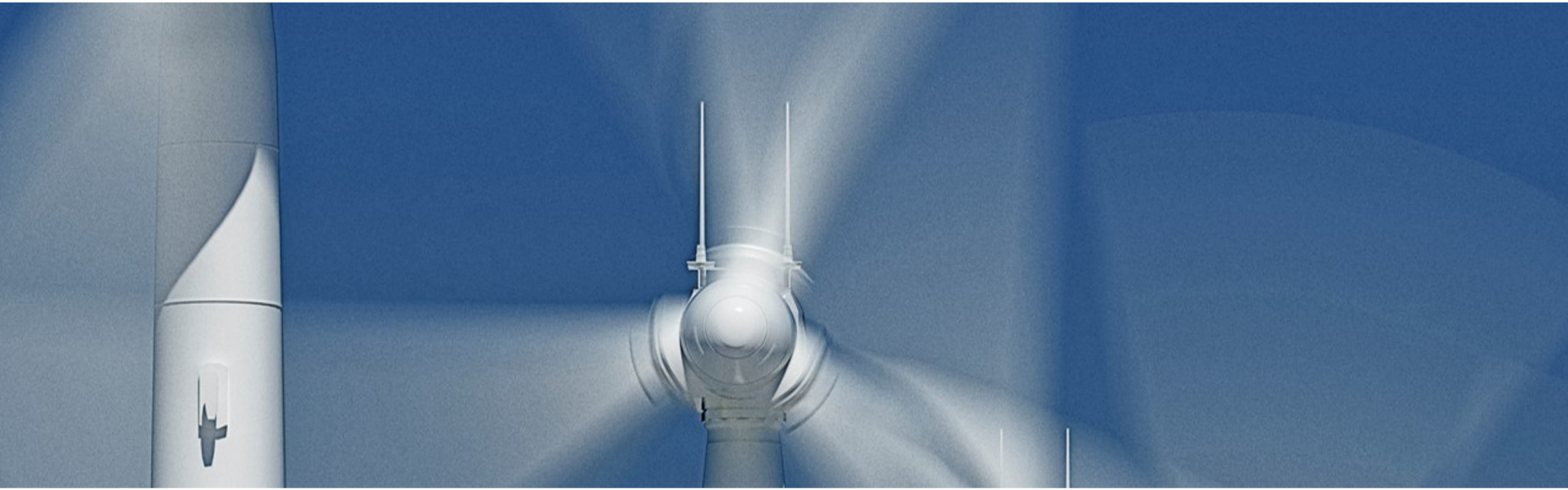


# Suitability of Reanalysis Data for Wind Plant Revenue Estimation

Jennifer F. Newman, Matthew Livingston, Carl Ostridge, Shane Hall, and Aaron Perry

January 14, 2020

# Use of Re-Analysis Data in Wind Energy

- Re-analysis datasets (e.g., MERRA2, ERA5) provide a long-term source of meteorological data at consistent spatial and temporal resolution
- When onsite met data are available, MCP methods can be used to correlate re-analysis data with local conditions
- When no onsite met data are available, re-analysis data may be used as a proxy for long-term wind resource

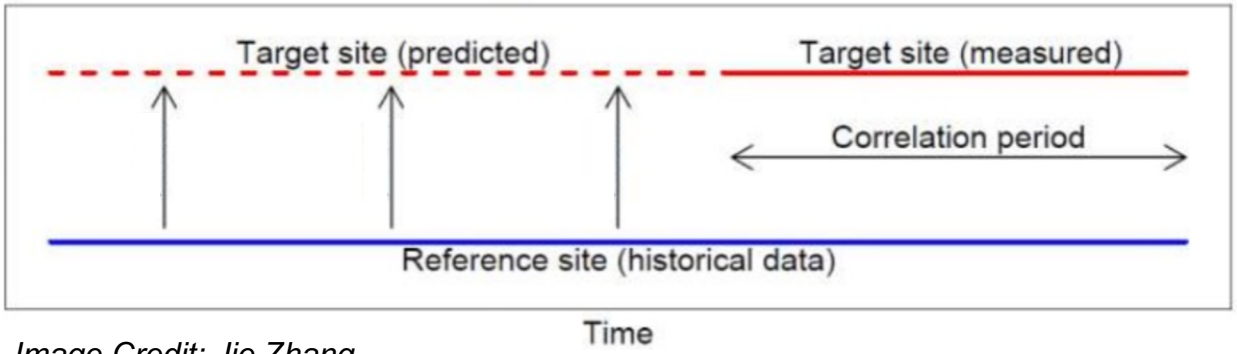
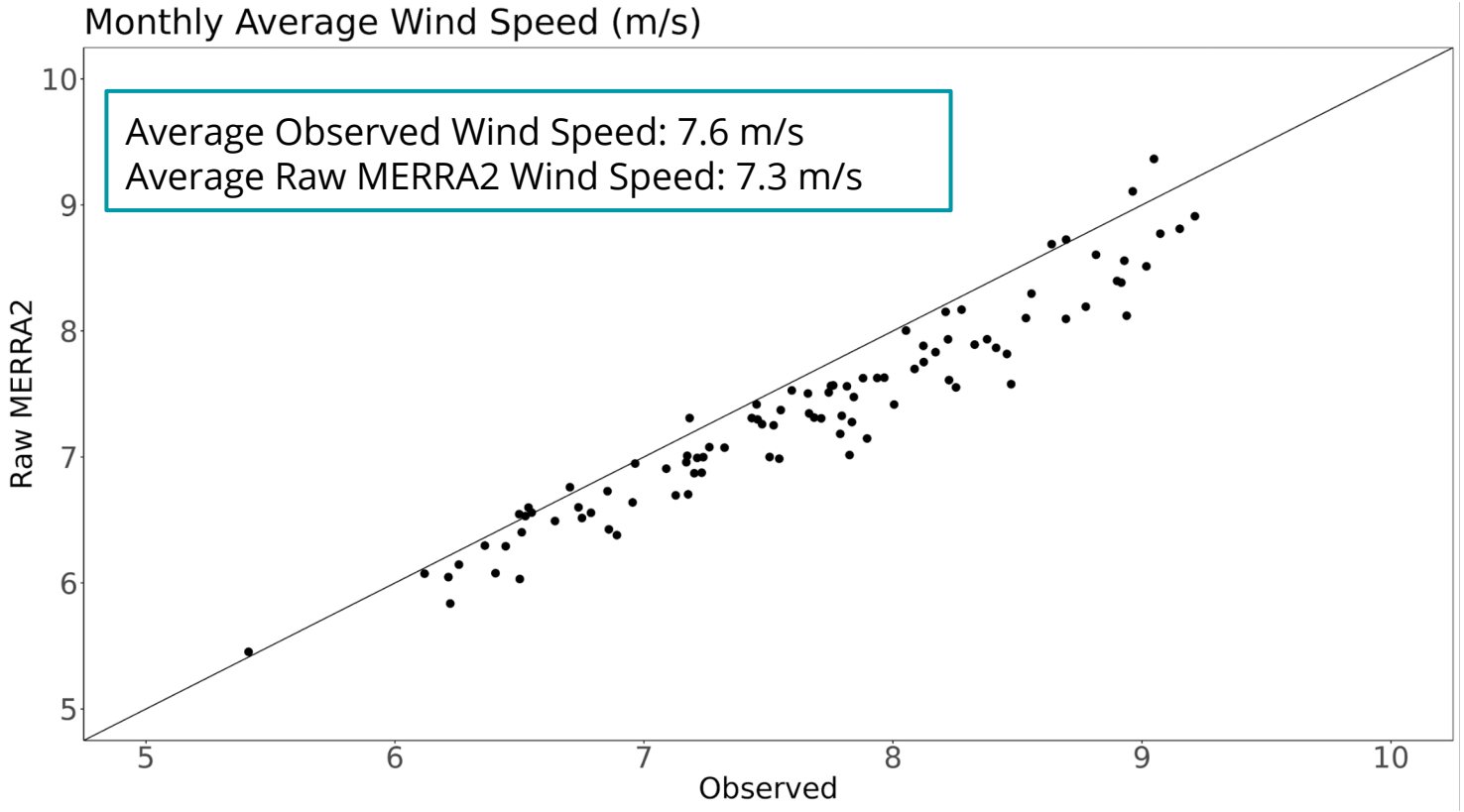
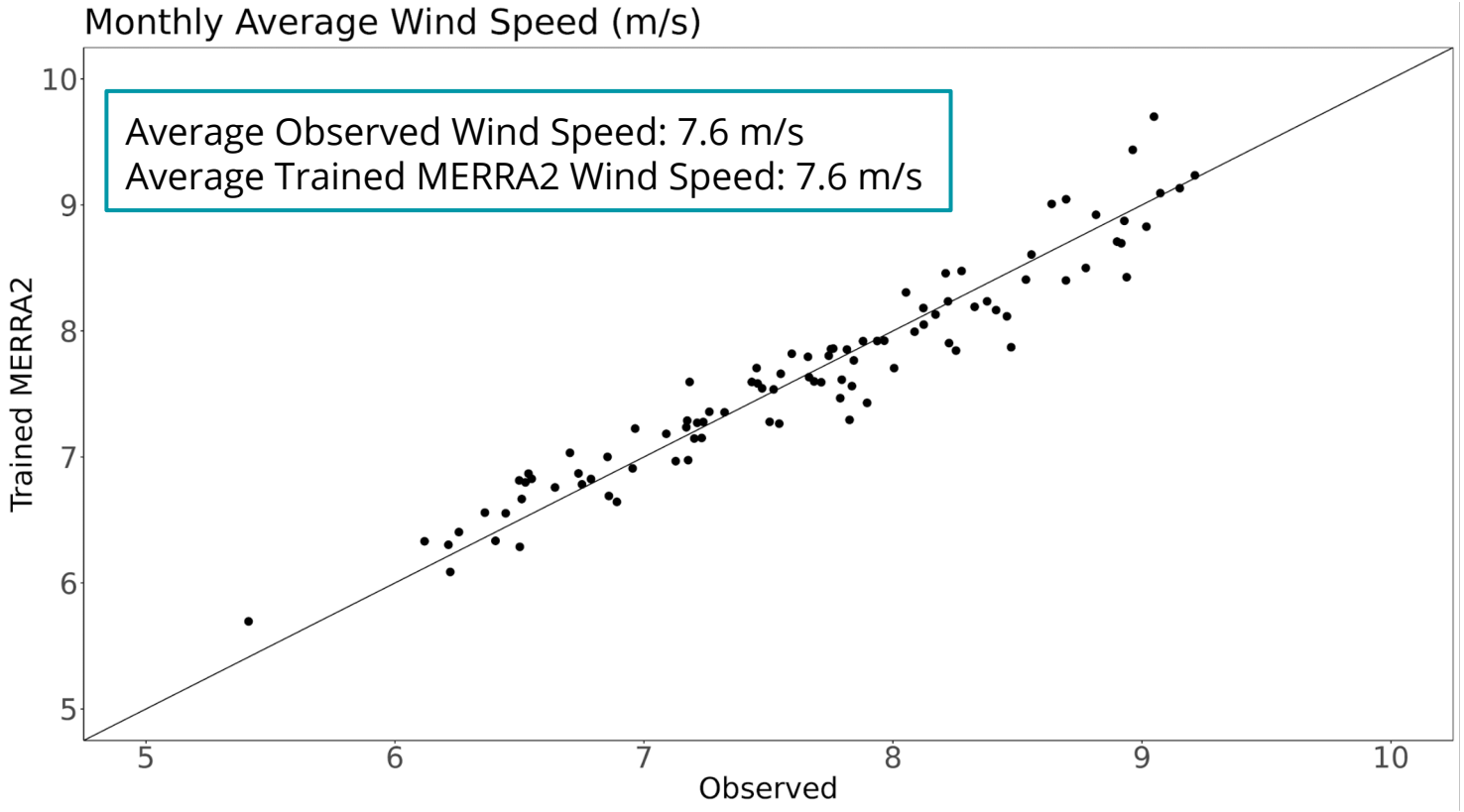



*Image Credit: Jie Zhang*

# MCP Example


Monthly Average Wind Speed (m/s)
Average Observed Wind Speed: 7.6 m/s
Average Raw MERRA2 Wind Speed: 7.3 m/s
Raw MERRA2
Observed
10
9
8
7
6
5
5
6
7
8
9
10

# MCP Example


Monthly Average Wind Speed (m/s)
Average Observed Wind Speed: 7.6 m/s
Average Trained MERRA2 Wind Speed: 7.6 m/s
Trained MERRA2
Observed
10
9
8
7
6
5
5
6
7
8
9
10

# Limitations of Re-Analysis Data

- Due to coarse spatial resolution (~50 km for MERRA2, ~30 km for ERA5), re-analysis data will not fully resolve mesoscale features such as seabreeze effects or flow in complex terrain
- Models can also have significant discontinuities at the hourly level (e.g., Kalverla et al. 2019)
- Even when a standard MCP method is applied (e.g., linear regression), significant errors can remain at the hourly level
- **Small errors in estimation of the diurnal power production profile can result in large errors in revenue estimation**

Kalverla, P.C., Duncan Jr, J.B., Steeneveld, G.J. and Holtslag, A.A., 2019. Low-level jets over the North Sea based on ERA5 and observations: together they do better. *Wind Energy Science*, *4*(2), 193-209.

# Are Re-Analysis Datasets Suitable for Wind Plant Revenue Estimation?

- Identify systematic periods of wind speed bias in re-analysis datasets
- Translate modeled and observed wind speeds to hourly generation for a 125-MW wind farm
- Pair hourly generation with hourly power prices to quantify differences between modeled and observed revenue

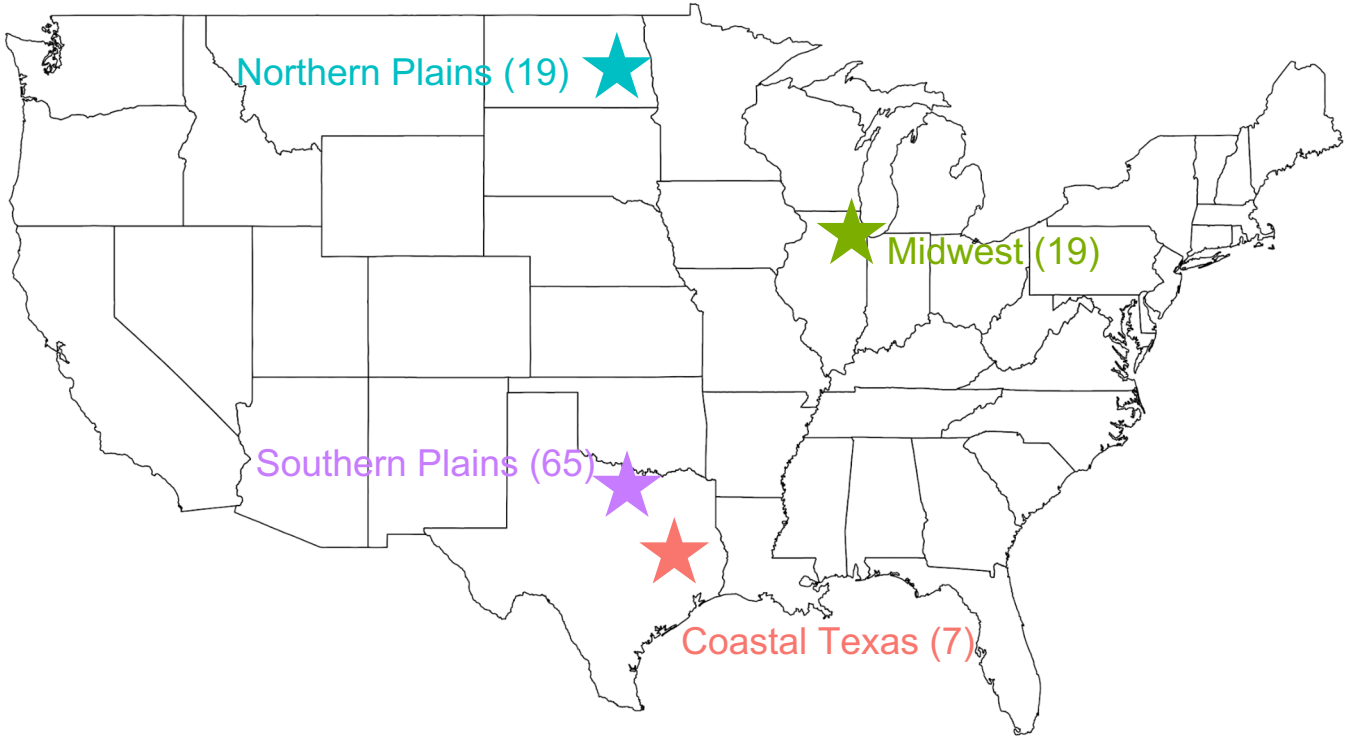
# Are Re-Analysis Datasets Suitable for Wind Plant Revenue Estimation?

- **Identify systematic periods of wind speed bias in re-analysis datasets**
  - This talk: MERRA-2 trained using linear regression on hourly wind speeds

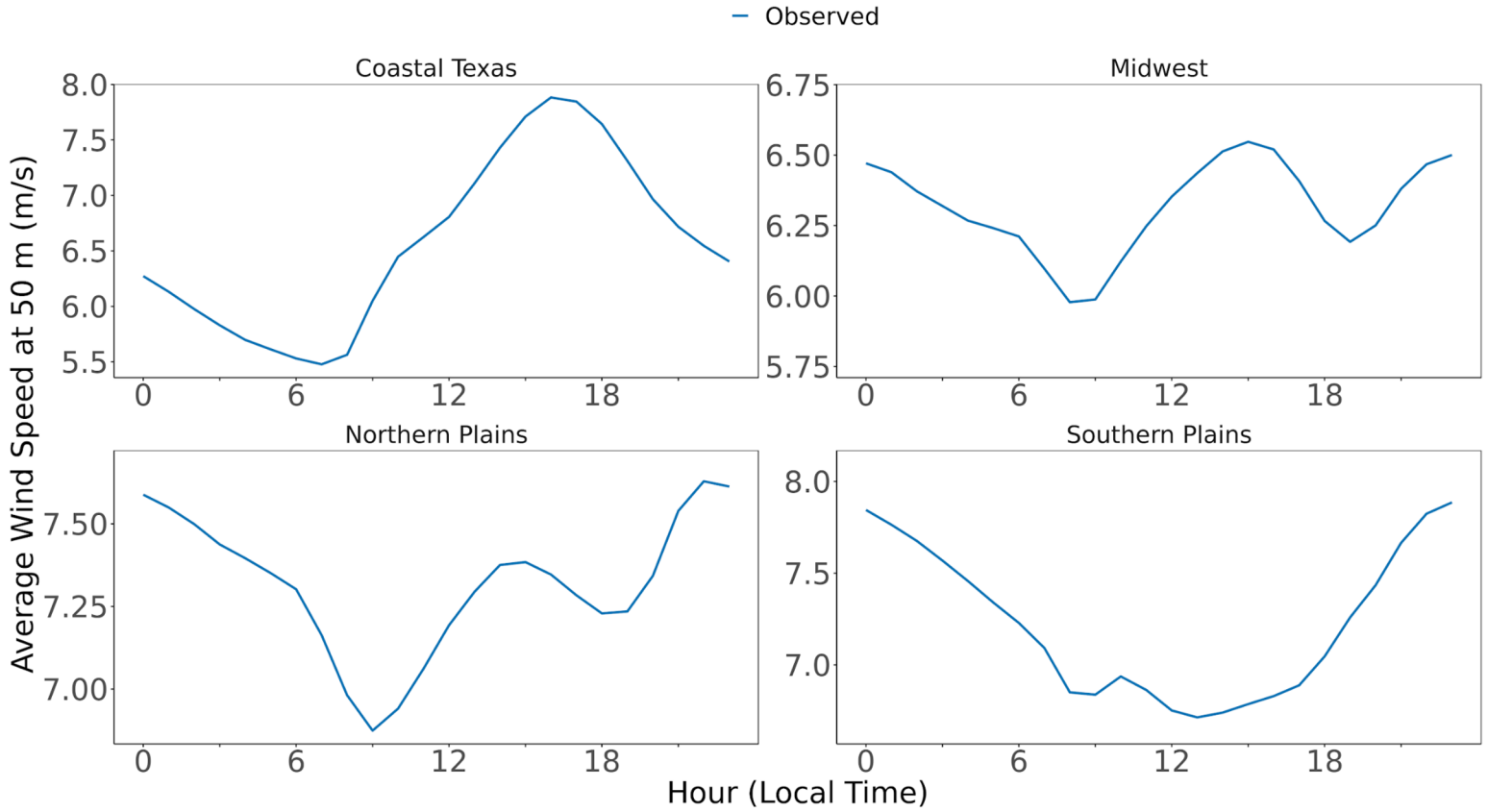
- Translate modeled and observed wind speeds to hourly generation for a 125-MW wind farm

- Pair hourly generation with hourly power prices to quantify differences between modeled and observed revenue

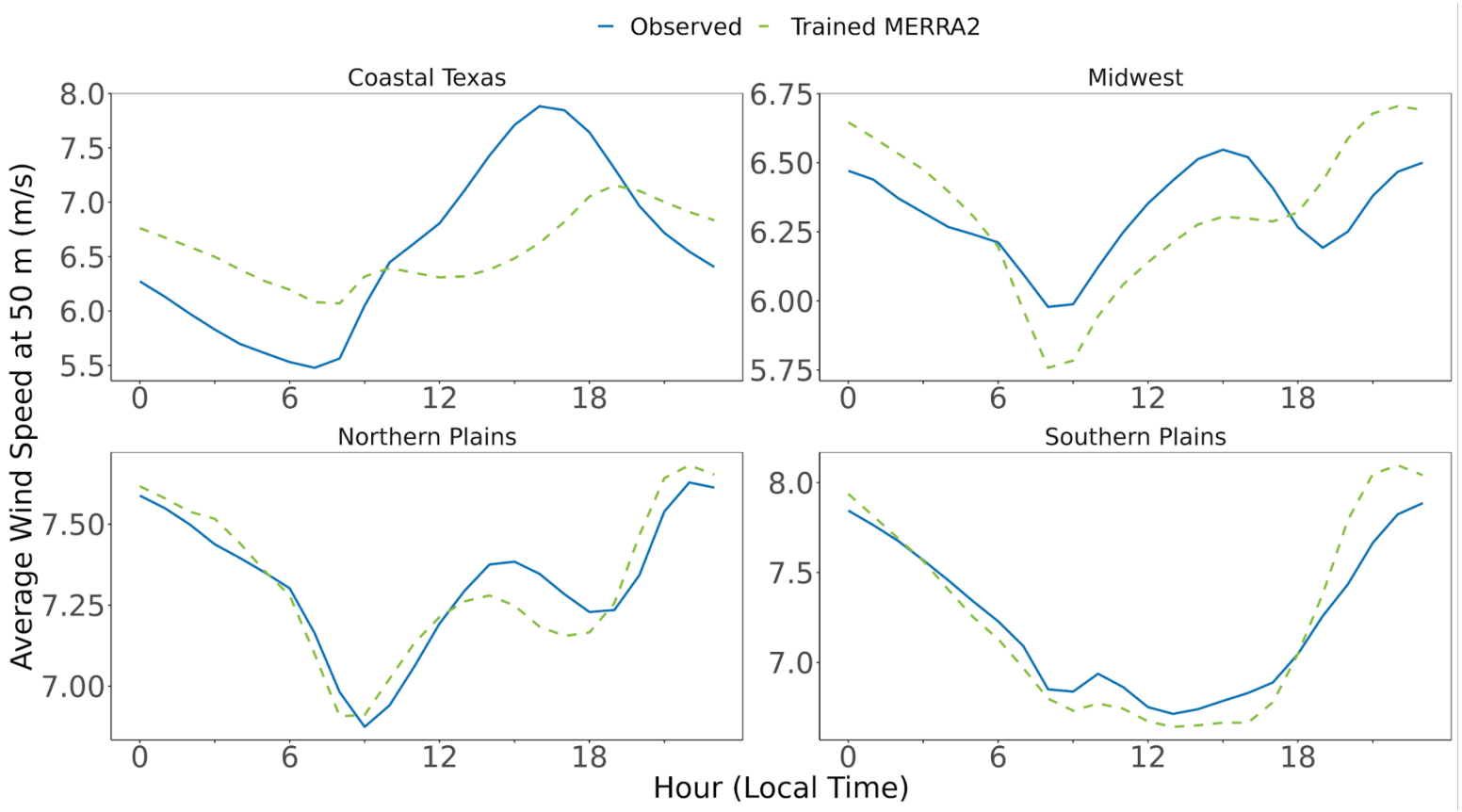
# Re-Analysis Bias for 110 Test Towers



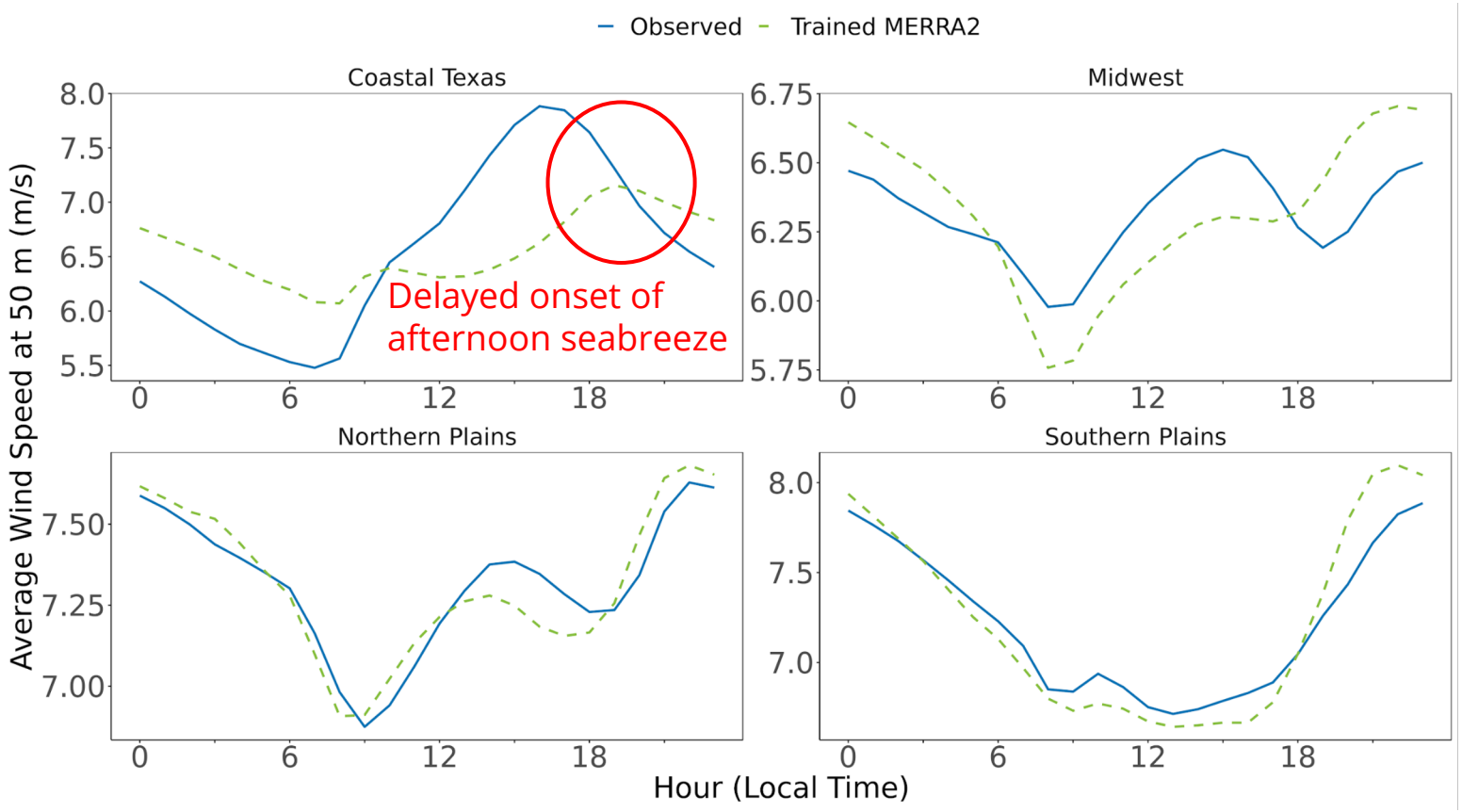
# Average Observed Wind Speed Profiles



# Average Trained MERRA2 Wind Speed Profiles



# Average Trained MERRA2 Wind Speed Profiles



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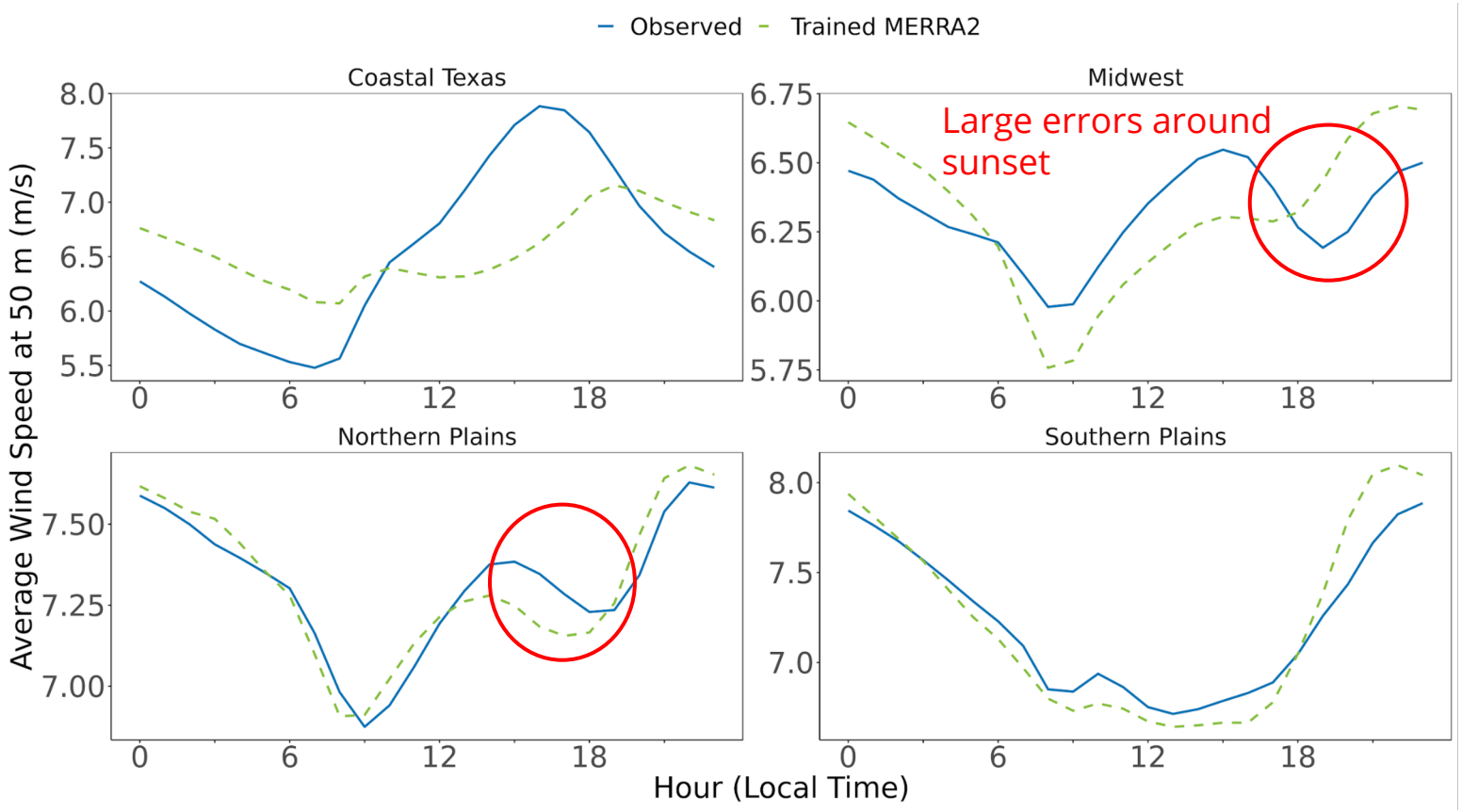

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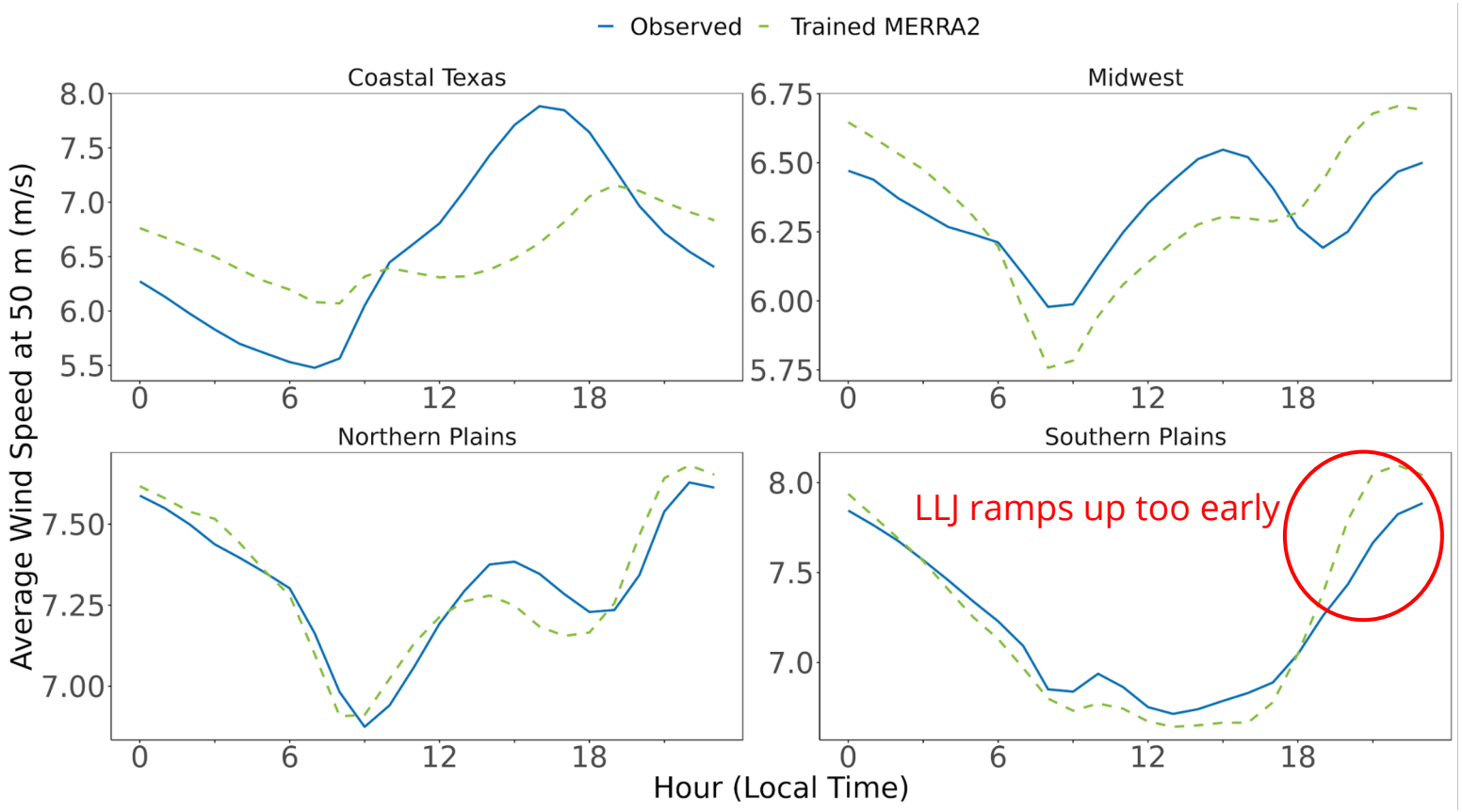
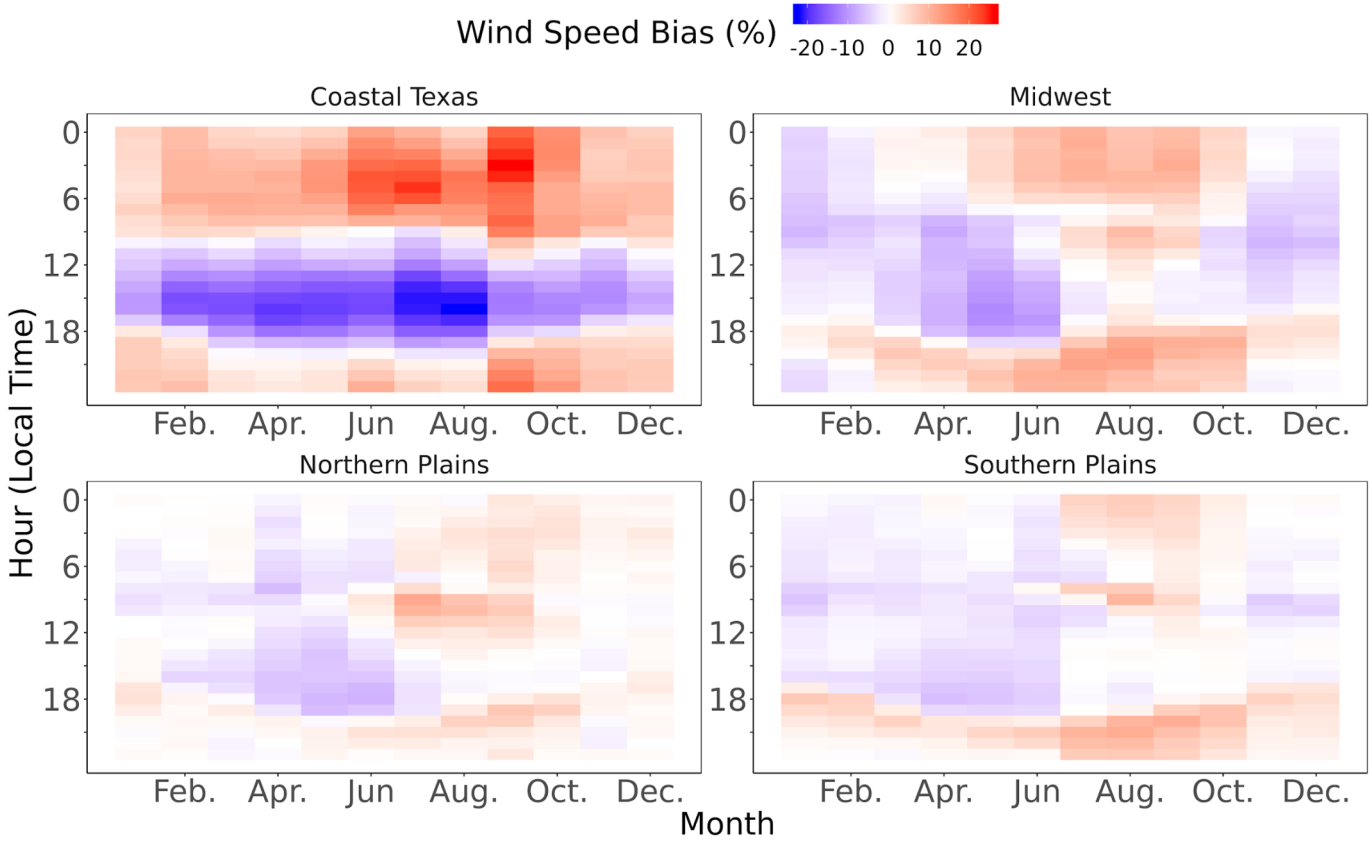
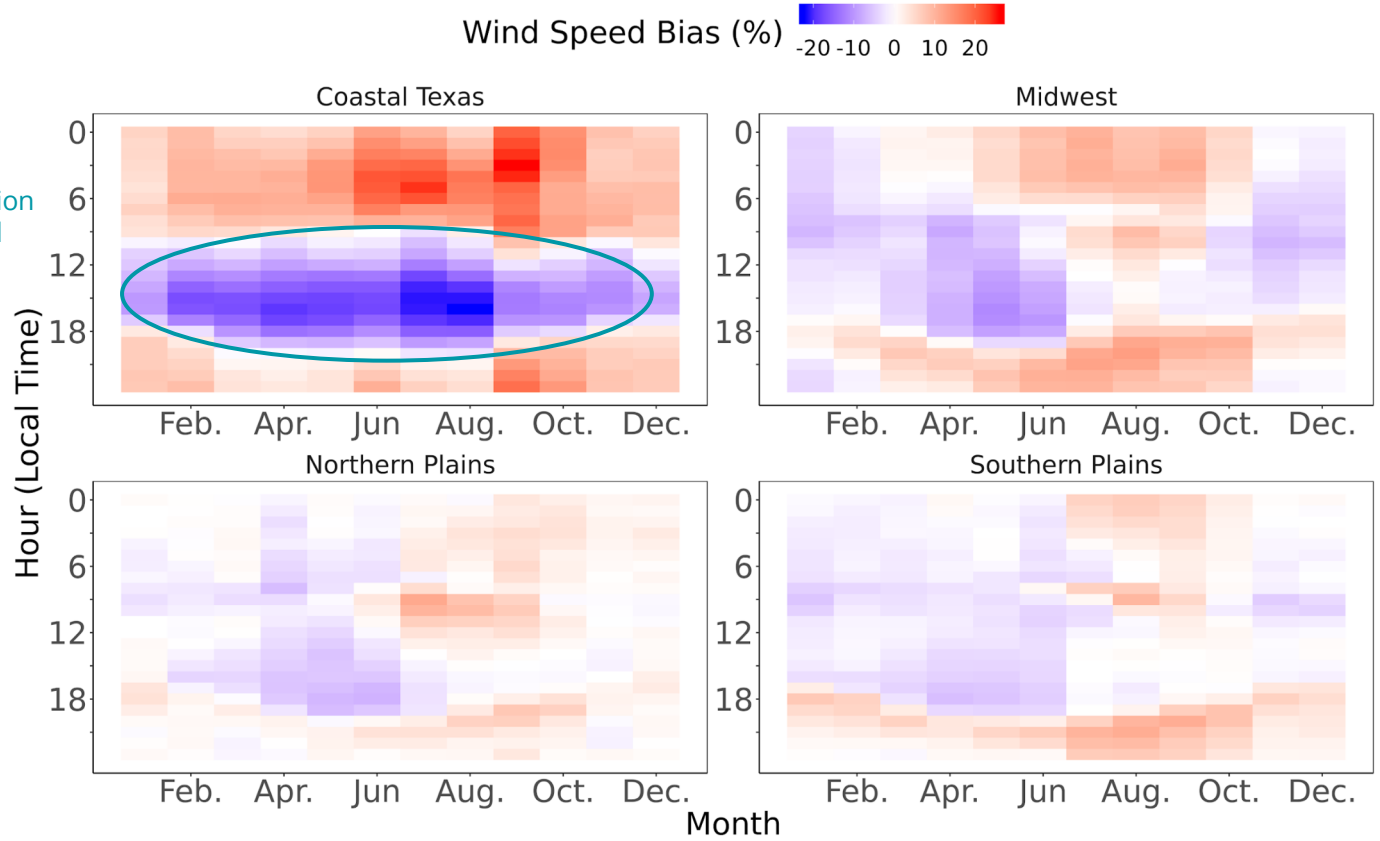


# MERRA2 Wind Speed Bias

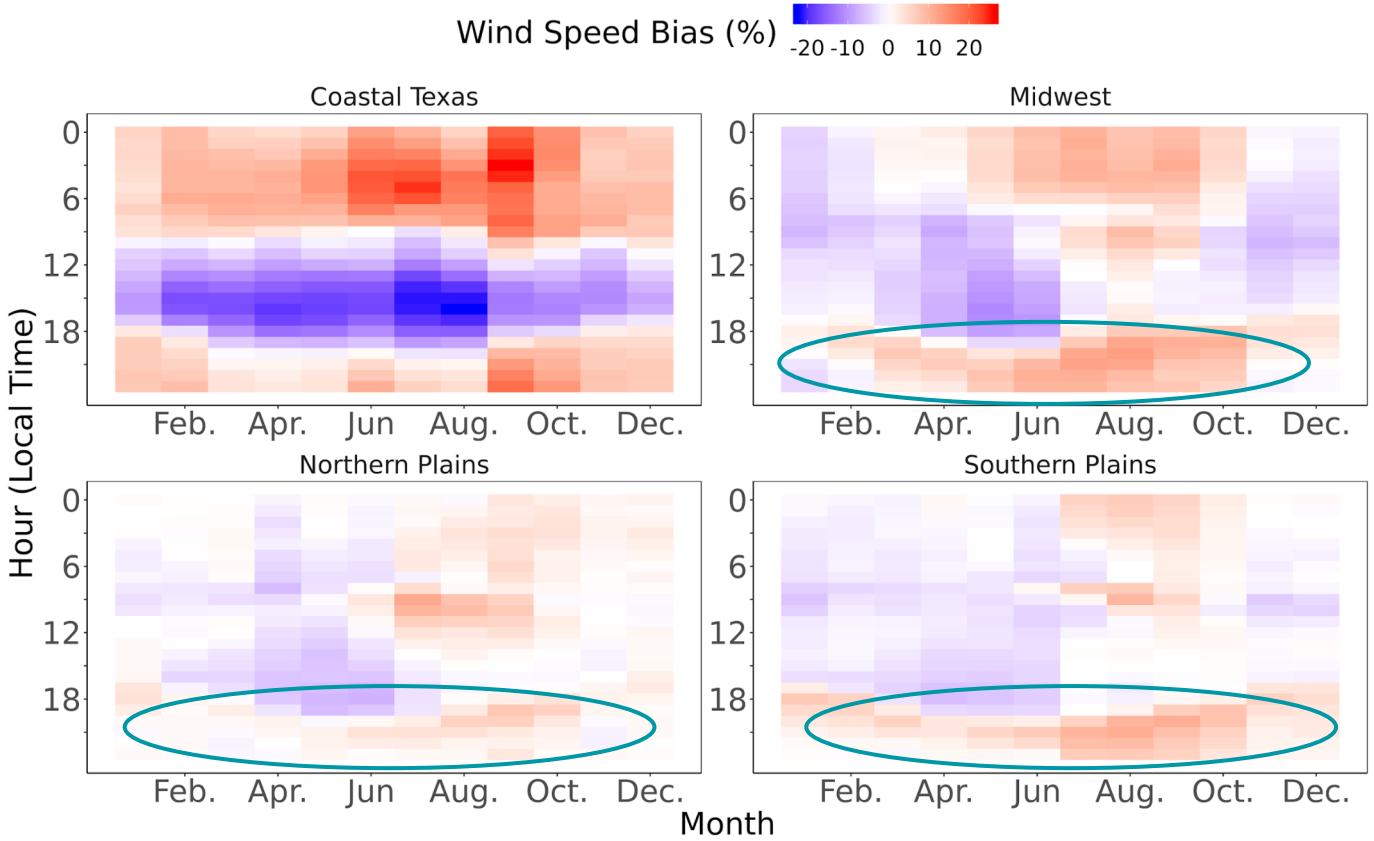


# MERRA2 Wind Speed Bias

Significant underestimation of wind speed during late morning and afternoon



# MERRA2 Wind Speed Bias




Consistent overestimation of wind speed around sunset and evening hours

# Are Re-Analysis Datasets Suitable for Wind Plant Revenue Estimation?

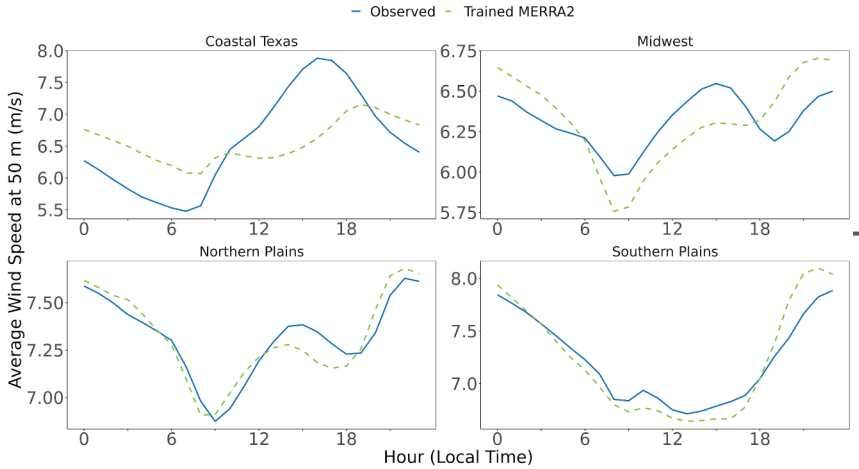
- Identify systematic periods of wind speed bias in re-analysis datasets
- **Translate modeled and observed wind speeds to hourly generation for a 125-MW wind farm**
- Pair hourly generation with hourly power prices to quantify differences between modeled and observed revenue

# Translation to Energy

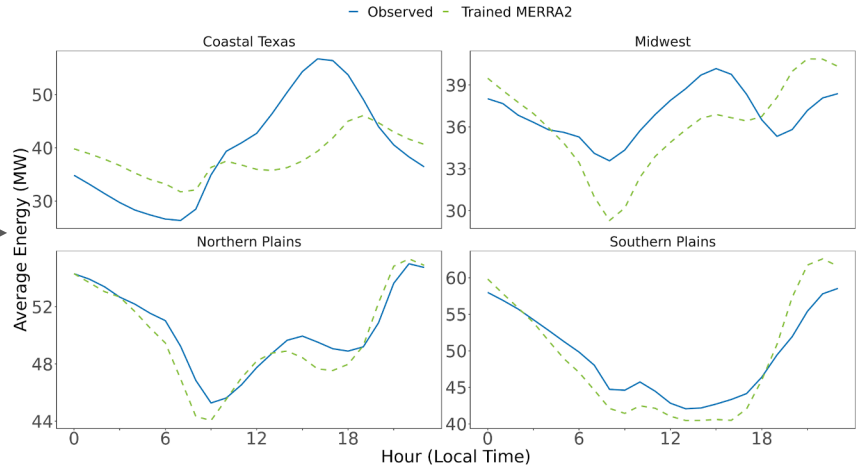
-Pass wind speeds through a power curve for a 2.5MW turbine

-Assume a 50 turbine wind farm with 90% expected operational efficiency

Average Hourly Wind Speed




Average Hourly Energy



# Are Re-Analysis Datasets Suitable for Wind Plant Revenue Estimation?

- Identify systematic periods of wind speed bias in re-analysis datasets
- Translate modeled and observed wind speeds to hourly generation for a 125-MW wind farm
- **Pair hourly generation with hourly power prices to quantify differences between modeled and observed revenue**

# Translation to Revenue

12x24 of Average Generation

| | Jan | Feb | Mar | ... |
|---|---|---|---|---|
| 0 UTC | 54 MW | 63 MW | 90 MW | |
| 1 UTC | 45 MW | 54 MW | 81 MW | |
| 2 UTC | 42 MW | 45 MW | 54 MW | |
| ... | | | | |

X

12x24 of Average Power Prices

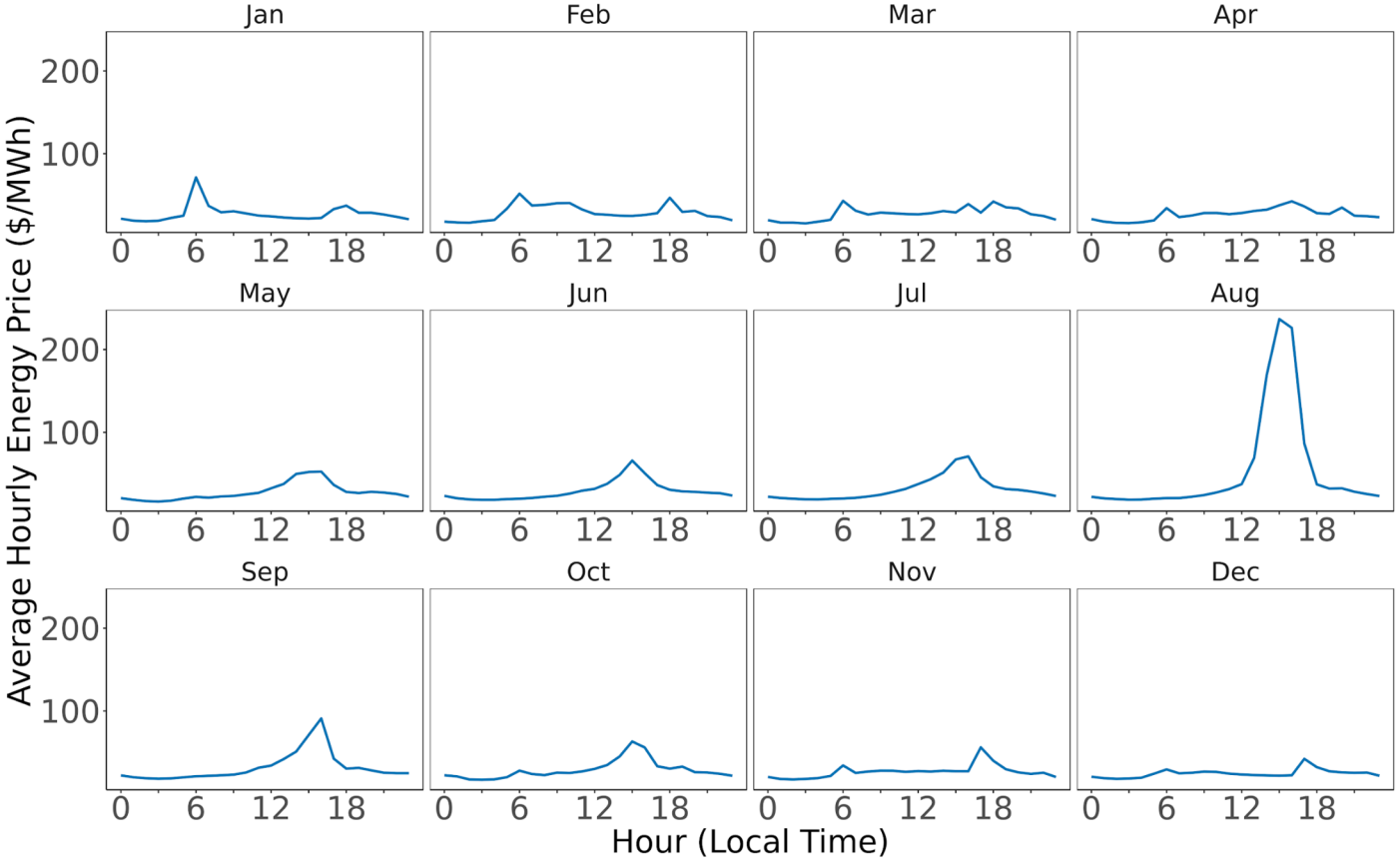
| | Jan | Feb | Mar | ... |
|---|---|---|---|---|
| 0 UTC | $20/MWh | $22/MWh | $15/MWh | |
| 1 UTC | $18/MWh | $20/MWh | $17/MWh | |
| 2 UTC | $16/MWh | $18/MWh | $18/MWh | |
| ... | | | | |

=

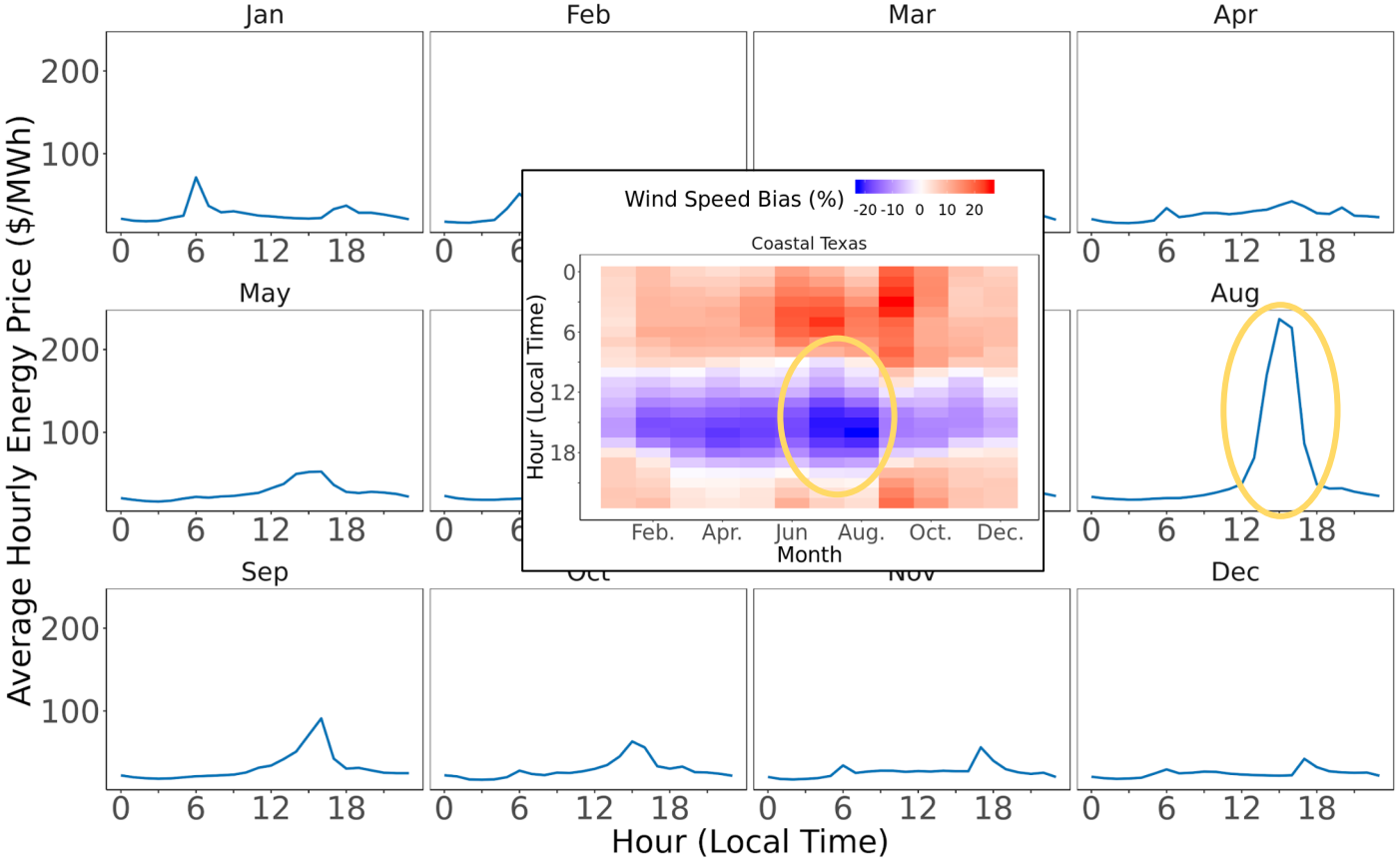
| | Jan | Feb | Mar | ... |
|---|---|---|---|---|
| 0 UTC | $1080 | $1386 | $1350 | |
| 1 UTC | $810 | $1080 | $918 | |
| 2 UTC | $672 | $810 | $972 | |
| ... | | | | |

12x24 of Average Revenue

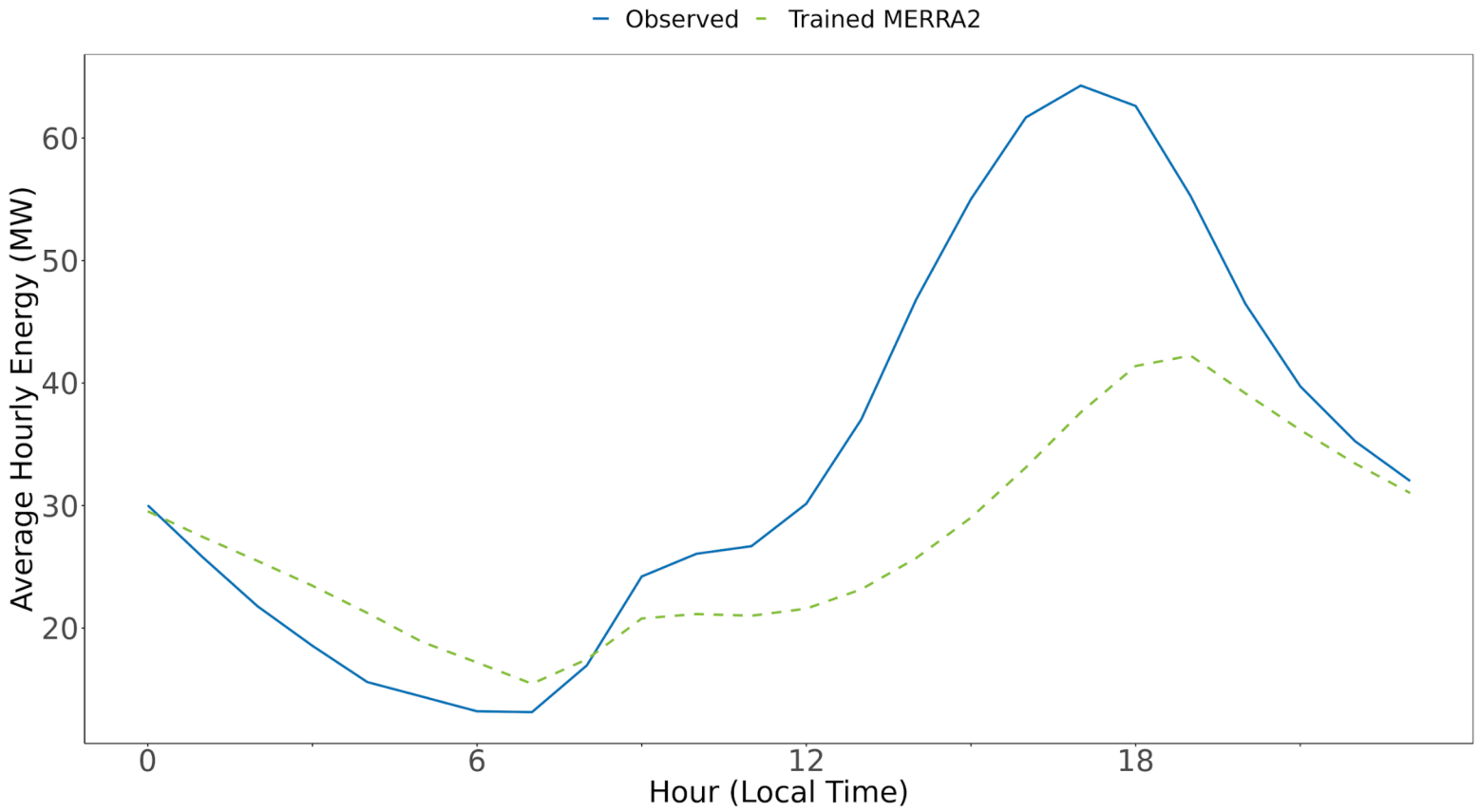
# Average Coastal Texas Prices



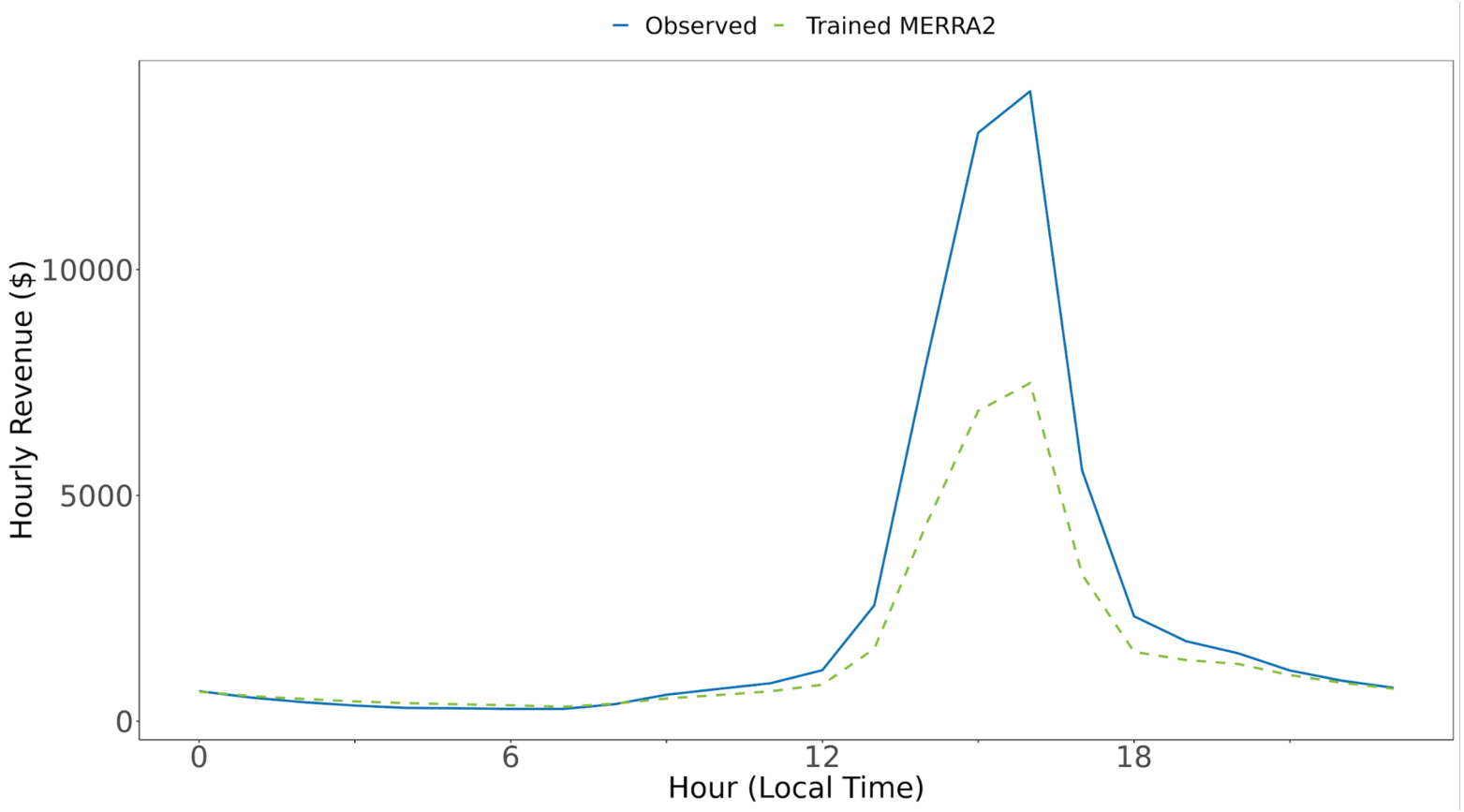
# Average Coastal Texas Prices



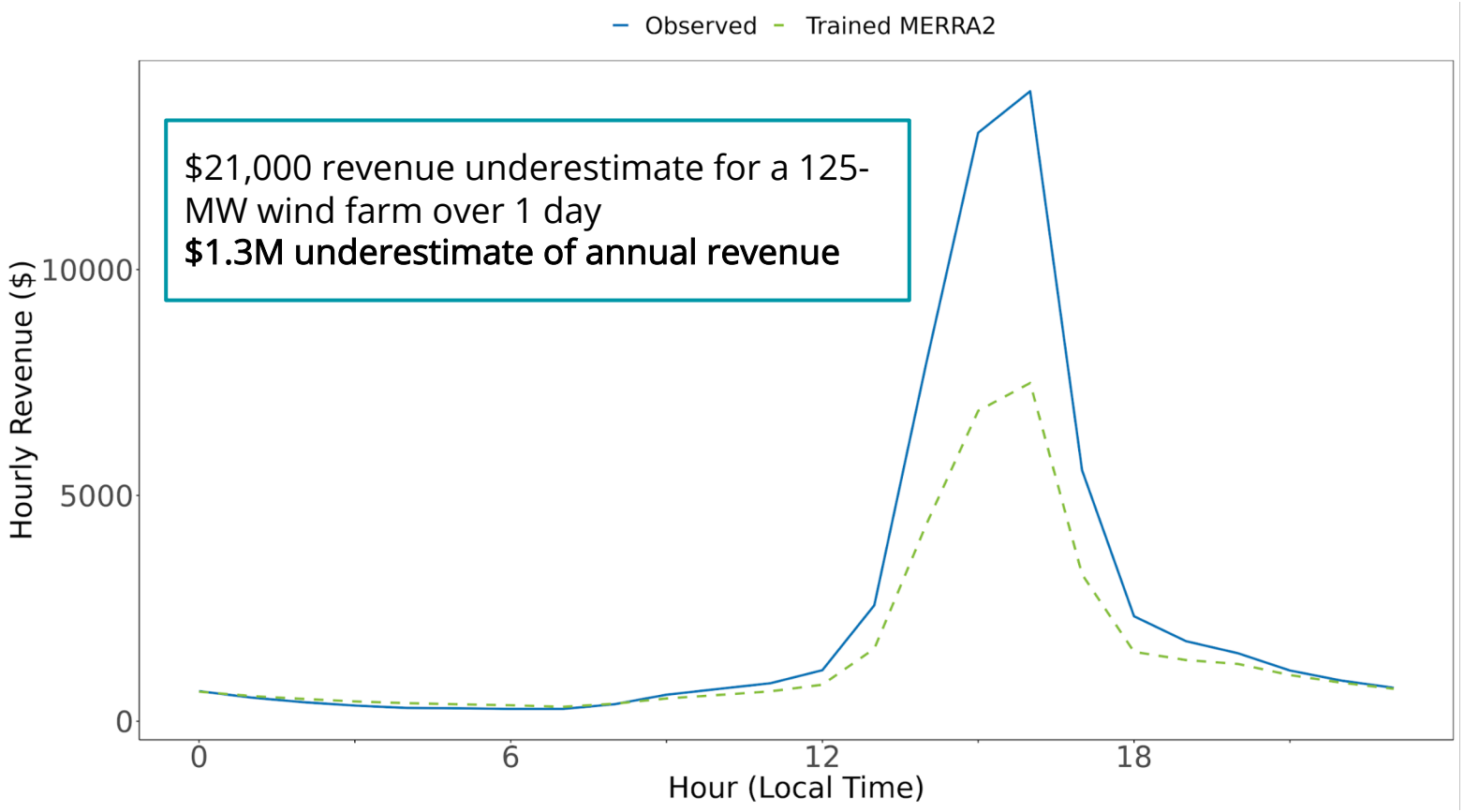
# Average Hourly Energy: August in Coastal Texas



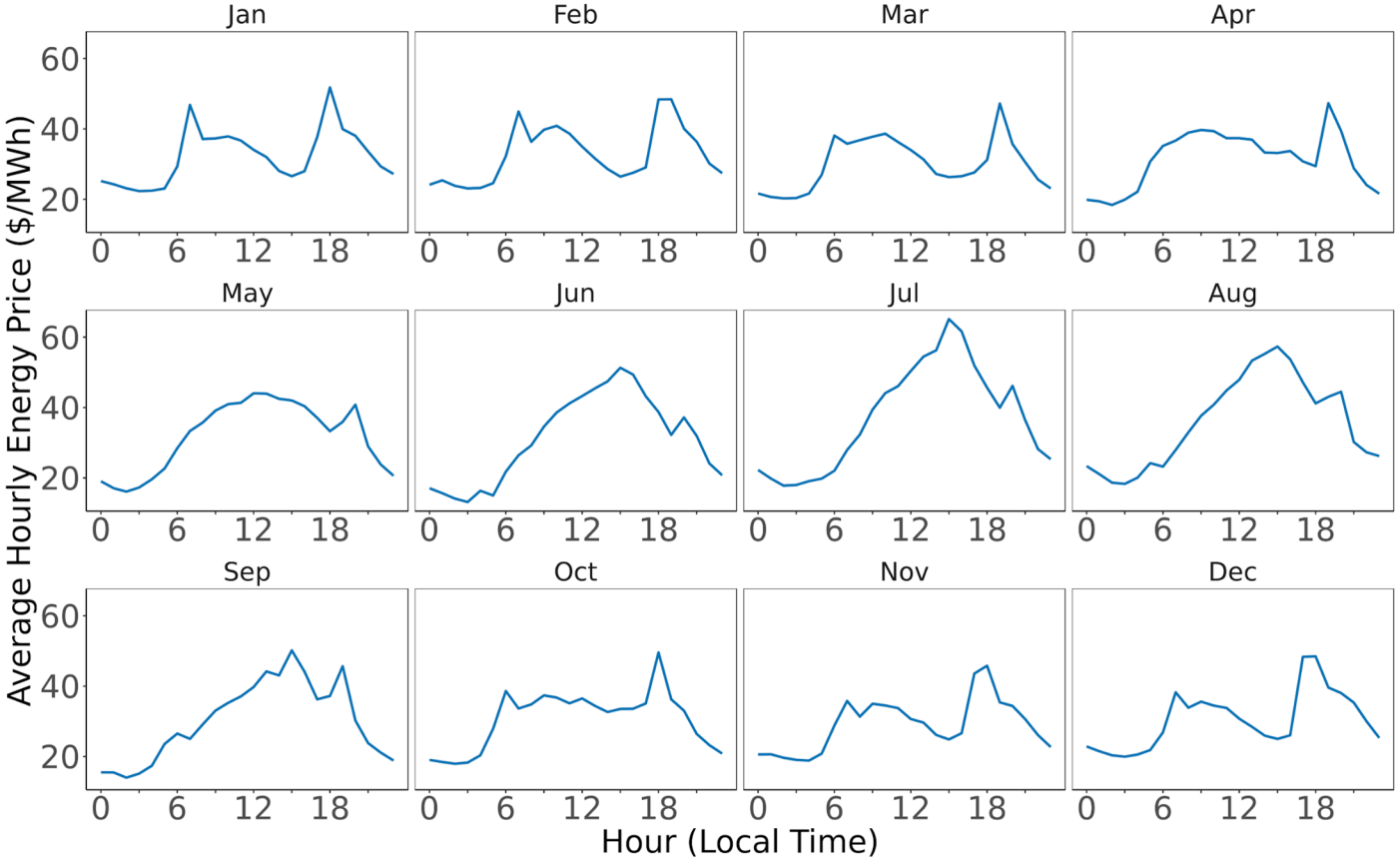
# Average Hourly Revenue: August in Coastal Texas



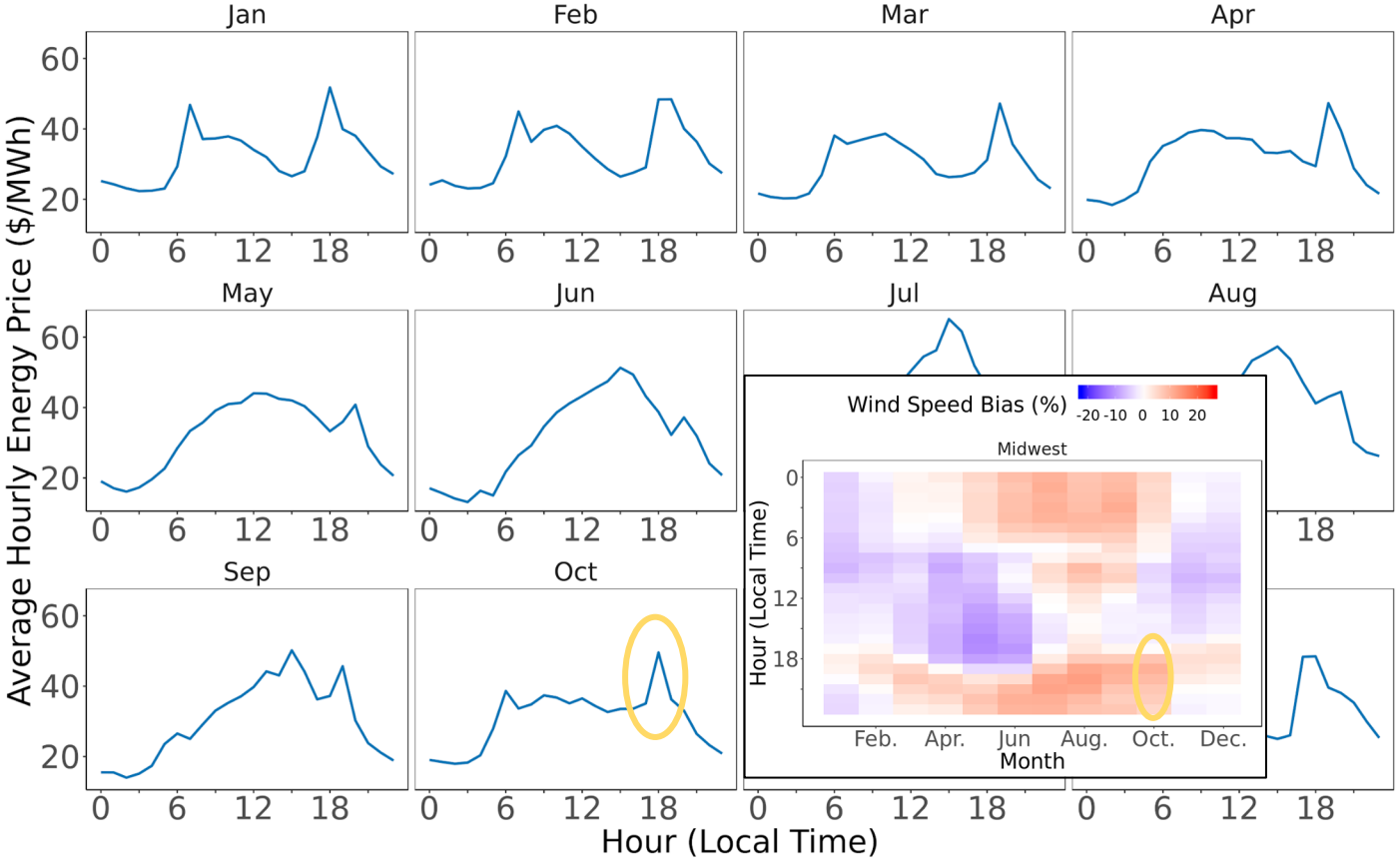
# Average Hourly Revenue: August in Coastal Texas



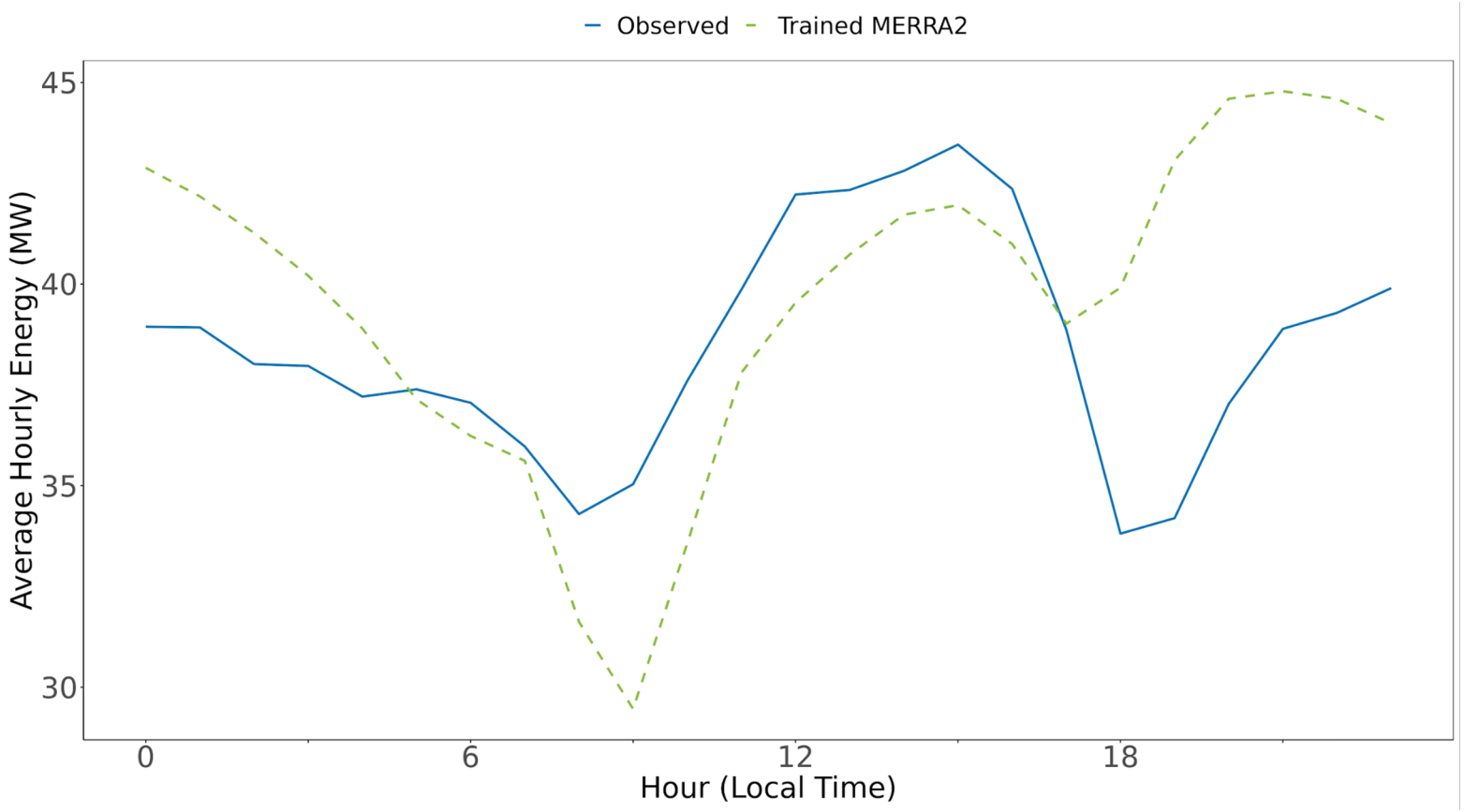
# Average PJM Prices



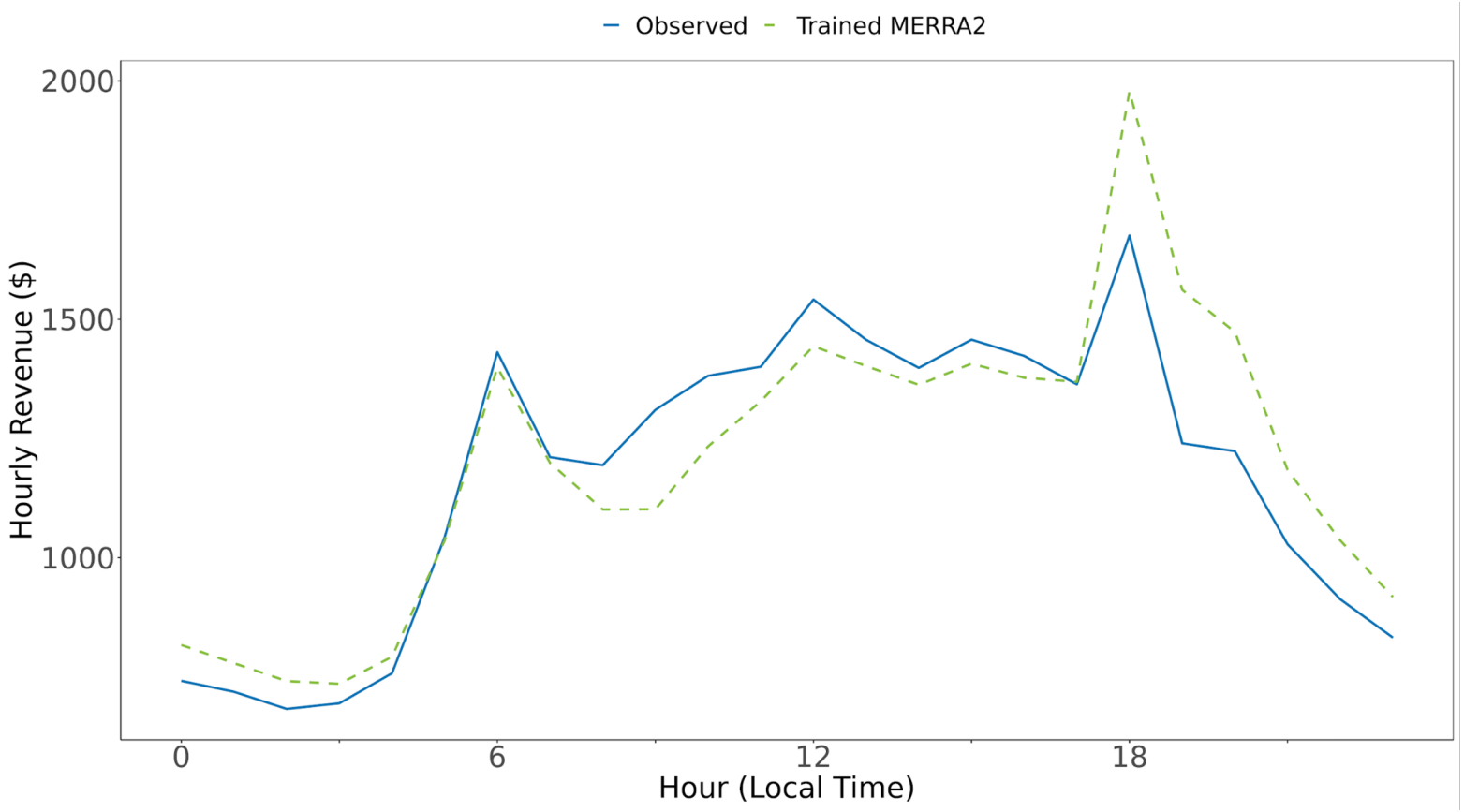
# Average PJM Prices



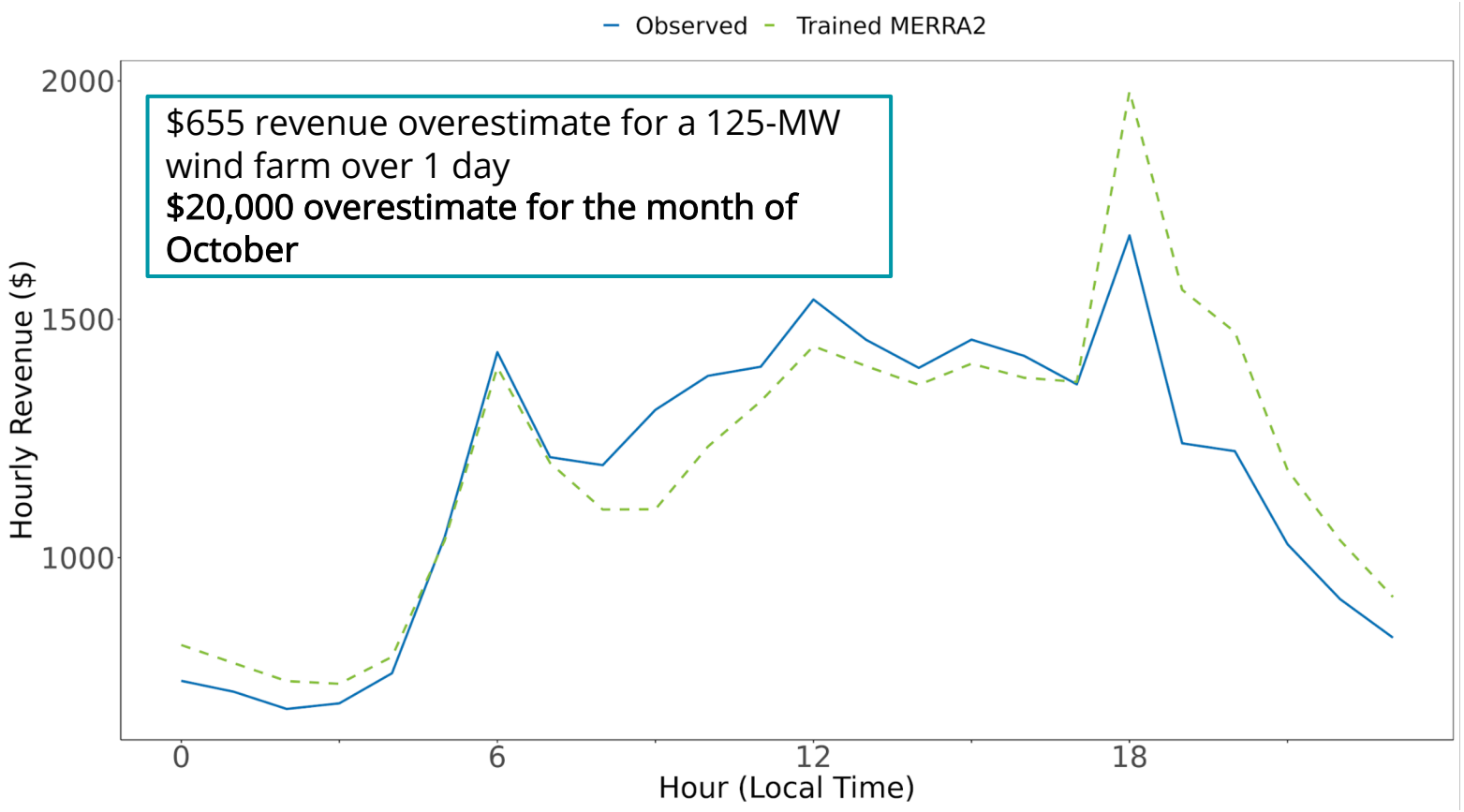
# Average Hourly Energy: October in PJM



# Average Hourly Revenue: October in PJM



# Average Hourly Revenue: October in PJM



# Summary and Conclusions

- MERRA2 significantly underestimates seabreeze effects in coastal Texas and can have large wind speed errors around sunrise and sunset
- Even when a simple MCP method is used to correct MERRA2 wind speeds, significant errors remain at the hourly level and can lead to large errors in revenue estimation
- **Best Practices:**
  - Use onsite data to correct re-analysis wind speeds whenever possible
  - Include seasonal/diurnal corrections in MCP methods