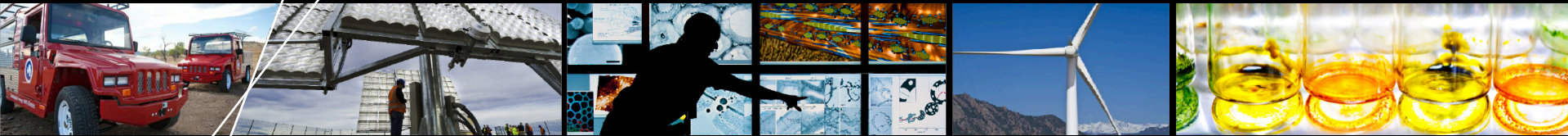


# The Wind Integration National Dataset (WIND) toolkit



**EWEA Wind Power Forecasting  
Workshop, Rotterdam**

**Caroline Draxl**

**December 3, 2013**

# Impact of high wind penetrations on power systems operations?



*Photo by Jamie Keller, NREL 19697*

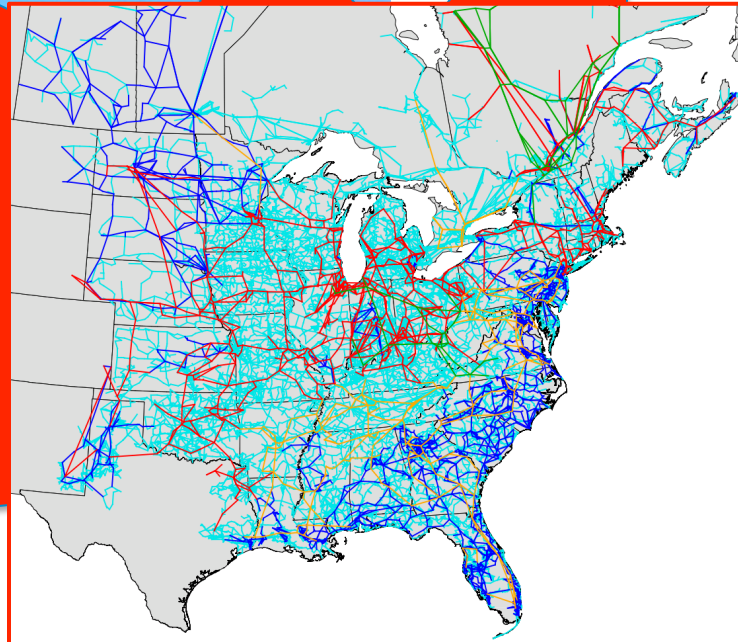


*Photo by Energy Northwest, NREL 12307*

# Impact of high wind penetrations on power systems operations?

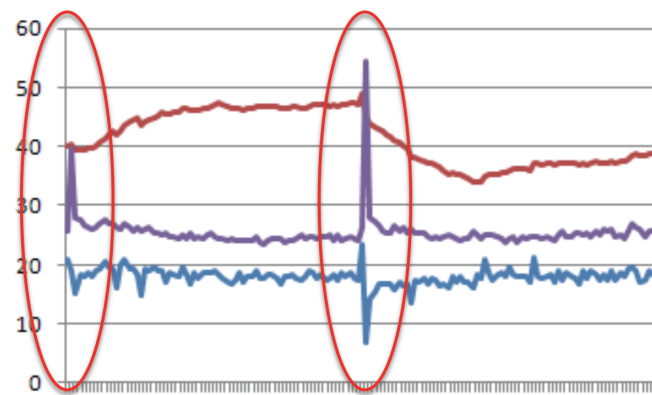
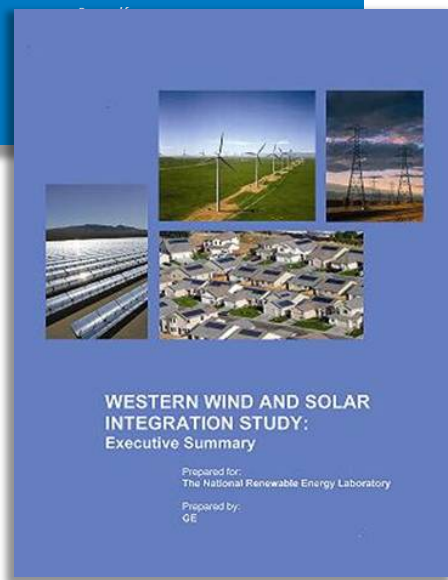
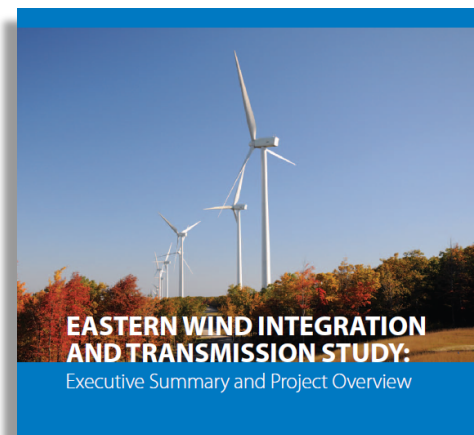


*Photo by Jamie Keller, NREL 19697*

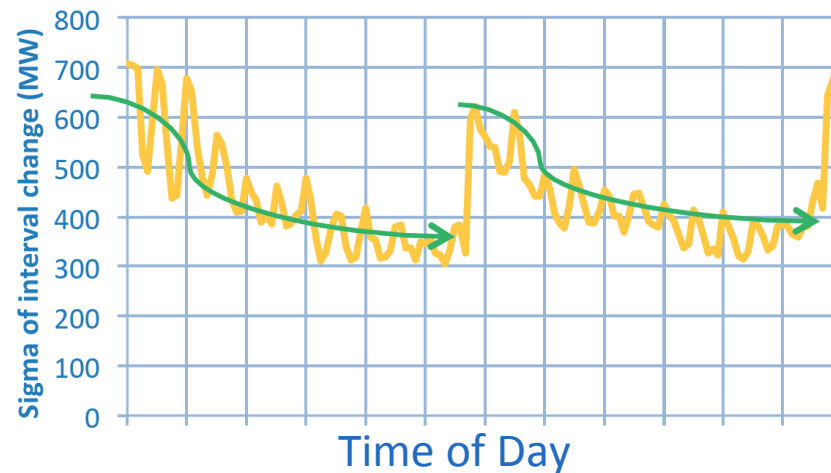


*Photo by Energy Northwest, NREL 12307*

# Need for high resolution wind power data



Artifacts still remain after corrections





# Need for high resolution wind power data

- Realistically reflects ramp characteristics
- Spatial seams
- Capacity factors of wind plant production
- Time-synchronous with load profiles
- Recent years
- Lasts at least 4 years to evaluate inter-annual variability
- Easy access.

# Wind power forecasts and production time series for 2007-2013

Wind Integration National Dataset WIND toolkit:

Re-analysis:  
Meteorological and  
power data set

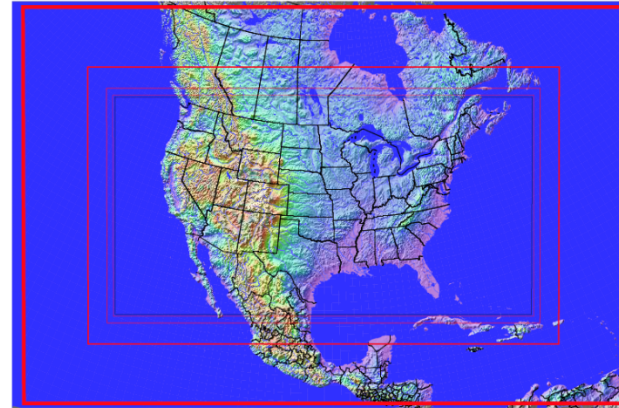
Re-forecast:  
power data set  
(1 h, 4 h, 6 h, 24 h)

**Freely available online data extraction tool**

## Acknowledgements:

- NREL: Bri-Mathias Hodge, Dan Getman, Wesley Jones, Kirsten Orwig
- 3 TIER: Jim McCaa, Padriac Fowler, Eric Gritmit
- Members of Technical Review Committee
- U.S. Department of Energy.

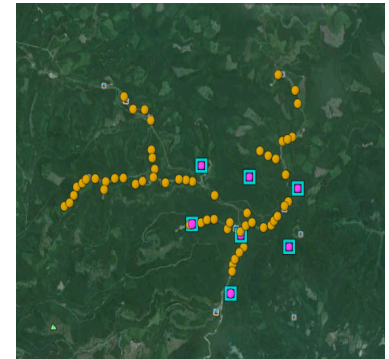
# The Weather Research and Forecasting (WRF) model setup



- **WRF V.3.4.1**
- **2 km for re-analysis, 6 km nest for forecasts**
- **Boundary conditions: NOAA Reforecast2 Global Ensemble Forecast System Control 1-degree, NCEP Real-time global 1/12<sup>th</sup> degree Sea Surface Temperature analysis**
- **Model output: 5 min for re-analysis, 1 h for forecasts**
- **Terrain U.S. Geological Survey GTOPO30**
- **Yonsei University (YSU) boundary layer scheme, topographic wind enhancement**
- **100+ terabytes model output: Parallel asynchronous I/O to improve output speed 50:1.**

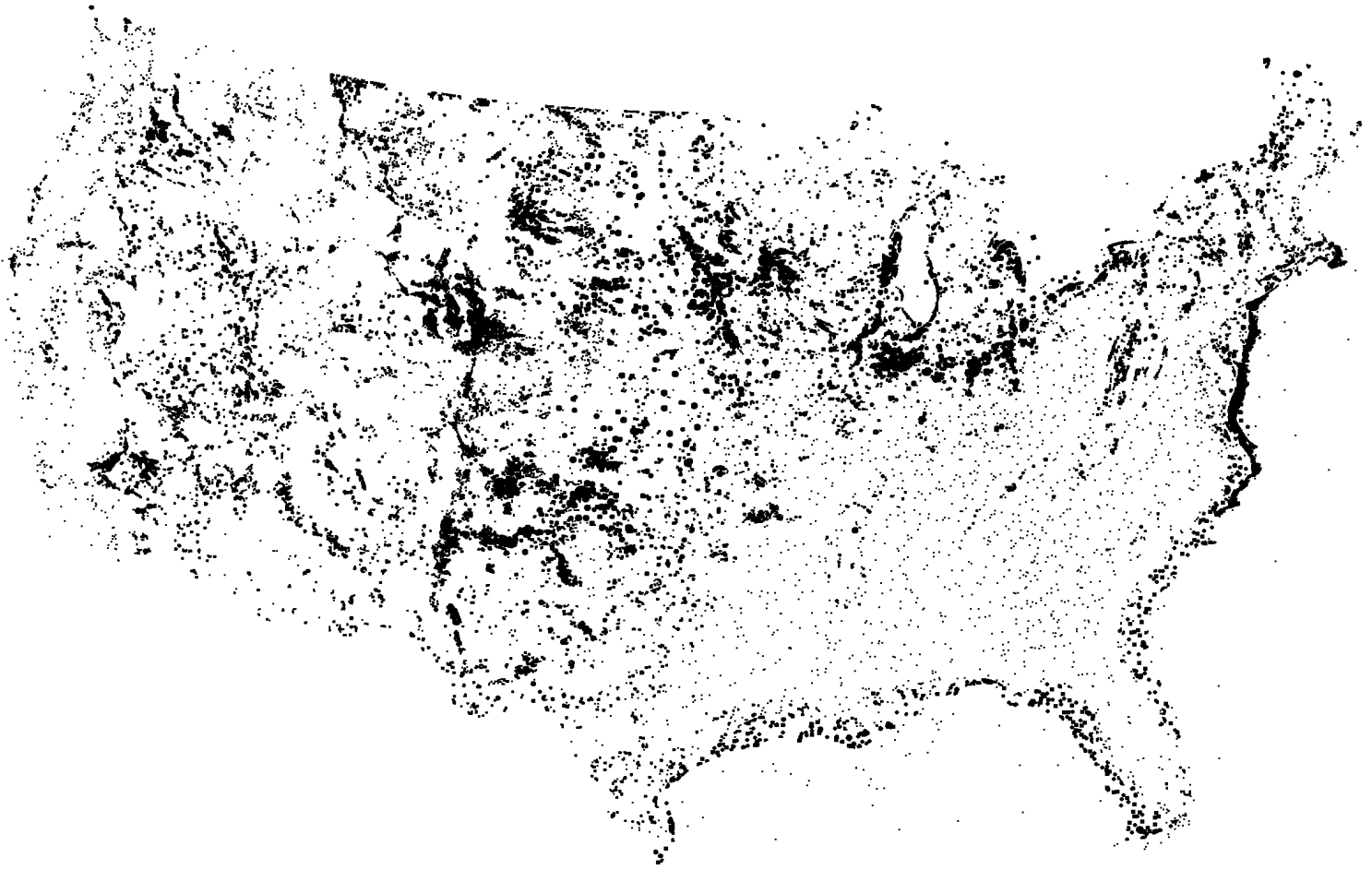
# 126,000 land-based and offshore existing and potential wind facilities

- Each site is a 2x2-km grid cell in the numerical weather prediction data set
- Site selection process
  - Exclusion criteria:
    - Federal lands, national parks, open water areas
    - Areas with slopes greater than 20%
    - Within buffer area of developed land and airports
    - Offshore: wind resource, distance from shore at least 8 km, bathymetry (max depth 30 m)
- Ranking based on computed potential MWh.





# 126,000 land-based and offshore existing and potential wind facilities



# Create state-of-the-art forecasts without “cheating”

by mimicking “real” forecast errors

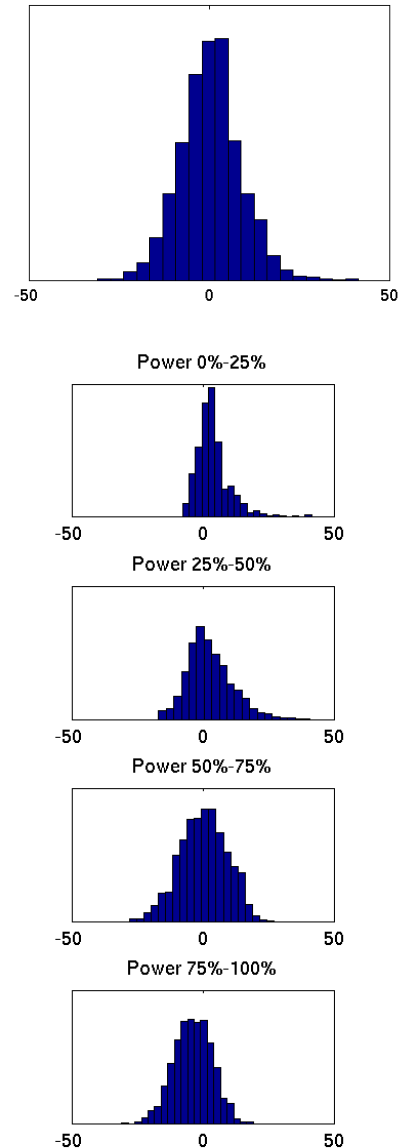
# Create state-of-the-art forecasts without “cheating”

by mimicking “real” forecast errors

- **NWP is the basis**
  - Initialized daily at 00 UTC
  - 6-km grid
  - Hourly output.
- **Respect the spatial-temporal correlation of typical forecast errors at forecast horizons**
- **For forecast horizons  $\leq 6$  h: statistical model for each site**
- **Post processing at each site to remove bias**
- **Each forecast: deterministic value + P10/P90 probability of exceedance values.**

# Probabilistic forecasts with nonparametric error quantiles

- Empirical forecast error distributions differ based on power regime
- Conditional, nonparametric dressing approach
- Yields approximate calibration (reliability)
- Dynamic adjustment to weather regime changes and seasonal forecast skill.



# Power conversion

- **Bias removal from wind speeds:**
  - Time series smoothing
  - Blend in “truth” with a limited weight
  - Adjust until forecast time series and error histograms are reasonable and error metrics are similar to state of the art.
- **Wind speed adjustment for wakes:**
  - Max. two turbines per square kilometer, each site max. eight 2-MW turbines
  - Apply wake losses to wind speed
  - Each 2x2-km site considered independently.
- **Application of power curves**
- **Statistical adjustment to power using total variance, autocorrelation of sites, spatial covariance.**



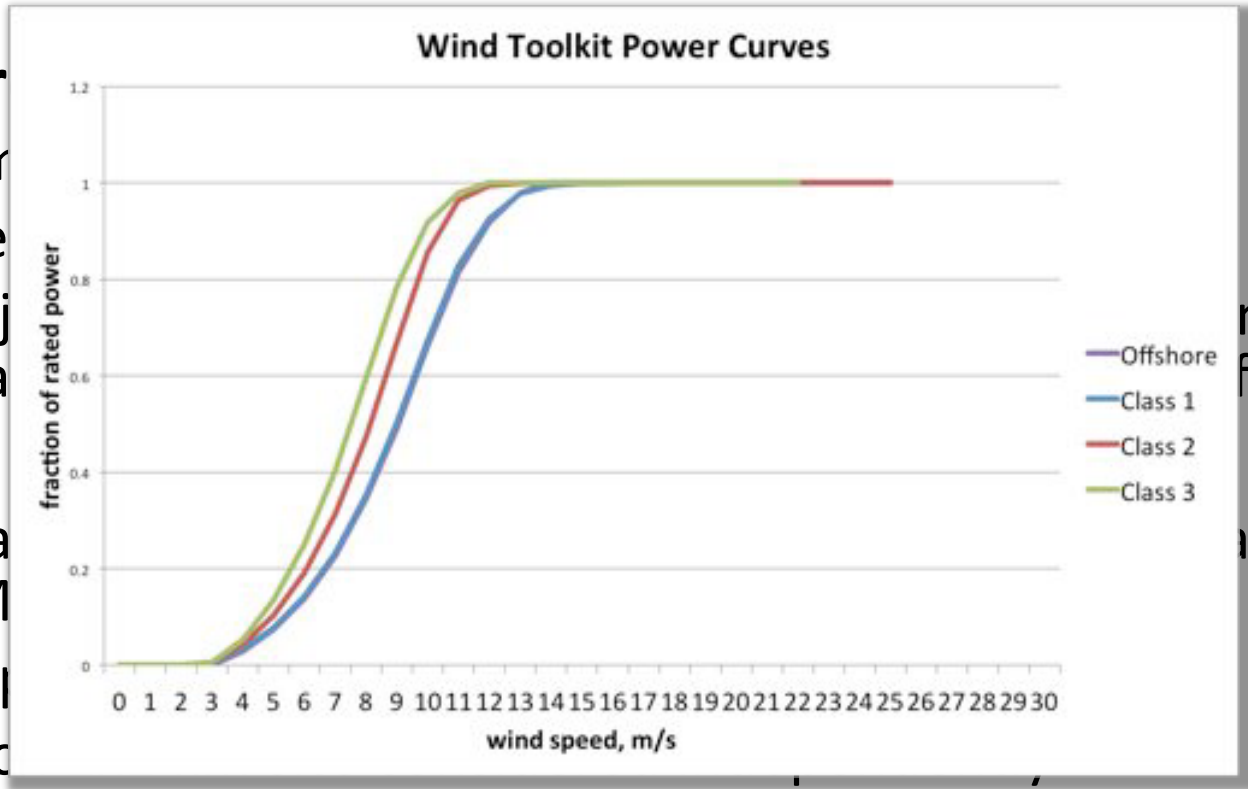
# Power conversion

- **Bias r**

- Tim
- Ble
- Adj
- rea

- **Wind**

- Ma
- 2M
- App
- Eac



- **Application of power curves**

- Statistical adjustment to power using total variance, autocorrelation of sites, spatial covariance.

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of the art.

ax. eight

# Power conversion

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Home Pan Zoom Measure Find Location Query Wind Analysis - BETA User Views Print Help Login Base Layers

(BETA) Select Download Dates for Site: 108946

**Select Beginning Date**

November 2013

S	M	T	W	T	F	S
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
1	2	3	4	5	6	7

Select Hour: 00

**Select End Date**

November 2013

S	M	T	W	T	F	S
27	28	29	30	31	1	2
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24	25	26	27	28	29	30
1	2	3	4	5	6	7

Select Hour: 00

**Select Attributes**

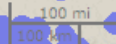
Available Attributes	Selected Attributes
Attribute	Attribute
Wind Power	
Wind Speed (meters/second)	
Temperature C	
Atmospheric Pressure	
Capacity Factor	

Reset Attribute Selection

Select a date range

Choose the attributes of interest

Stay within the size limit



# Summary

**State-of-the-art  
wind  
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continental  
U.S.A.**

**Deterministic and  
probabilistic  
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