The Wind Forecast Improvement Project: Final Results from the Southern Study Area

a DOE sponsored / NOAA collaborative effort

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How do (did) we improve the performance of short term (0 - 6 hours) wind forecasting?
How do (did) we accurately measure the improvement?

Focus here: Southern Study Domain encompassing most of north, central, and west Texas
Balancing Authority: Electric Reliability Council of Texas (ERCOT)
Wind Power on the ERCOT System

System Load (2011 - 2012)

Average hourly: 38,255 MW
Range: 22,386 to 68,392 MW

Wind Power
Total: 9801 MW (Jan 2012)
In WFIP area: 8296 MW (85%)
Referred to as ”WFIP project aggregate”

Much of capacity concentrated in a small area of NW Texas (near Sweetwater, TX)

Frequent occurrence of large system-wide ramps (large excursions of power production in short time periods, e.g. 20% change in 30 minutes)

Southern Study Area: focus on Electric Reliability Council of Texas (ERCOT) domain — largest number of operating wind farms (> 10,000 MW) in the U.S.
Field Deployment

Additional Instrumentation
3 profilers w/RASS
7 sodars
6 surface met and flux stations
200-m TTU tower and 15 - 35 Tall Towers (wind farms; 50 total)
WFIP Forecast System

- Large Scale Models (GFS, RAP)
- Ensemble of Rapid Update Short-term NWP (MASS, WRF, ARPS, HRRR)
- Statistical Adjustment Process (e.g. MOS)
- Ensemble Composite Algorithm (weighting application)
- Final Forecast
Phenomena

1. Synoptic scale (fronts, dry lines) ➤ big ramps; easier to predict

2. Low-level jets (LLJs) ➤ common (Freedman et al. 2008); periodic but large variability in small $\Delta z$ presents forecast difficulty

3. Mesoscale (convection, outflow boundaries) ➤ tougher to predict given temporal and spatial scales
LLJs are a dominant mechanism responsible for the nocturnal wind speed max...key is where and when $\Rightarrow f(x, y, z, t)$

One-year composite Reagan TX

Sept 2011 - August 2012
Evident in power production - regular, periodic, predictable?

Capacity Factor - sequence of days
Temporal and spatial extent

30 June 2013

Ozona

Cleburne

Reagan

Lubbock
Sequence Forecast Performance

Observations and 3-hr Forecasts for WFIP Aggregate

Undadjusted Raw Model Output And Final STWFP, WFIP From 28-Jun to 2-Jul 2012 UTC

Power (MW)

28-Jun 29-Jun 30-Jun 1-Jul 2-Jul

Decimal Day

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Model Performance - 3 hr forecast

Taylor diagram

Visualize the phase and amplitude of model performance compared with the observations

3 metrics ($R^2$, RMSE, and SD) on 2D space

Observations - the perfect forecast

Improvement in all 3 domains
Removed diurnal bias

Baseline

Issue with evening and morning transition

Capacity Factor
2 hr forecast

WFIP

Capacity Factor
4 hr forecast of
\(\Delta 15\) min

Baseline

\(\Delta 15\) min

15-min Delta Capacity Factor Bias for the Baseline Forecast Time = 4 for AGG

WFIP

\(\Delta 15\) min

15-min Delta Capacity Factor Bias for the WFIP Forecast Time = 4 for AGG
Model Performance

Diurnal patterns - 3 hr forecast

Distinct diurnal pattern in R2, SD, and RMSE

Better performance across stats - more clustered

Baseline

WFIP
Largest Up Ramp Events and Their Causes

- Analyzed 10 largest 60-minute upward ramp rate events
- Subjectively identified cause
  - Blue: Cold front
  - Red: Thunderstorms/outflow boundaries
  - Green: Low Level Jet (LLJ)
    - Dark: strengthening large scale pressure gradient at night
    - Light: diurnal cycle with embedded convection

**Ramp:** a specified excursion in (variable energy) power production during a defined time period - particular to utility, ISO, BA, etc.
NWP Ensemble Performance on Big Events

• **Metric:** Fraction of ensemble members that achieve a "hit"

• **Hit:** > 75% of amplitude within +/- 2 hours of event

• **Hit Rate by Type**
  – Cold Front (blue)
    • 8-10 hrs ahead: 84%
    • 2-4 hrs ahead: 95%
  – Thunderstorm-related (red)
    • 8-10 hrs ahead: 10%
    • 2-4 hrs ahead: 48%
  – Low Level Jet (green)
    • 8-10 hrs ahead: 46%
    • 2-4 hrs ahead: 71%

8-10 hrs ahead forecast: left bar for each event
2-4 hrs ahead forecast: right bar for each event
Big Ramp Event: 8 September 2012

9/7 18z - 9/8 00z
Cold front over TX panhandle, extending SW to NE and progressing southward

9/8 00z-01z
Front reaches ERCOT area

SWN: 00:45z
SWE: 01:30z
ETX: 01:30z

Legend: dBZ

REFLECTIVITY
ELEV ANGLE: 0.54
Observed Power Output By Capacity Factor For All ERCOT WFIP and Regional Aggregates

For 9/7/2012 To 9/8/2012

From 17% to 80% (1400 MW to 6350 MW) in 1.56 hours!
Summary

• Observations demonstrate ability to capture temporal and spatial dimensions of mesoscale and synoptic features/events common to the ERCOT domain, and in particular, those affecting wind power production

• Spatial extent of LLJ (“sheet”) can cover large portions of ERCOT

• WFIP model system a significant improvement over baseline (STWPF) forecasts
  - notable improvement in statistical space (RMSE, SD, R²)
  - elimination of diurnal biases (particularly evening and morning transition)
  - much better performance on ramp predictions (RPSS)

• Final Report - next few weeks
Thank You!