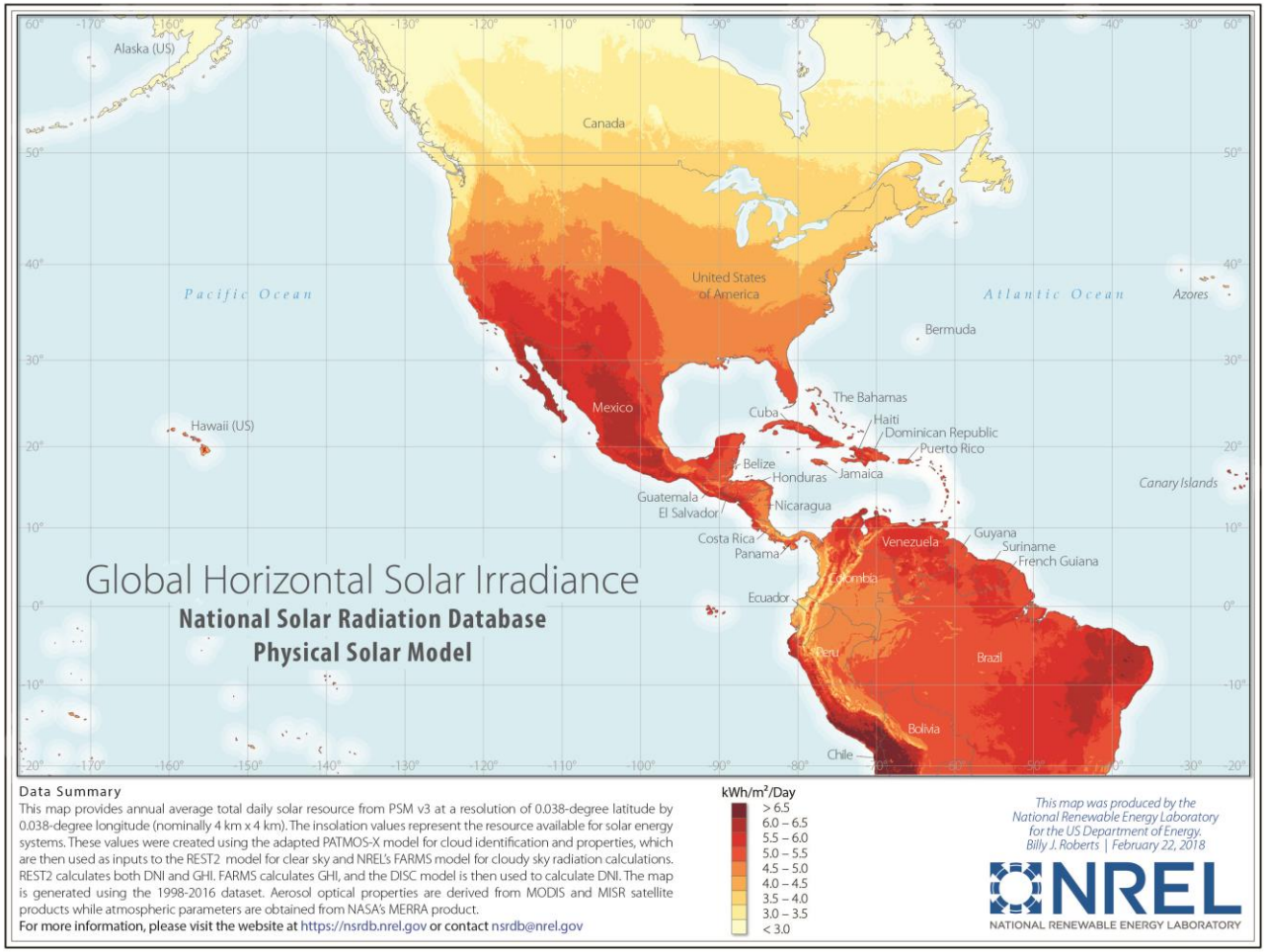
Domain C

- NREL created using similar method
- 2009-2013
- Southern Mexico

5-minute resolution
2km x 2km spatial resolution

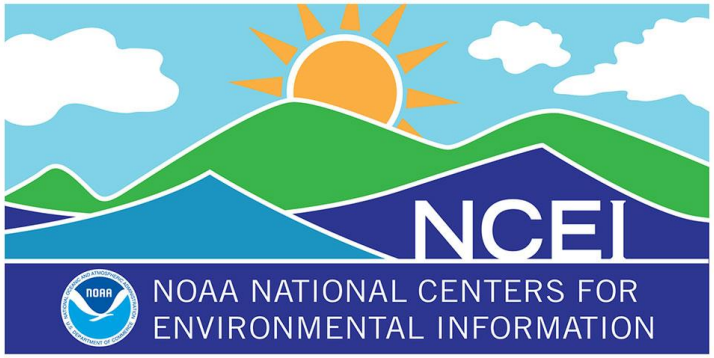
National Solar Radiation Database (NSRDB)

- 1998 – 2017
- 30-minute resolution
- 4km x 4km spatial resolution

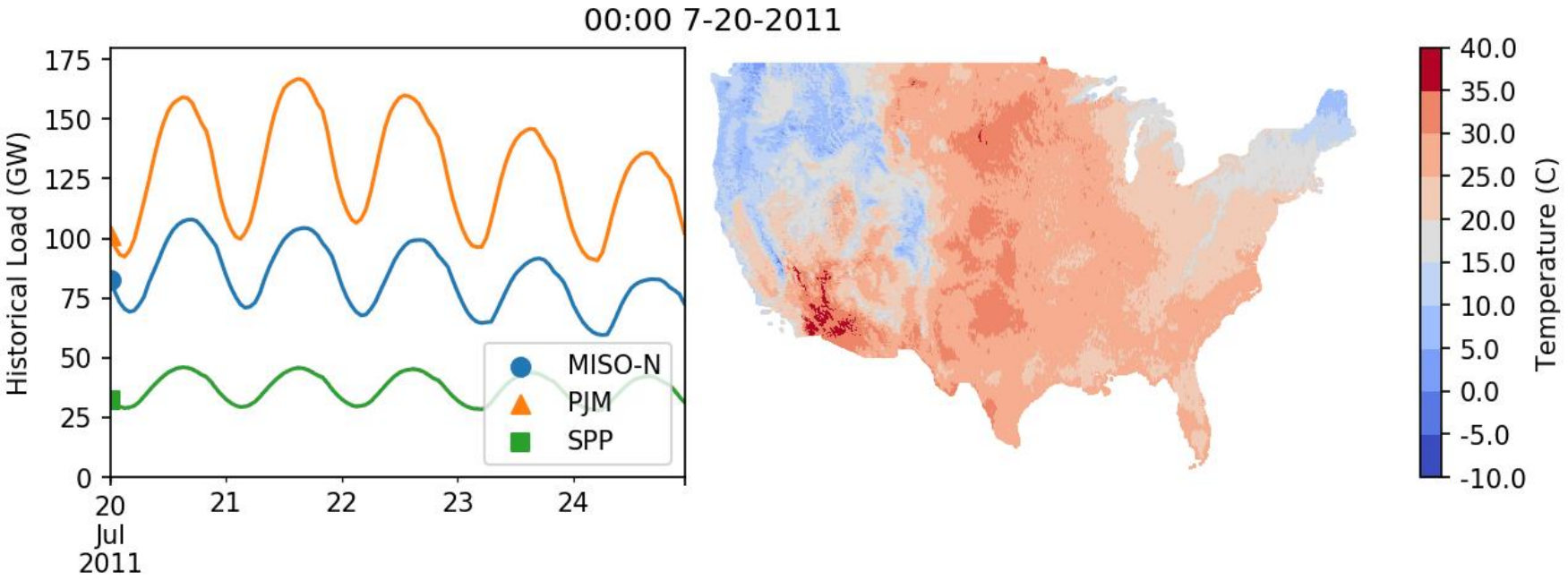


Local Climatological Data (LCD)

- Local Climatological Data (LCD) consist of hourly, daily, and monthly summaries for approximately 1,600 U.S. locations.
- Hourly data includes major meteorological fields:
  - present weather
  - sky cover
  - precipitation amount and type
  - wind direction, sustained speed and gust
- Summary of the day:
  - Max/min temperature
  - Deviations from normal
  - Heating/Cooling Degree Days
- Best set for providing ground truth of fields impacting load and renewable resources



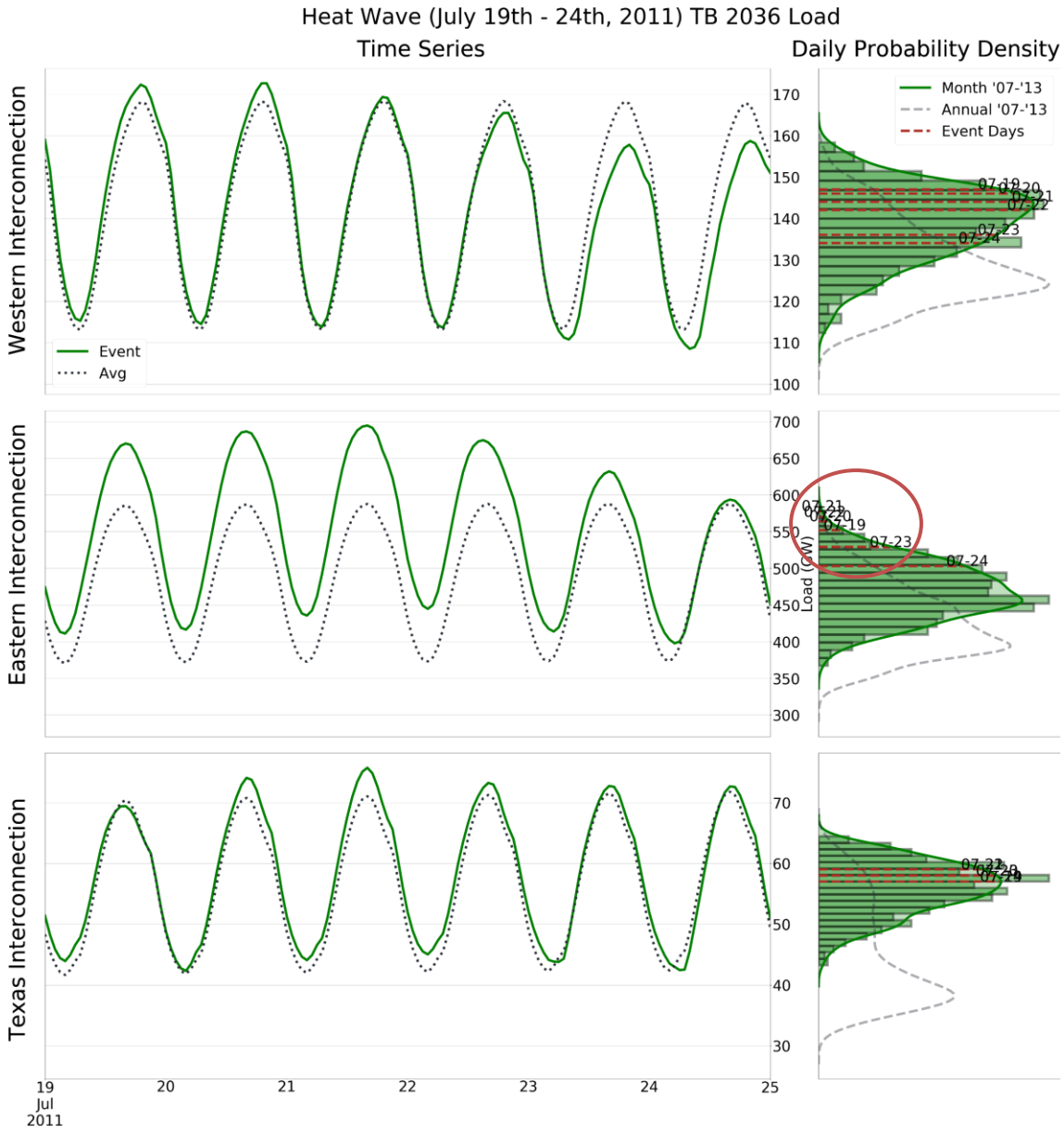
Operators Need To Plan For Extreme Loads, Right?



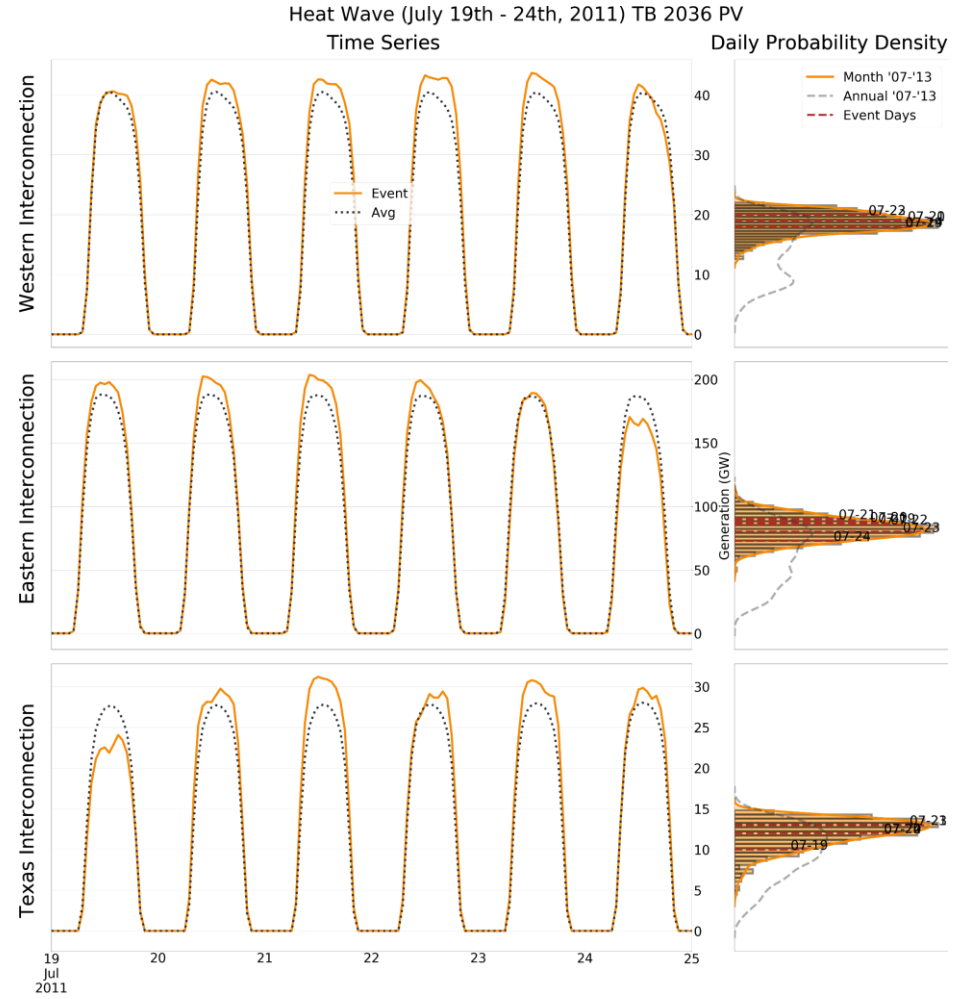
Hottest Period in the 7-year Record

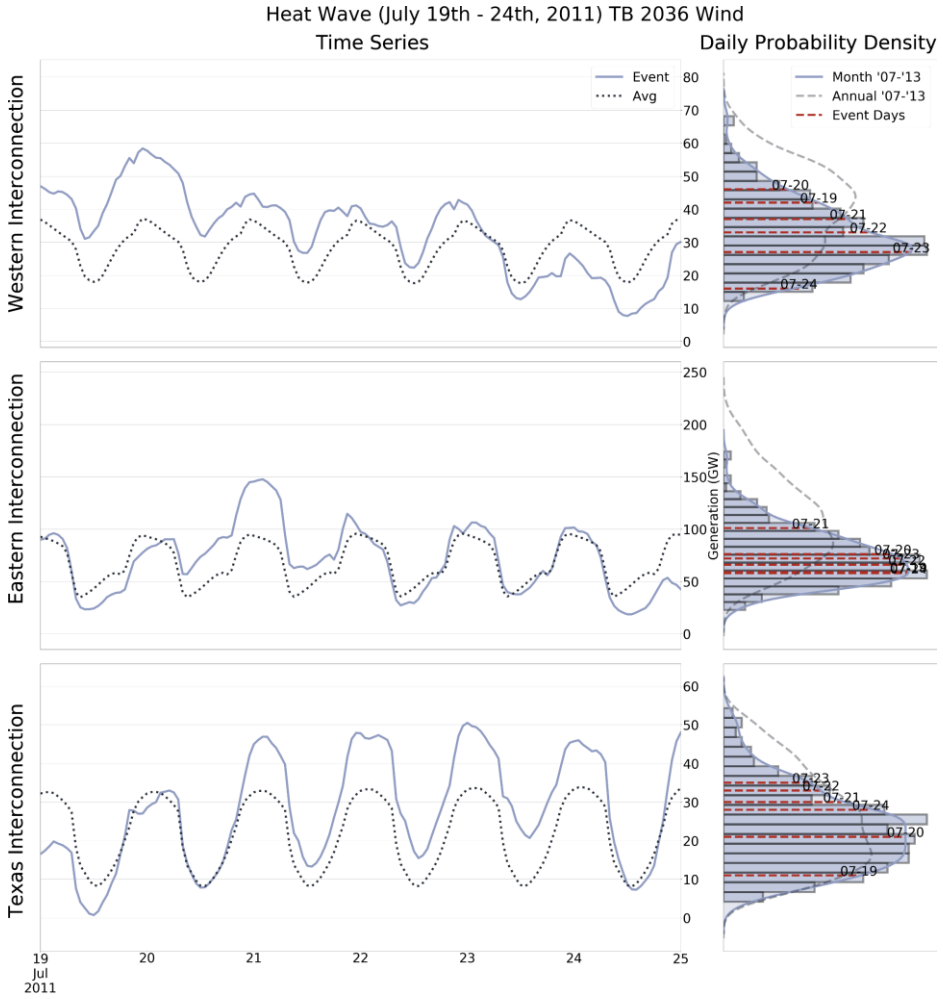
This plot shows the hourly load time series for a period that, with the average for the same period (dashed). On the right is the distribution for the 29 days centered around the middle of the event for each of the 7-years in the dataset. The actual event days are labelled, and the dashed line is the annual distribution.

The July 2011 heatwave saw the 1st, 2nd, 3rd, 4th, 8th and 9th highest number of cooling degree days across 31 large load centers.



Wind and Solar Resource

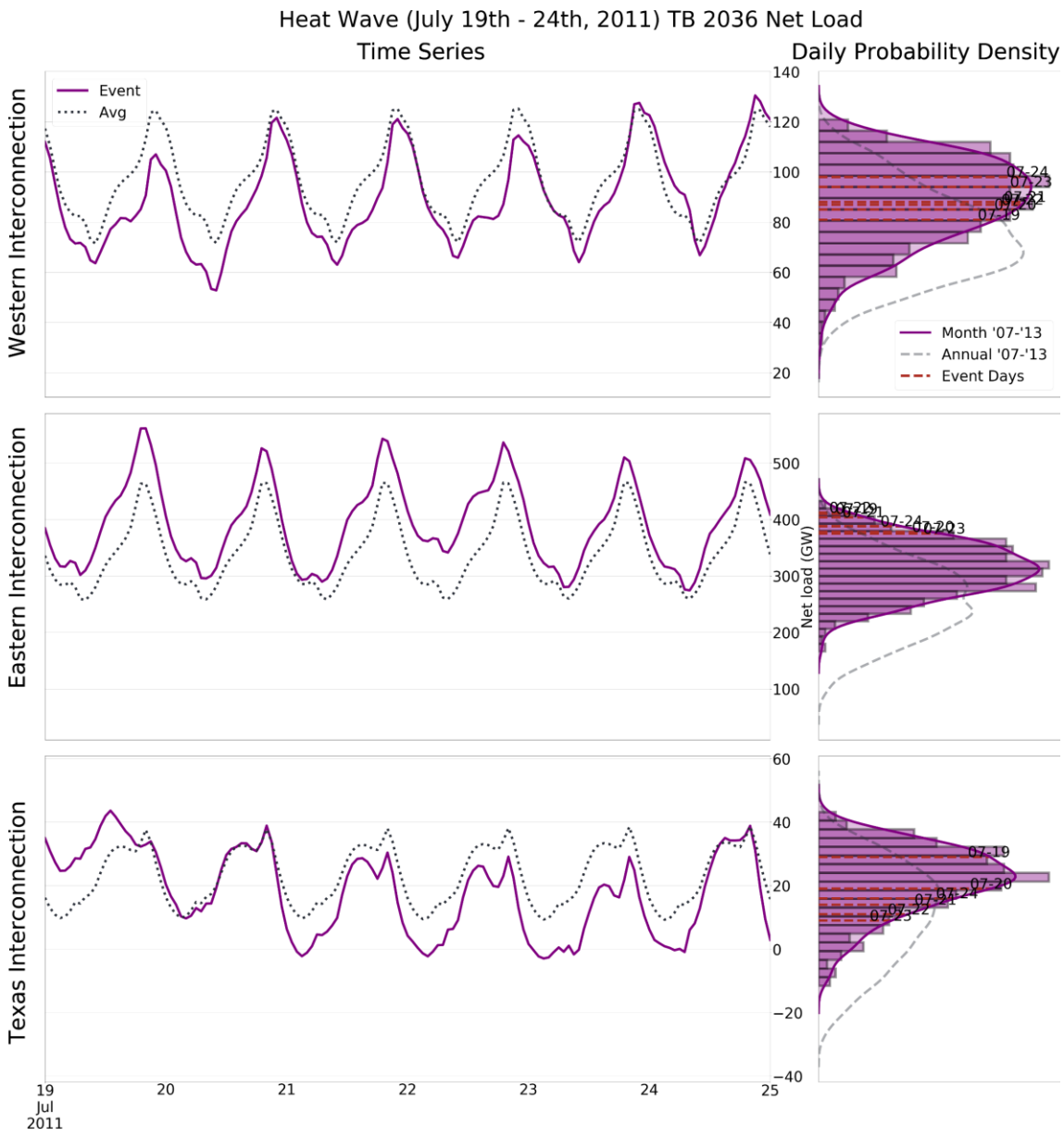




Residual Load Net Renewables

Data is for 2036 Tech-break Scenario

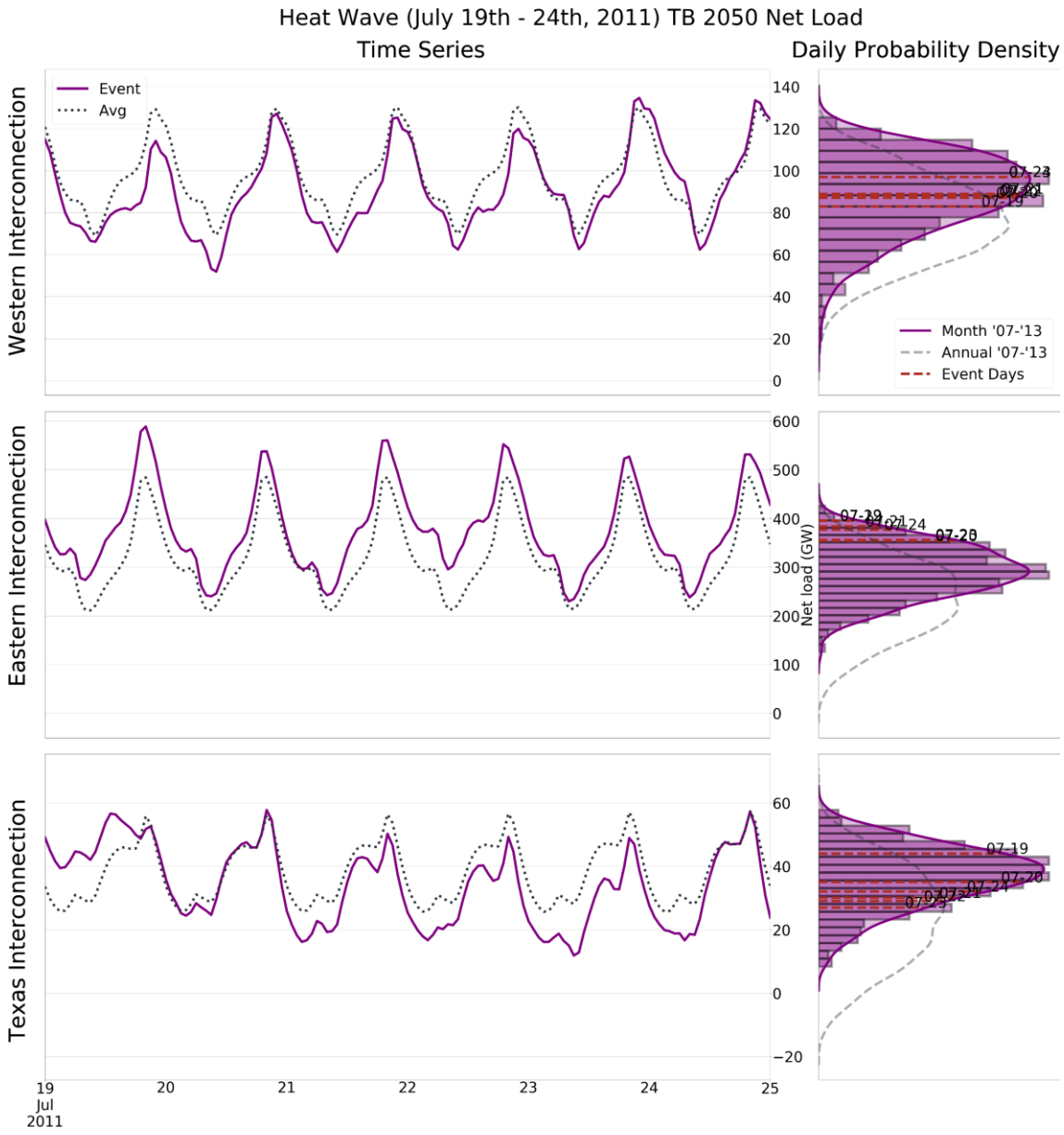
Note how the time series is closer to average for the EI and below average for Texas. The distribution shift downwards and for the EI, out of the far tail.



Residual Load Net Renewables

Compare to 2050 Tech-break where lots more renewables have been added.

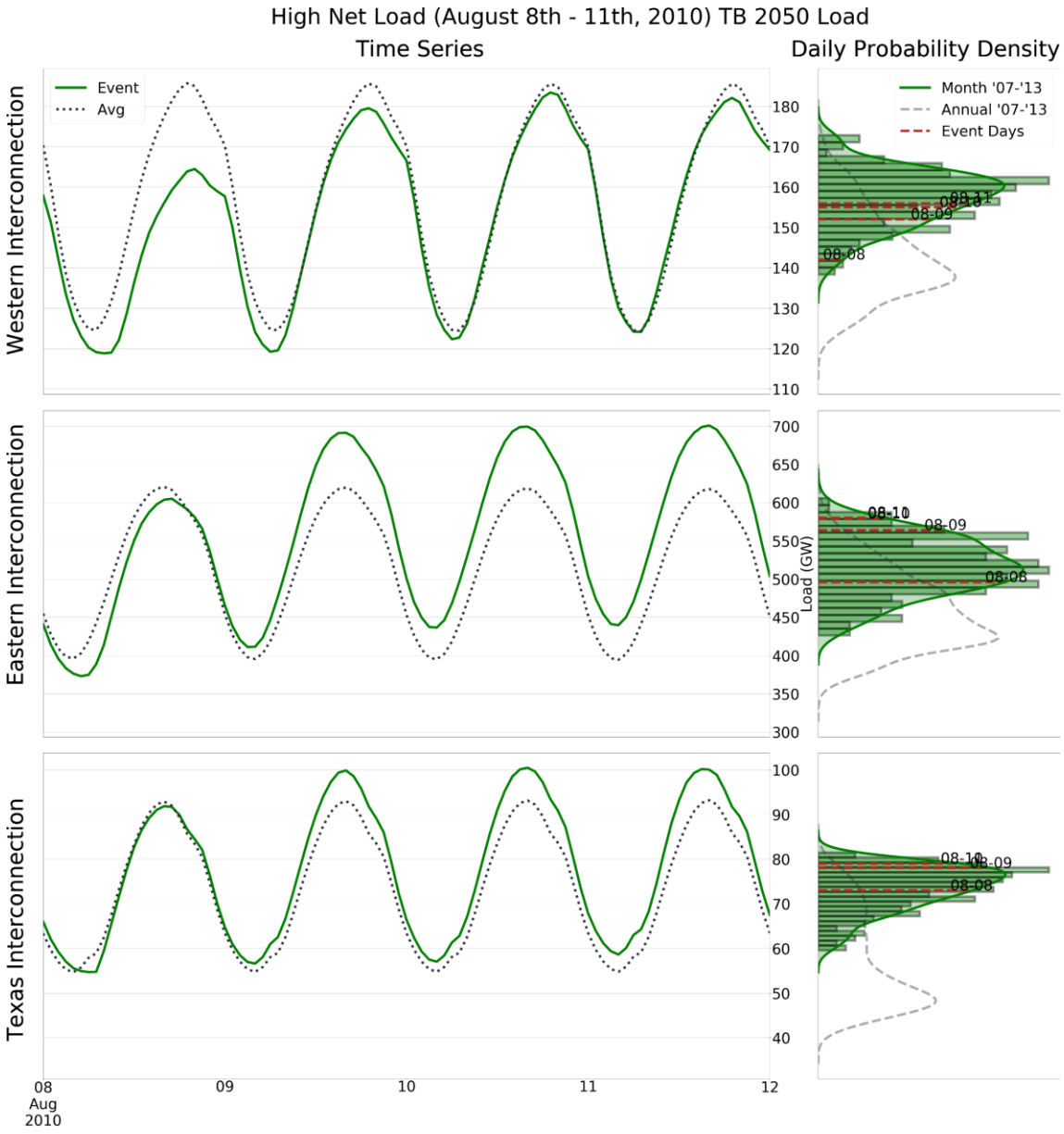
Note the significant shift out of the tail in the EI. This was a characteristic result for extreme load excursions. Typically, extreme heat does not correlate with poor wind and solar resource over the study area. A definitive analysis of this impact is still needed in future work.



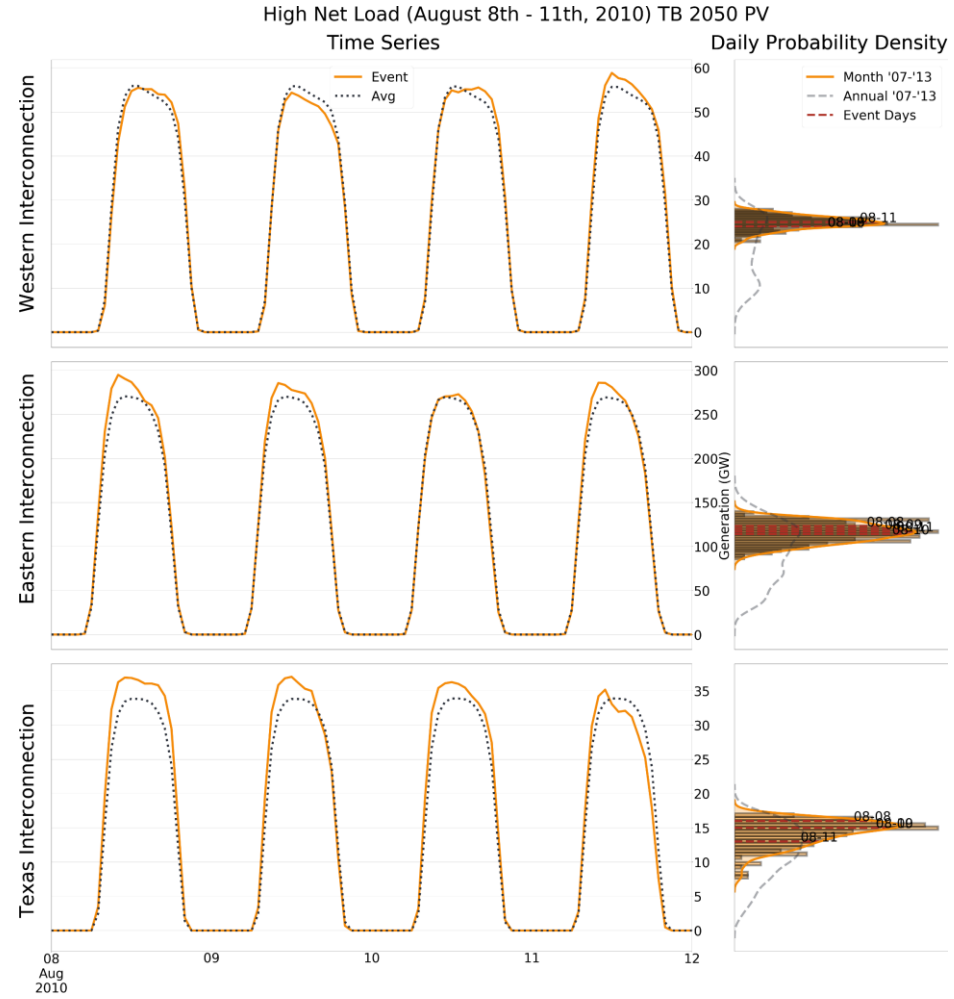
August 8-11, 2010 Warm Period

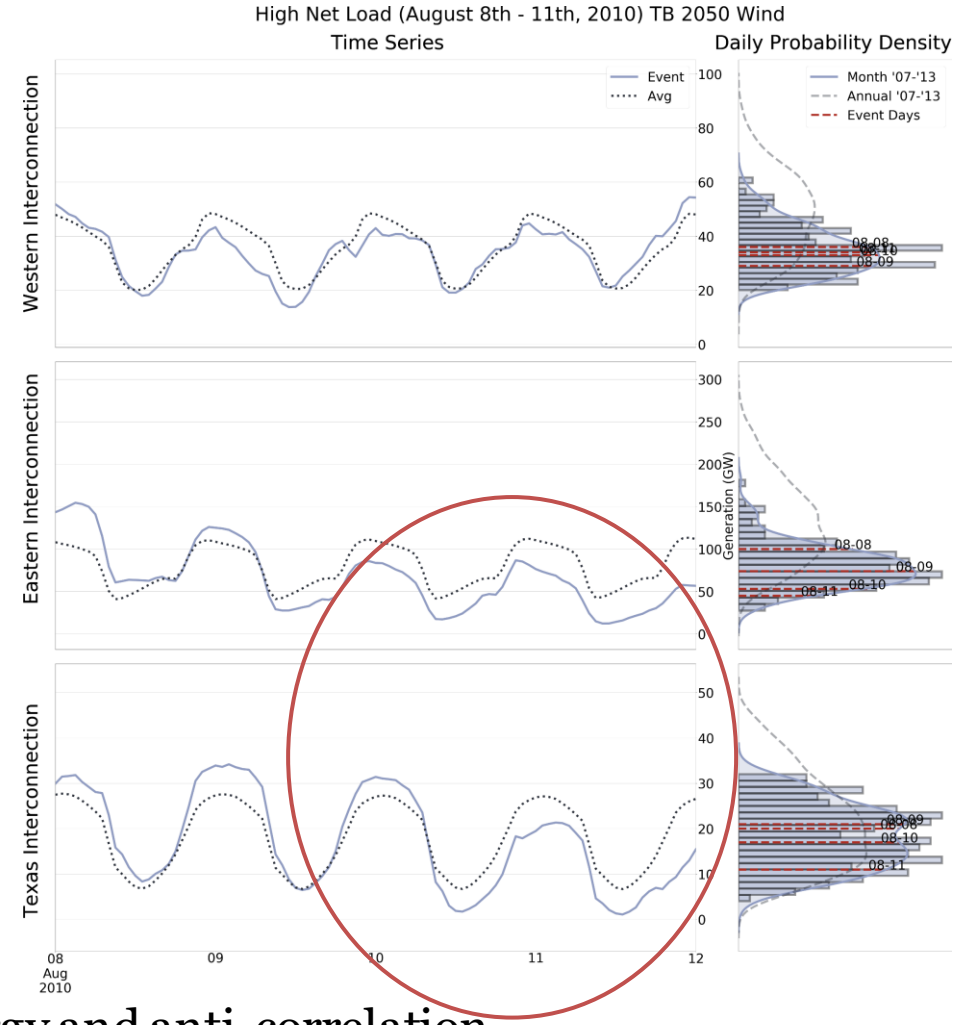
This period experienced moderately above normal temperatures. August 11 was 14th in the record for CDD, mainly driven by Texas. Other days were not noteworthy. somewhat above normal temperatures. As a result the daily averages fall closer to the middle of the distribution as expected.

(Note, this plot shows 2050 load which is scaled higher than 2036 for load growth)



Wind and Solar Resource below average in EI/TX

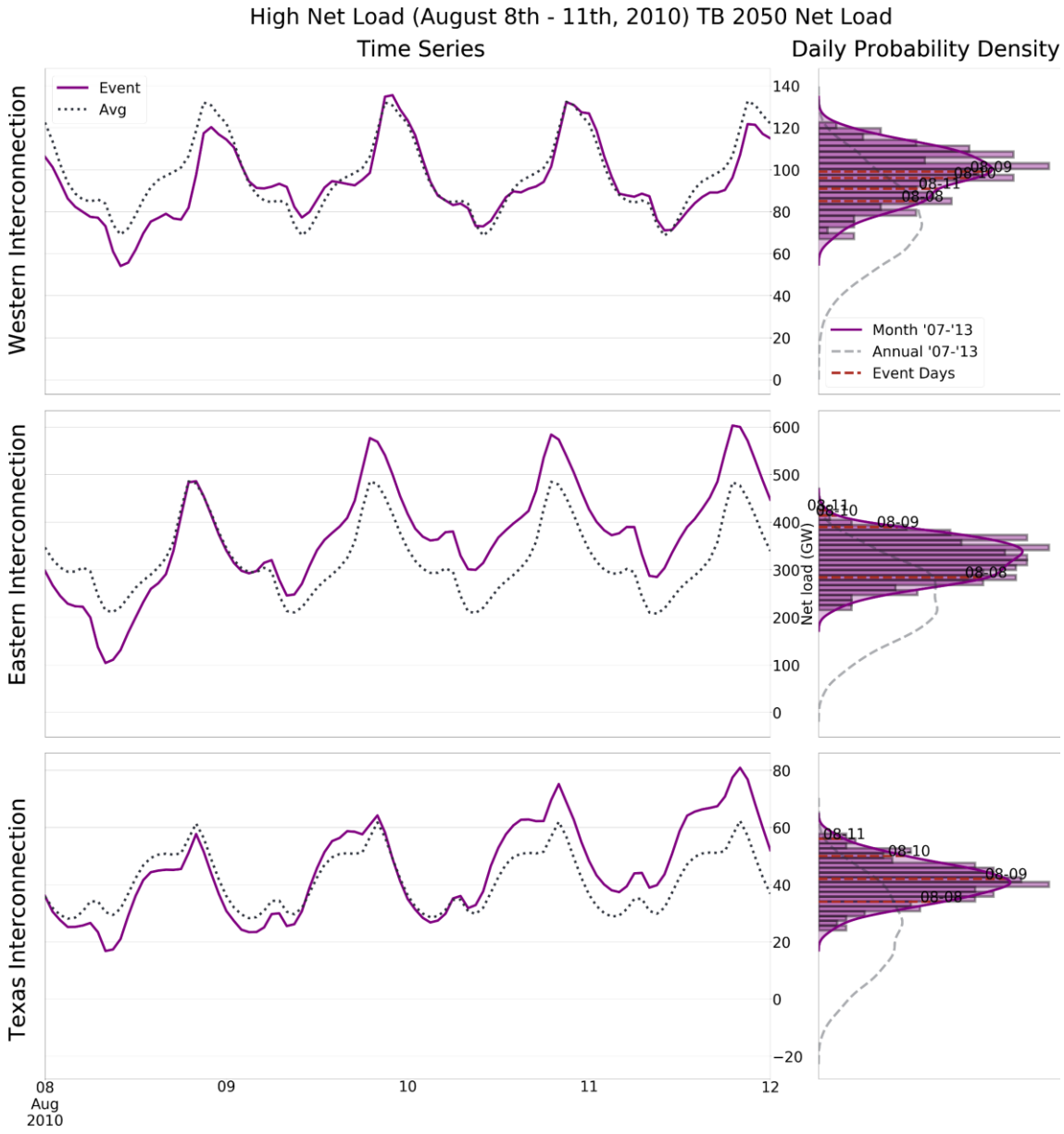




Note the wind/solar synergy and anti-correlation

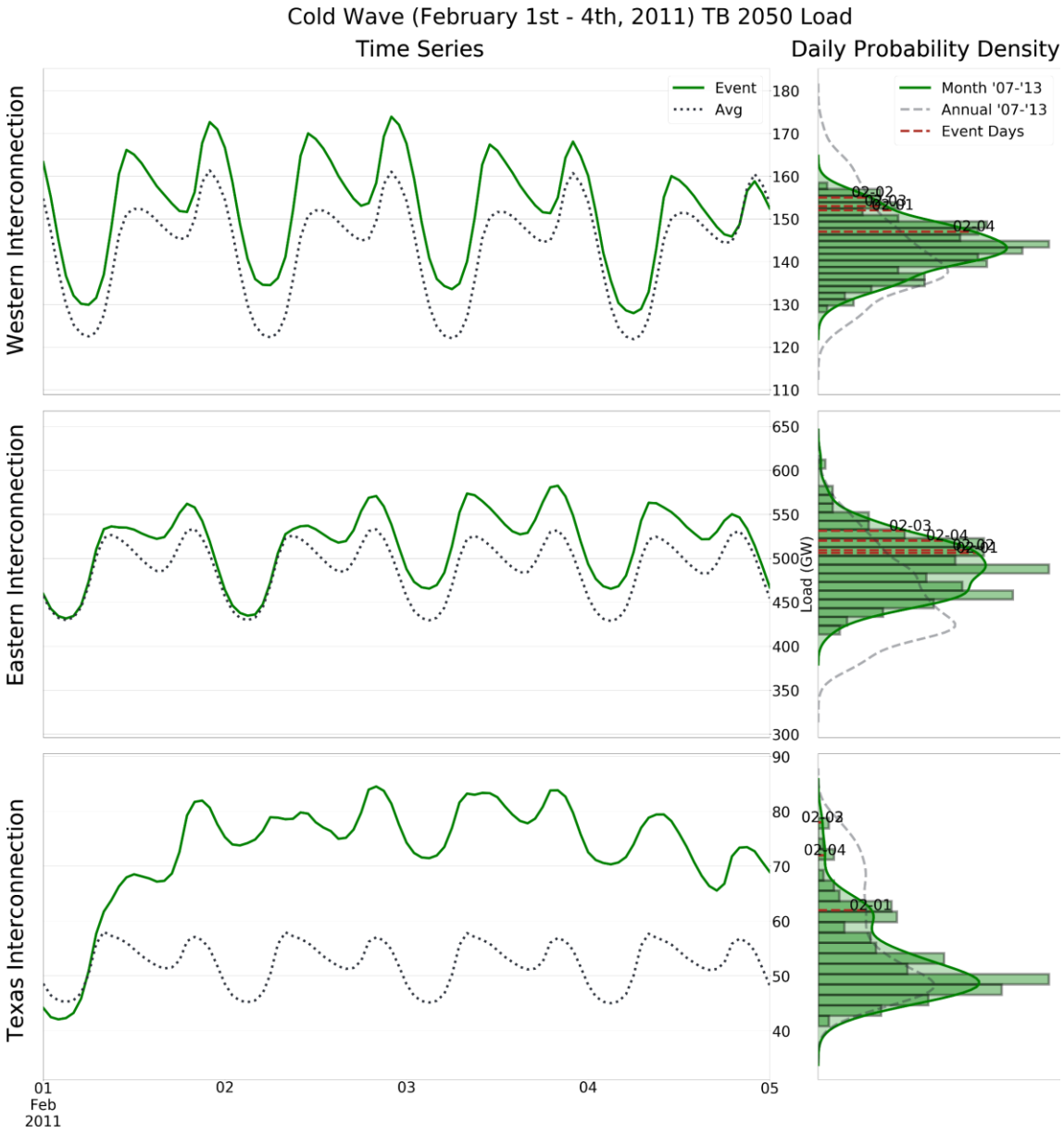
Residual Load Net Renewables

Lower resource pushes the netload curve up, forcing some days into the tails despite this not being an exceptionally warm period.



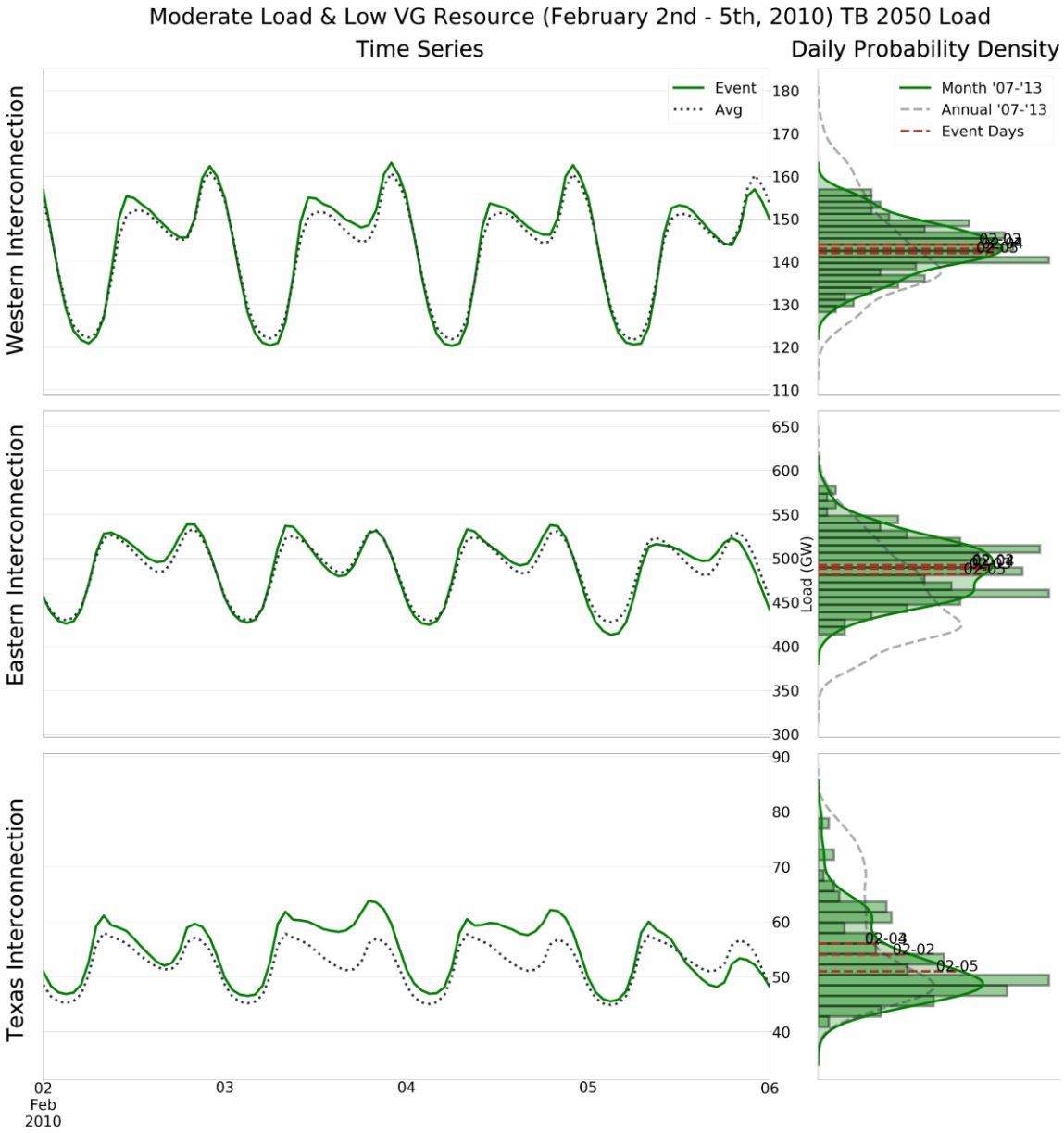
Coldest Period in the 7-year Record

February 3, 2011 has the most HDD in the record, 2/2 is 6th and the other days are in the top 40. The cold reached far south setting many records in Texas which saw extreme load excursions as a result.

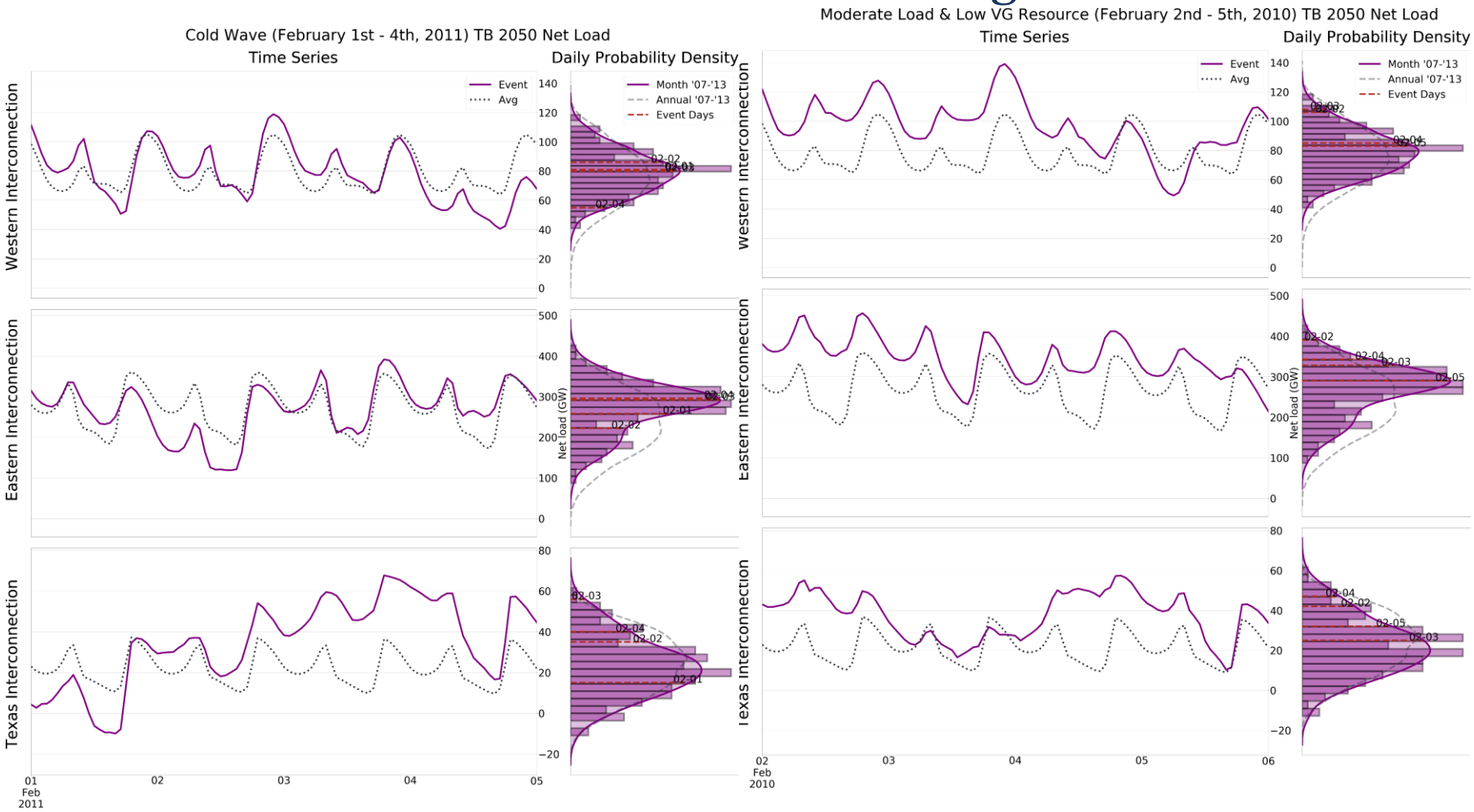


Compare to a more typical period

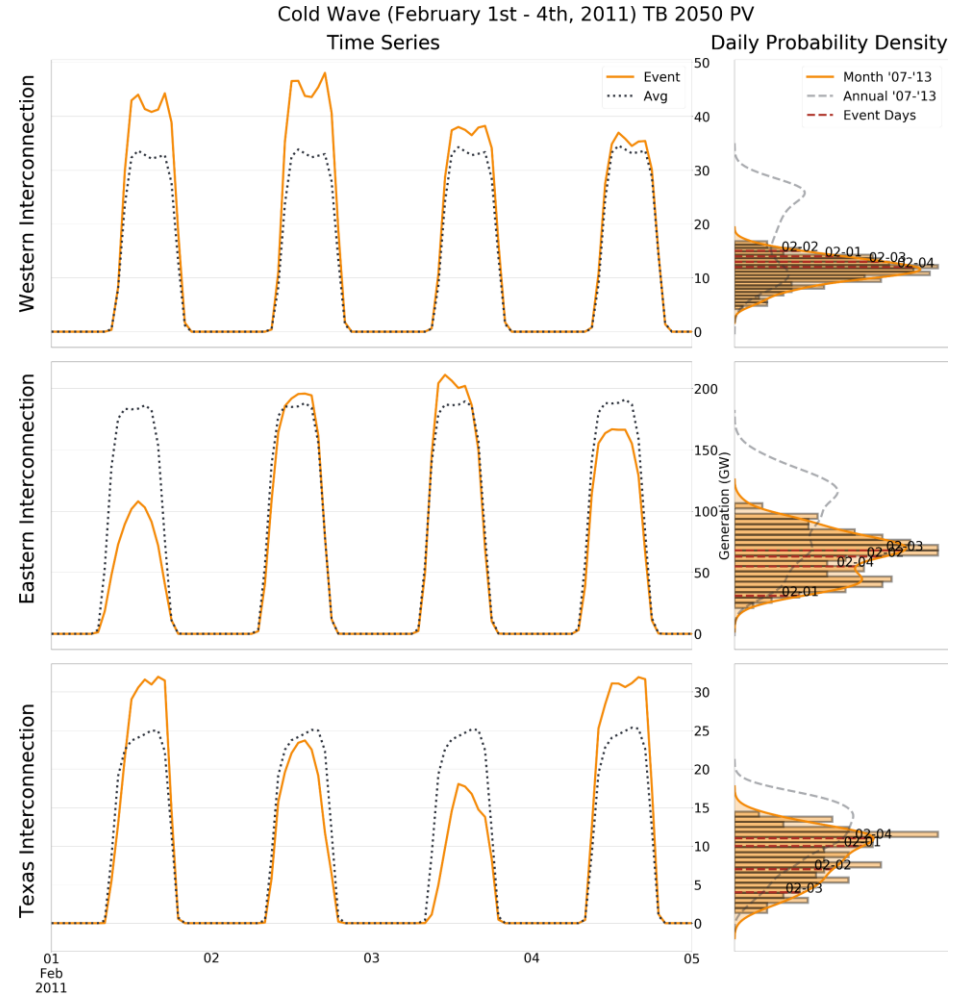
February 2 – Feb 5, 2010 was a fairly typical period as can be clearly seen here.

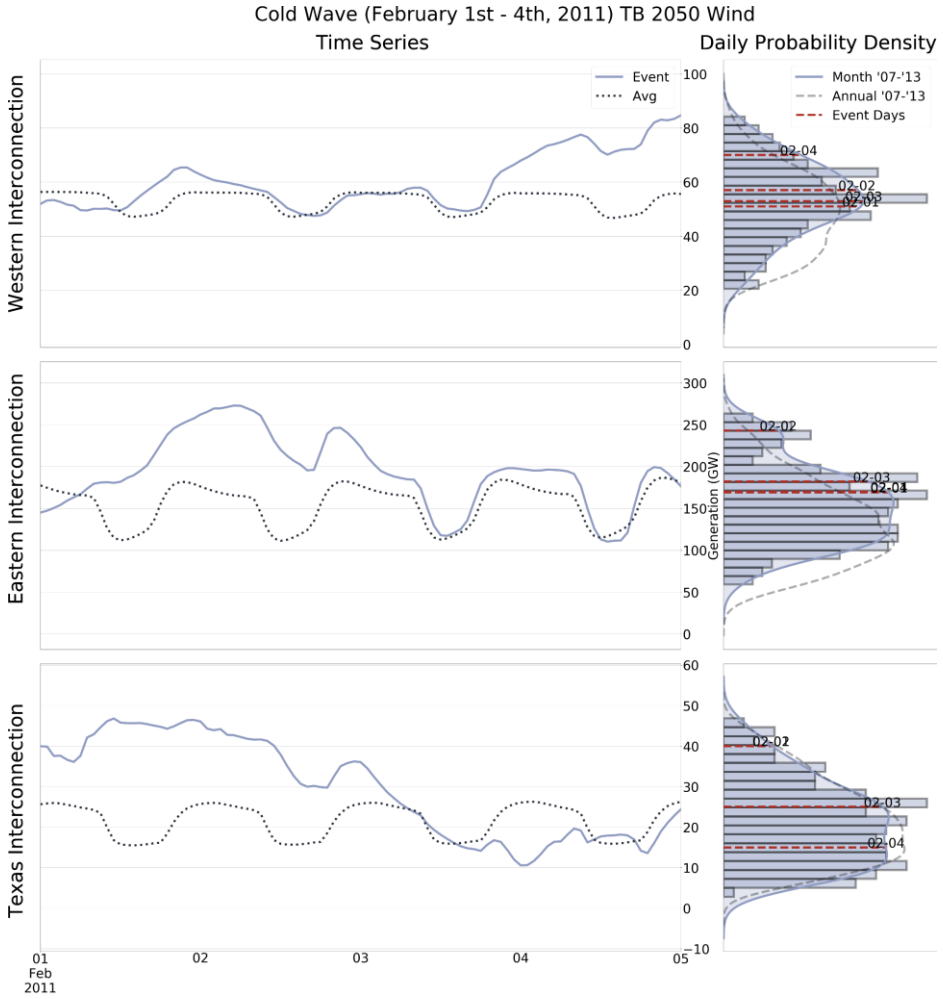


Above average renewables mitigate load excursion during the cold wave. Compare to the more typical period where low renewable resource drives net-load higher.

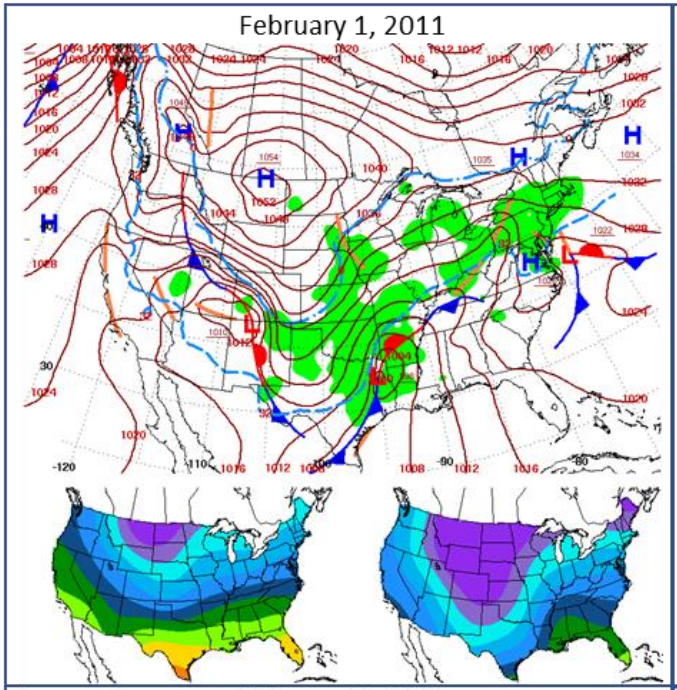


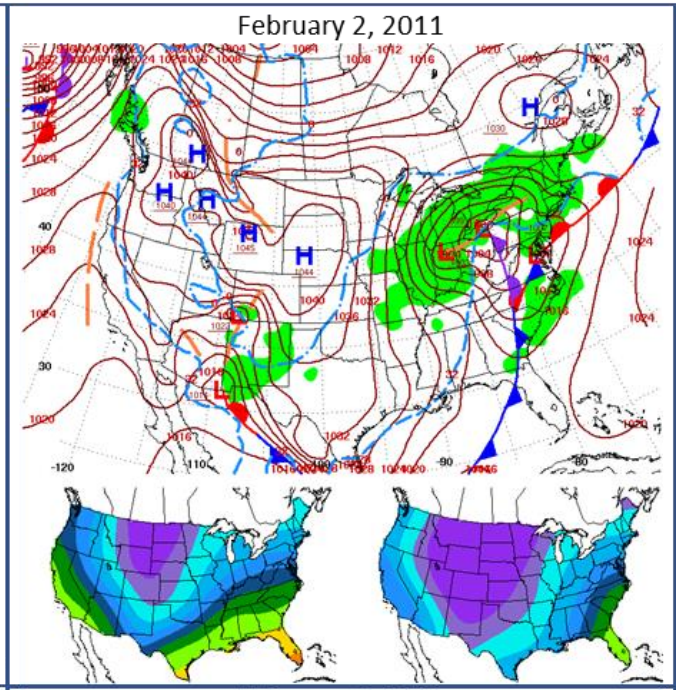
2011 Wind and Solar Resource above average

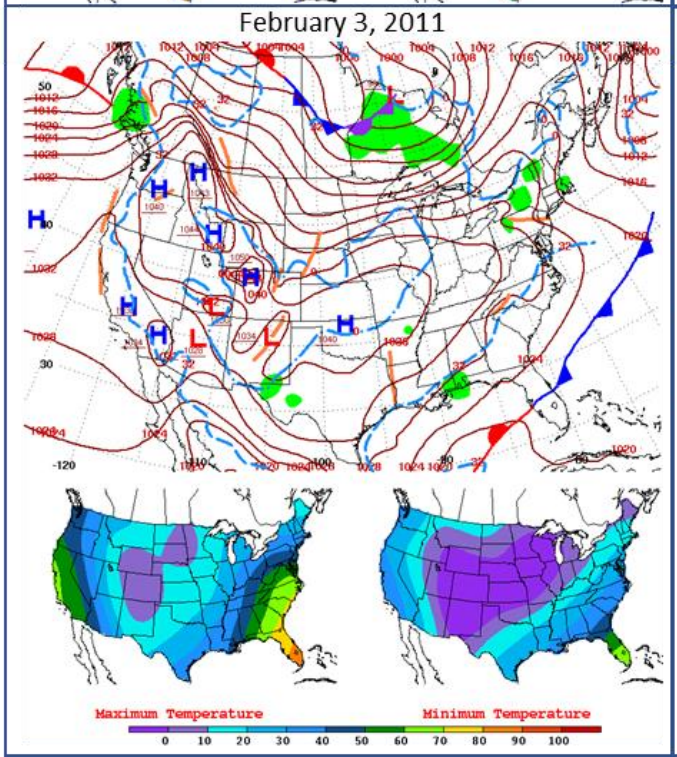


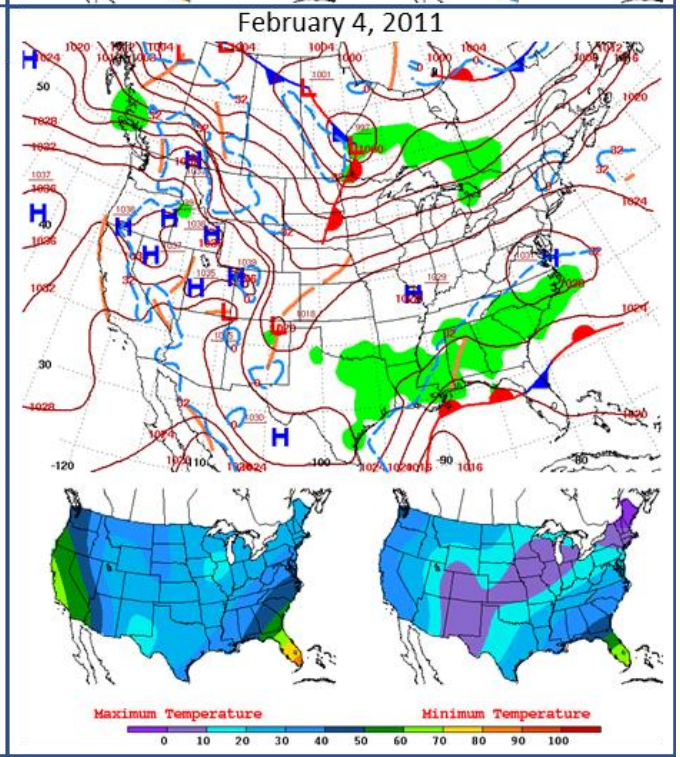


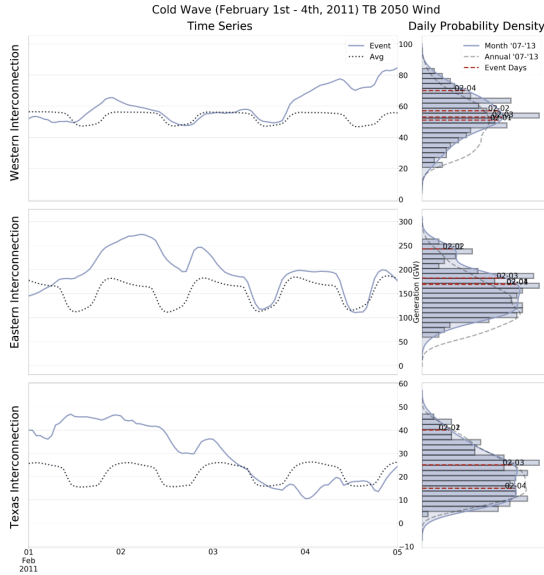
Note the wind/solar synergy and anti-correlation

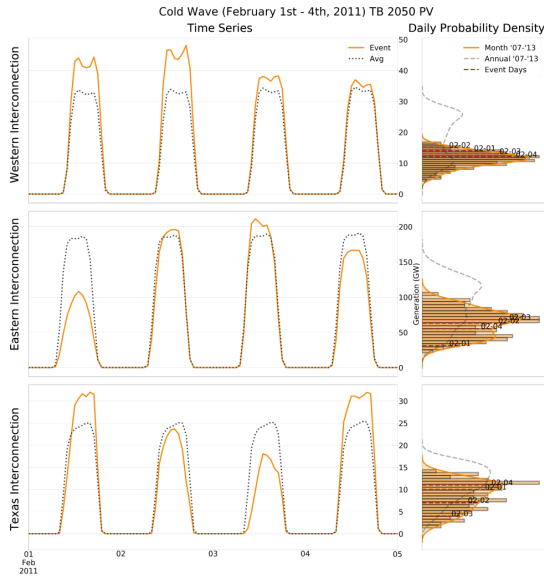

February 1, 2011


February 2, 2011

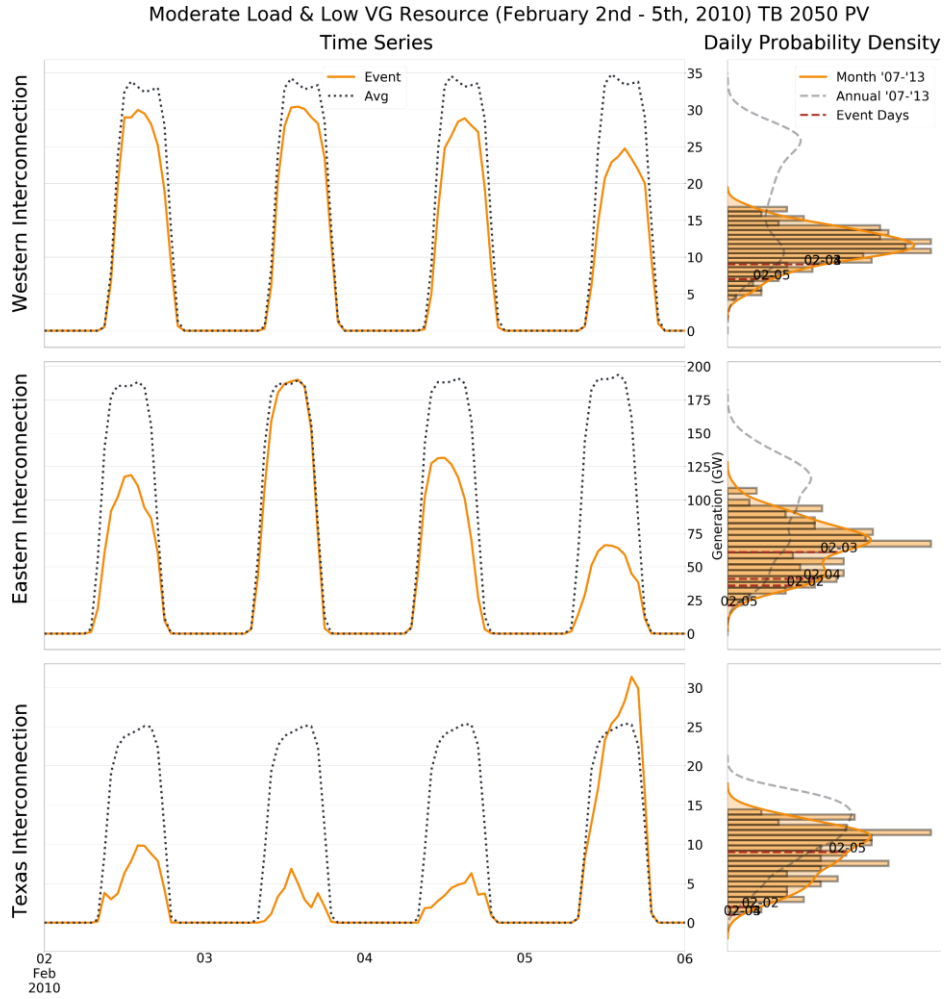

February 3, 2011
Maximum Temperature
Minimum Temperature
0 10 20 30 40 50 60 70 80 90 100

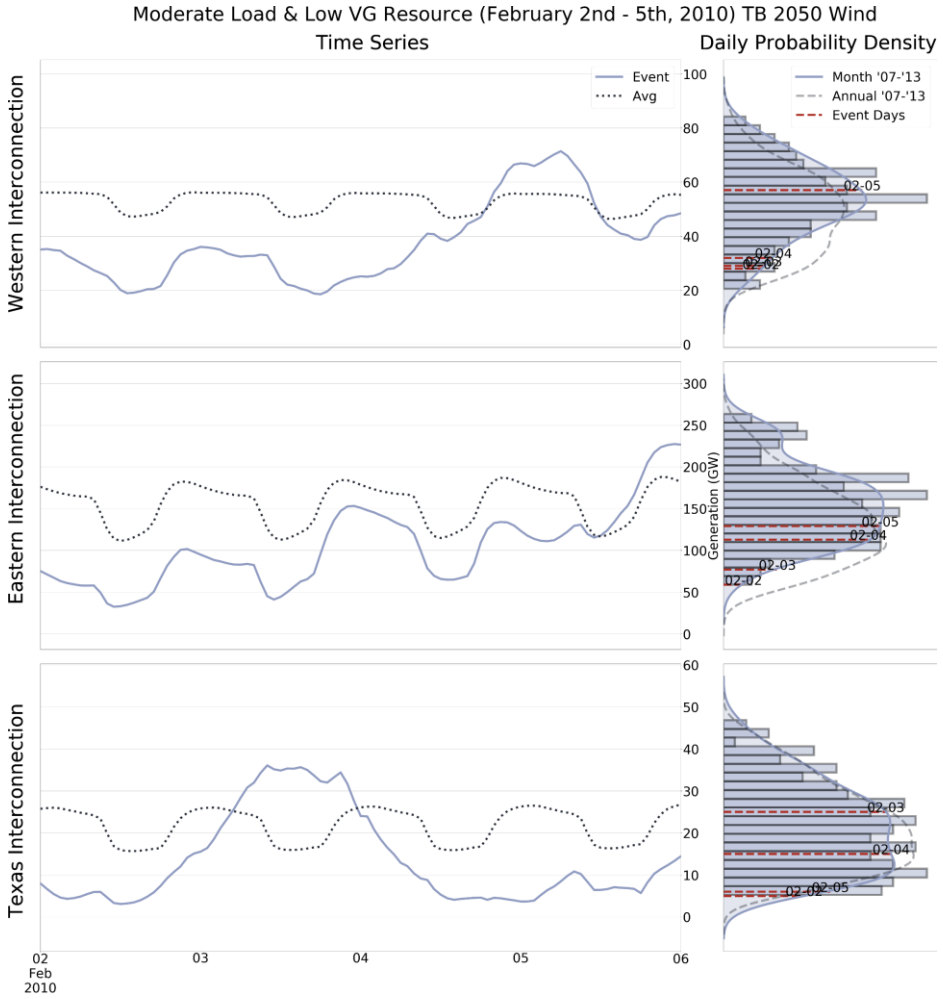

February 4, 2011
Maximum Temperature
Minimum Temperature
0 10 20 30 40 50 60 70 80 90 100

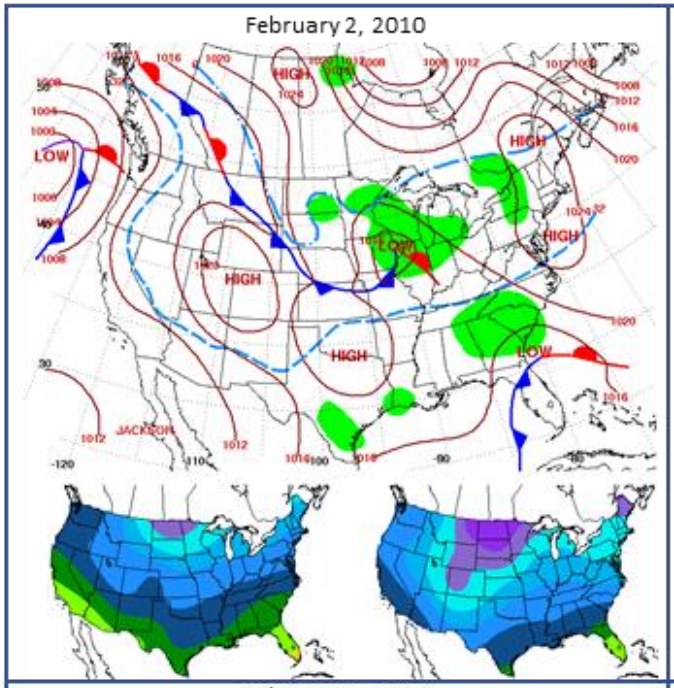

Cold Wave (February 1st - 4th, 2011) TB 2050 Wind
Time Series
Daily Probability Density
Western Interconnection
Eastern Interconnection
Texas Interconnection
Event
Avg
Month '07-'13
Annual '07-'13
Event Days
Generation (GW)
01 Feb 2011
02
03
04
05

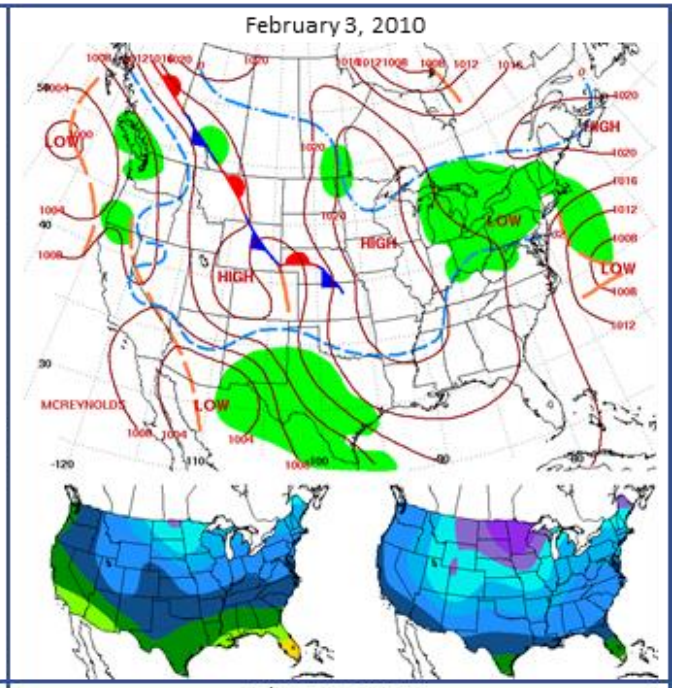

Cold Wave (February 1st - 4th, 2011) TB 2050 PV
Time Series
Daily Probability Density
Western Interconnection
Eastern Interconnection
Texas Interconnection
Event
Avg
Month '07-'13
Annual '07-'13
Event Days
Generation (GW)
01 Feb 2011
02
03
04
05

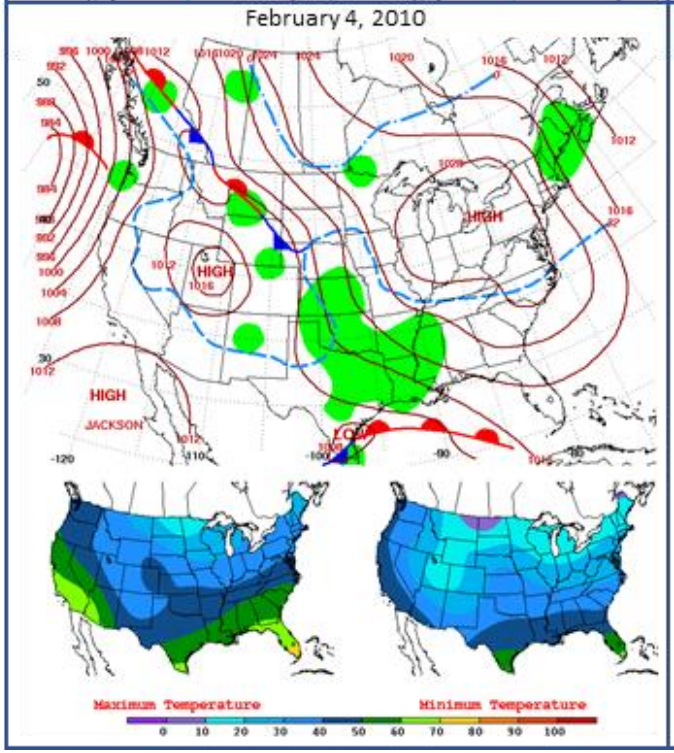
2010 Wind and Solar Resource well below average

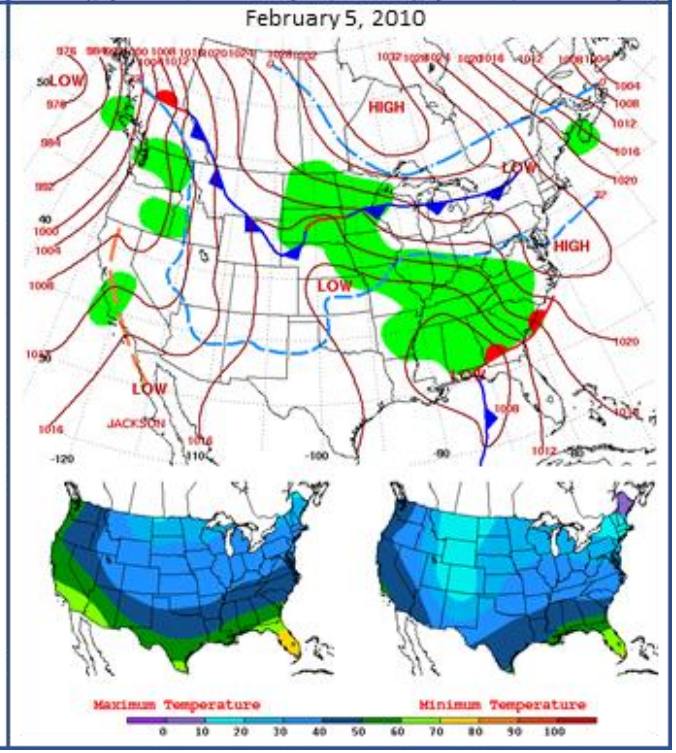


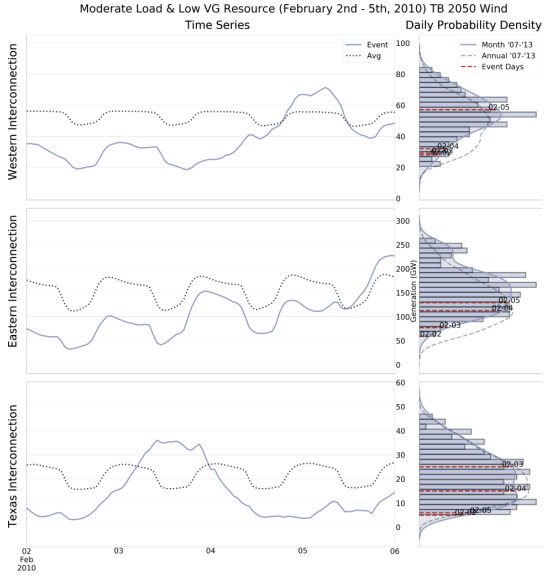


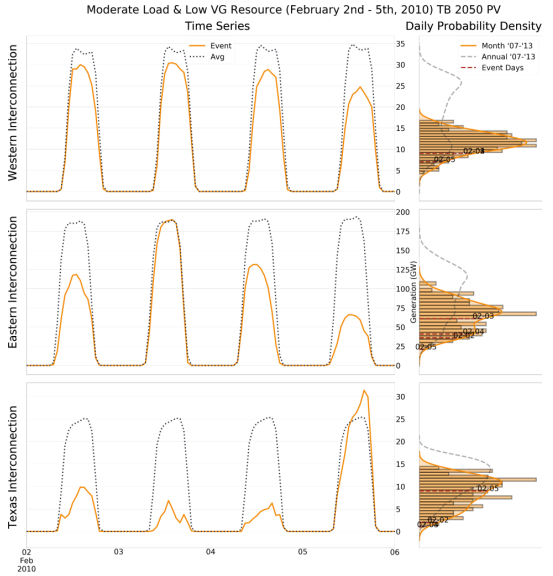

February 2, 2010
HIGH
LOW
JACKSON
Maximum Temperature
Minimum Temperature
0 10 20 30 40 50 60 70 80 90 100


February 3, 2010
HIGH
LOW
MCREYNOLDS
Maximum Temperature
Minimum Temperature
0 10 20 30 40 50 60 70 80 90 100

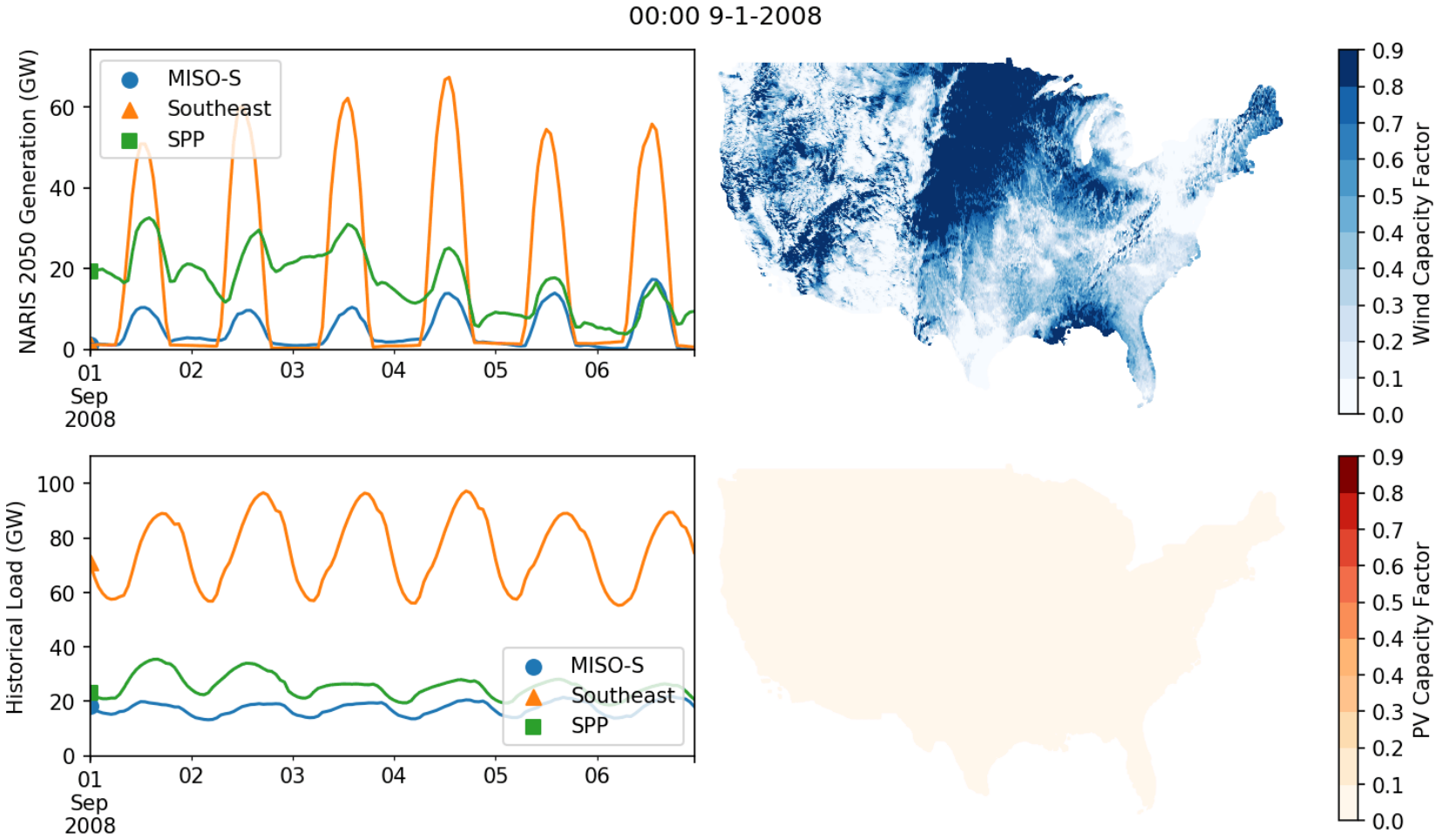

February 4, 2010
HIGH
LOW
JACKSON
Maximum Temperature
Minimum Temperature
0 10 20 30 40 50 60 70 80 90 100


February 5, 2010
HIGH
LOW
JACKSON
Maximum Temperature
Minimum Temperature
0 10 20 30 40 50 60 70 80 90 100


Moderate Load & Low VG Resource (February 2nd - 5th, 2010) TB 2050 Wind
Time Series
Daily Probability Density
Event
Avg
Month '07-'13
Annual '07-'13
Event Days
Western Interconnection
Eastern Interconnection
Texas Interconnection
Generation (GW)
02 Feb 2010
03
04
05
06

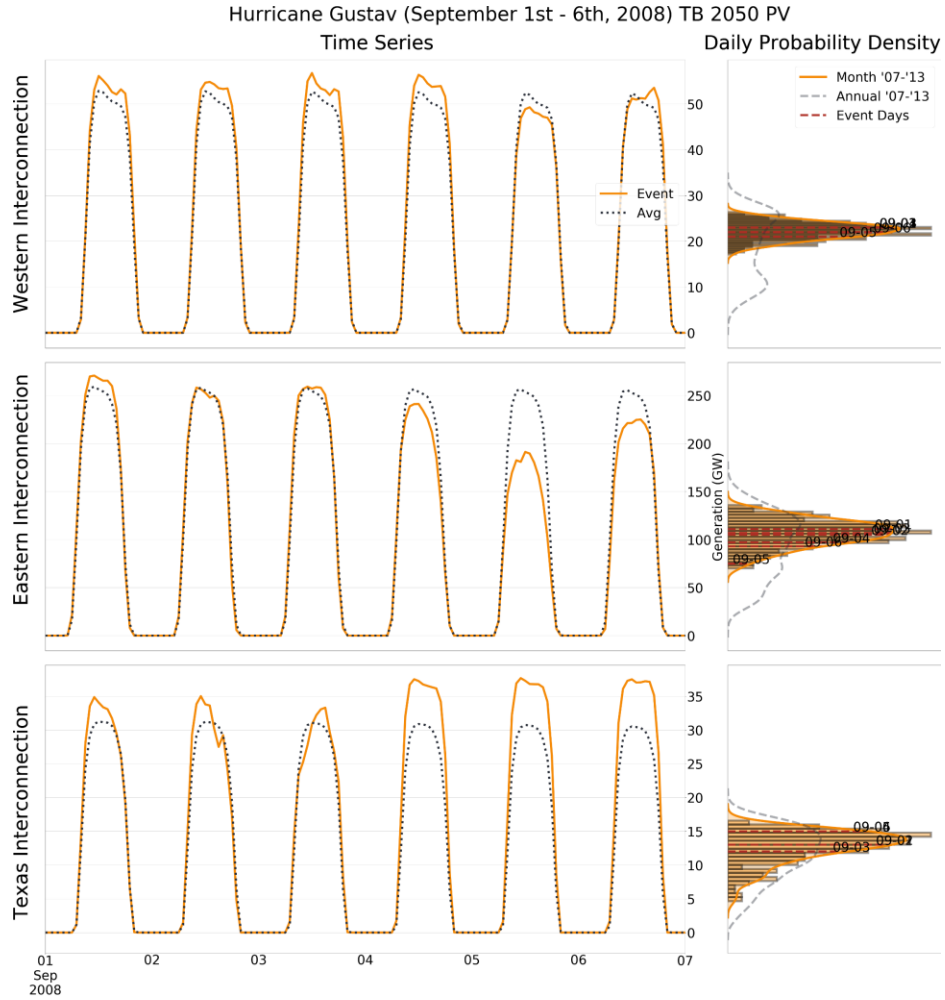

Moderate Load & Low VG Resource (February 2nd - 5th, 2010) TB 2050 PV
Time Series
Daily Probability Density
Event
Avg
Month '07-'13
Annual '07-'13
Event Days
Western Interconnection
Eastern Interconnection
Texas Interconnection
Generation (GW)
02 Feb 2010
03
04
05
06

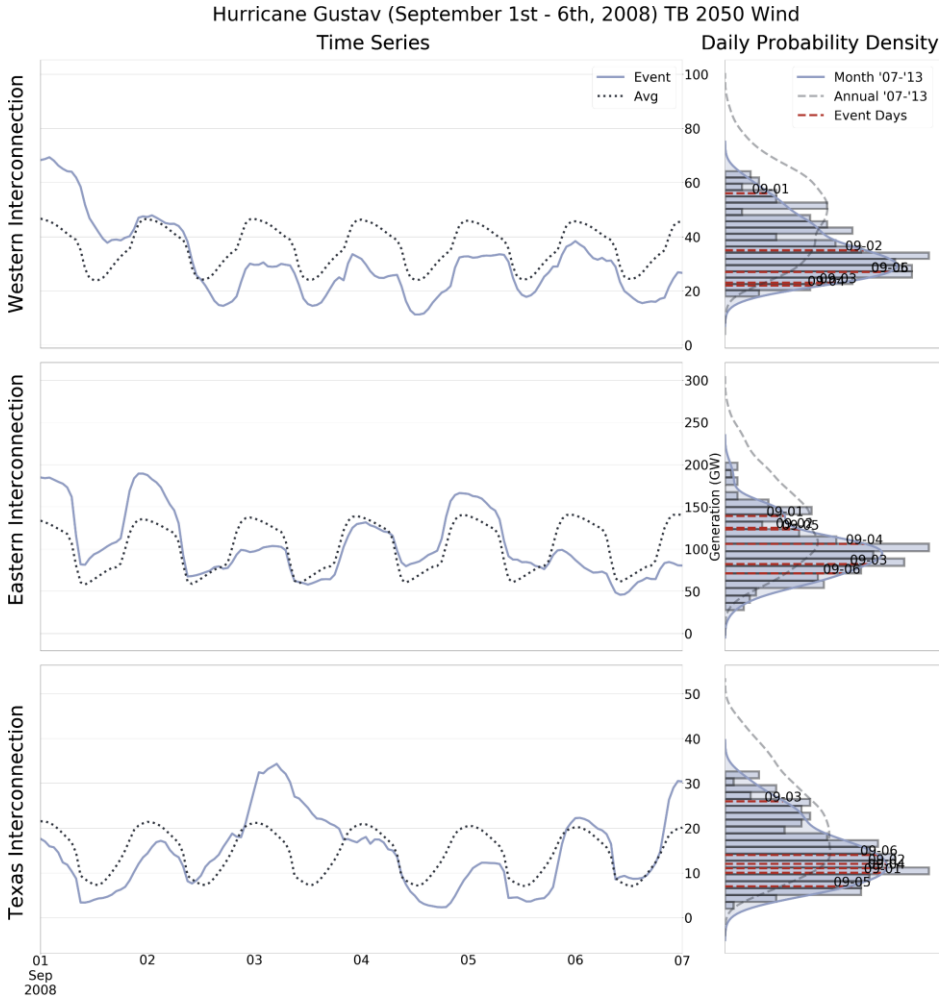
Tropical Storms and Hurricanes - Gustav



Scale of the storm is smaller than typical mid-latitude storms, so impact is minimal except locally. Wind and solar impact tend to cancel to some extent too.

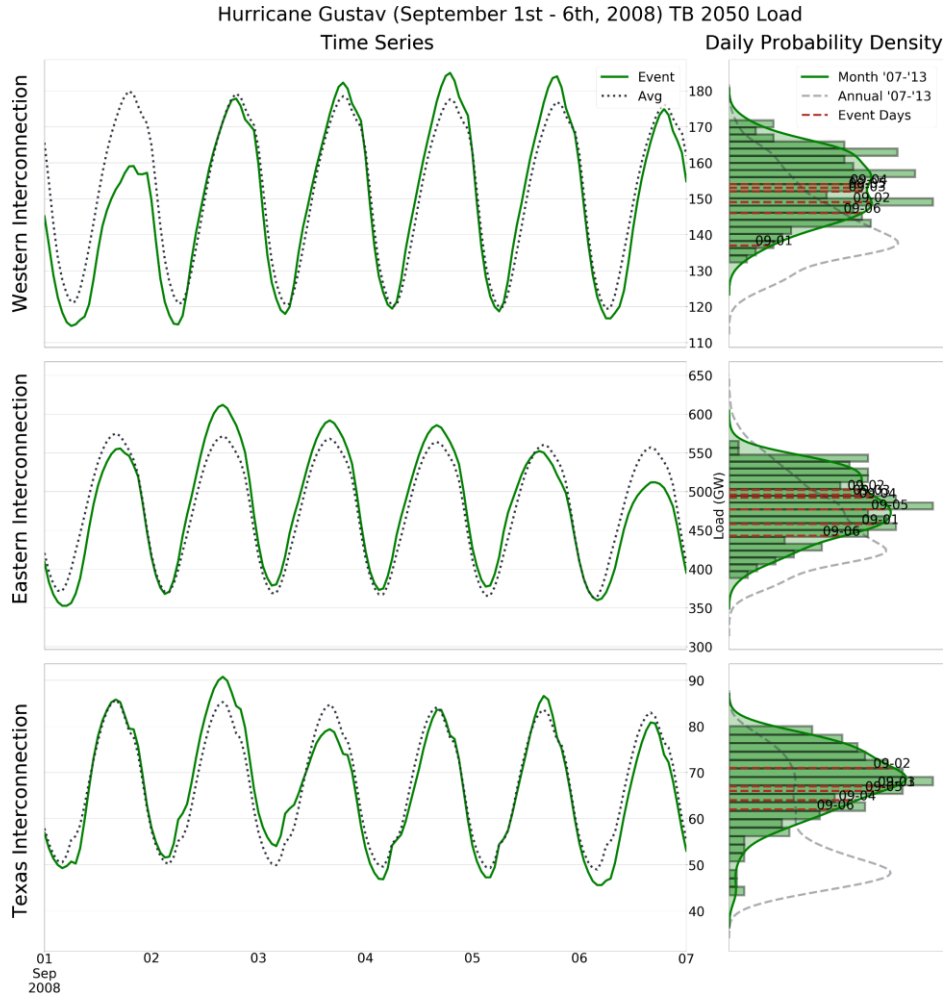
Wind/Solar During Gustav

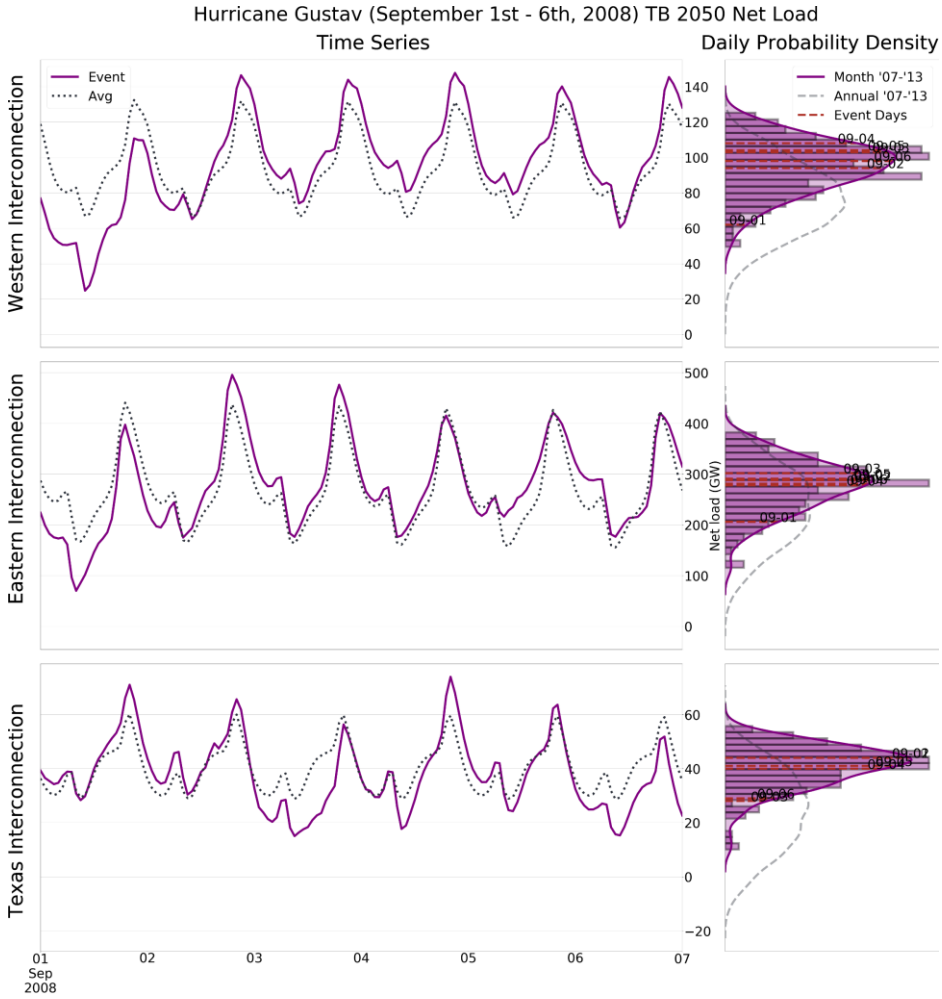




Significant impact is not detectable on a system wide scale

Load and Net-load During Gustav

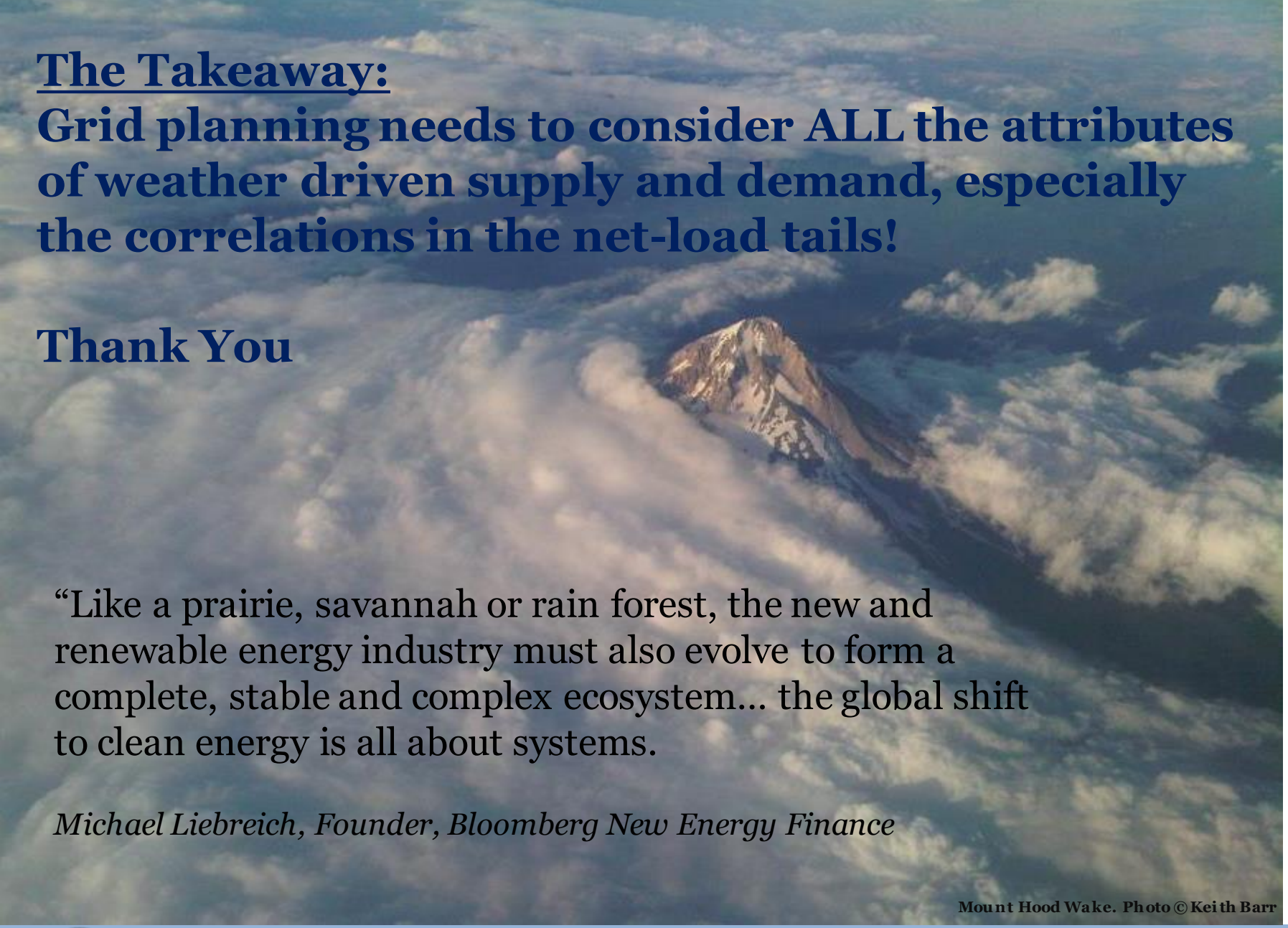




Significant impact is not detectable on a system wide scale

Summary

- Temperature stops being the primary modulator of supply/demand balance
- Weather driving generation becomes the primary modulator
- Wind/Solar are synergistic most of the time
- Supply constraints no longer typically coincides with record warmth/cold
- Concurrent weakness of wind and solar resource is a bigger driver than temperature excursions. The weather causing this is often boring!
- Net load distributions tighten as penetration increases and the tails narrow!
- Should season high wind and solar combos will lead to over supply. Hydro will exacerbate this in the spring (not shown)
- Cut out due to T, ice and snow now matters (not discussed)
- Hurricanes and other "severe" weather have only local negative impact; severe weather is a developer concern but is typically less so a grid operator concern with respect to generation (existing T&D impacts remain).



The Takeaway:

Grid planning needs to consider ALL the attributes of weather driven supply and demand, especially the correlations in the net-load tails!

Thank You

"Like a prairie, savannah or rain forest, the new and renewable energy industry must also evolve to form a complete, stable and complex ecosystem… the global shift to clean energy is all about systems.

Michael Liebreich, Founder, Bloomberg New Energy Finance

Mount Hood Wake. Photo © Keith Barr