AI Based Forecasting, Performance Evaluation & Asset Management in Wind Power

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Points to Remember

- A presentation by a Wind Expert on AI but not an AI Expert on Wind
- All questions don’t have answers
- All slides are not explainable
- When in serious doubt ask AI not the presenter

AI uses large volumes of data to extract insights and patterns and predict outcomes, and then learns to do this more effectively.

IBM simplifies AI as “a field, which combines computer science and robust datasets, to enable problem-solving.”

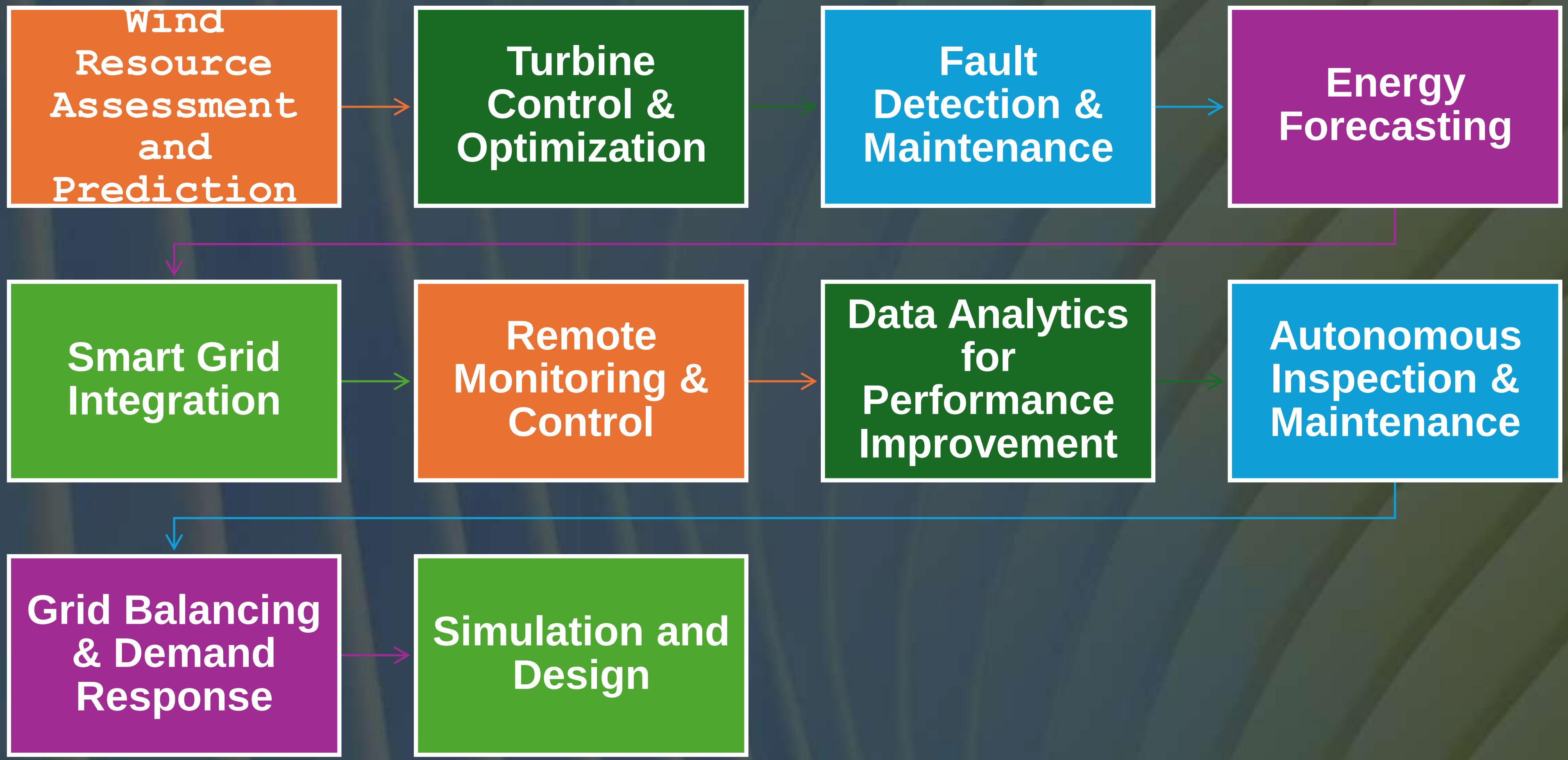
Artificial Intelligence can be used in any field where we have **temporal** or **spatial** generation of bigdata. In power sector a huge amount of data is created not only in load despatch and flow of power but also in the connected machines and demand response to climate parameters. In this presentation we highlight opportunities for the use of AI in Wind Turbines and cite examples of such usage.

Introductory Comments

Use of AI and wind energy leads to more accurate predictions, long term assessments, enhanced operational control, and improved overall performance.

AI has emerged as a transformative force in addressing challenges faced by the wind energy sector.

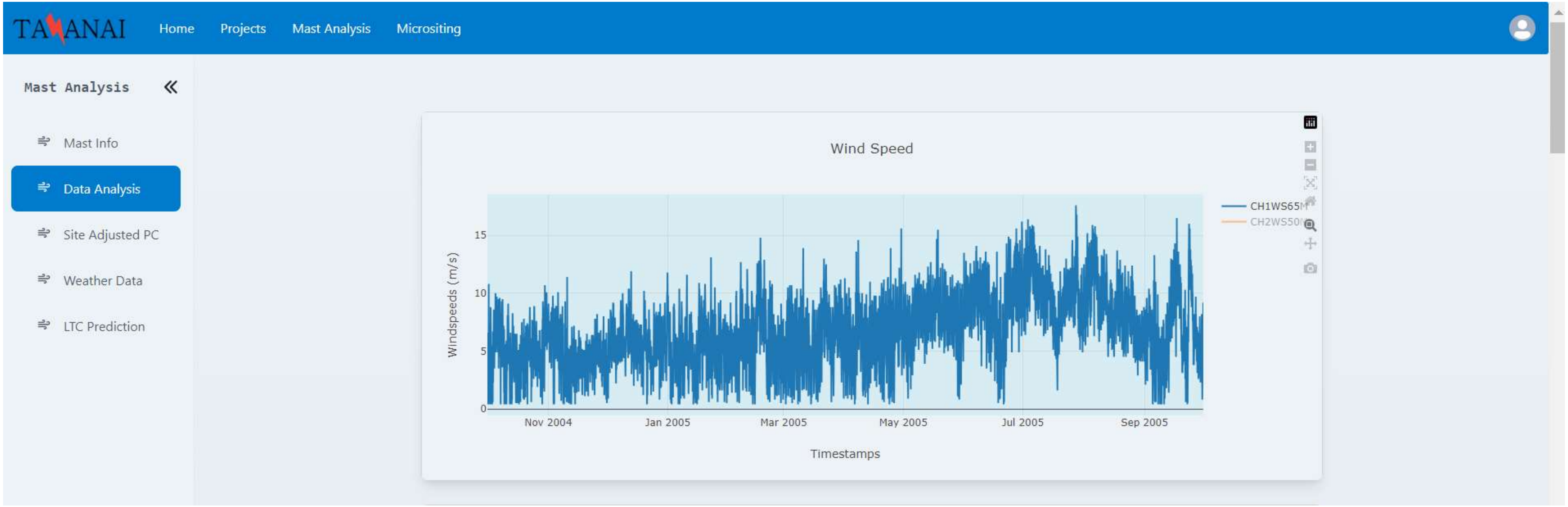
AI Potential in Wind Energy



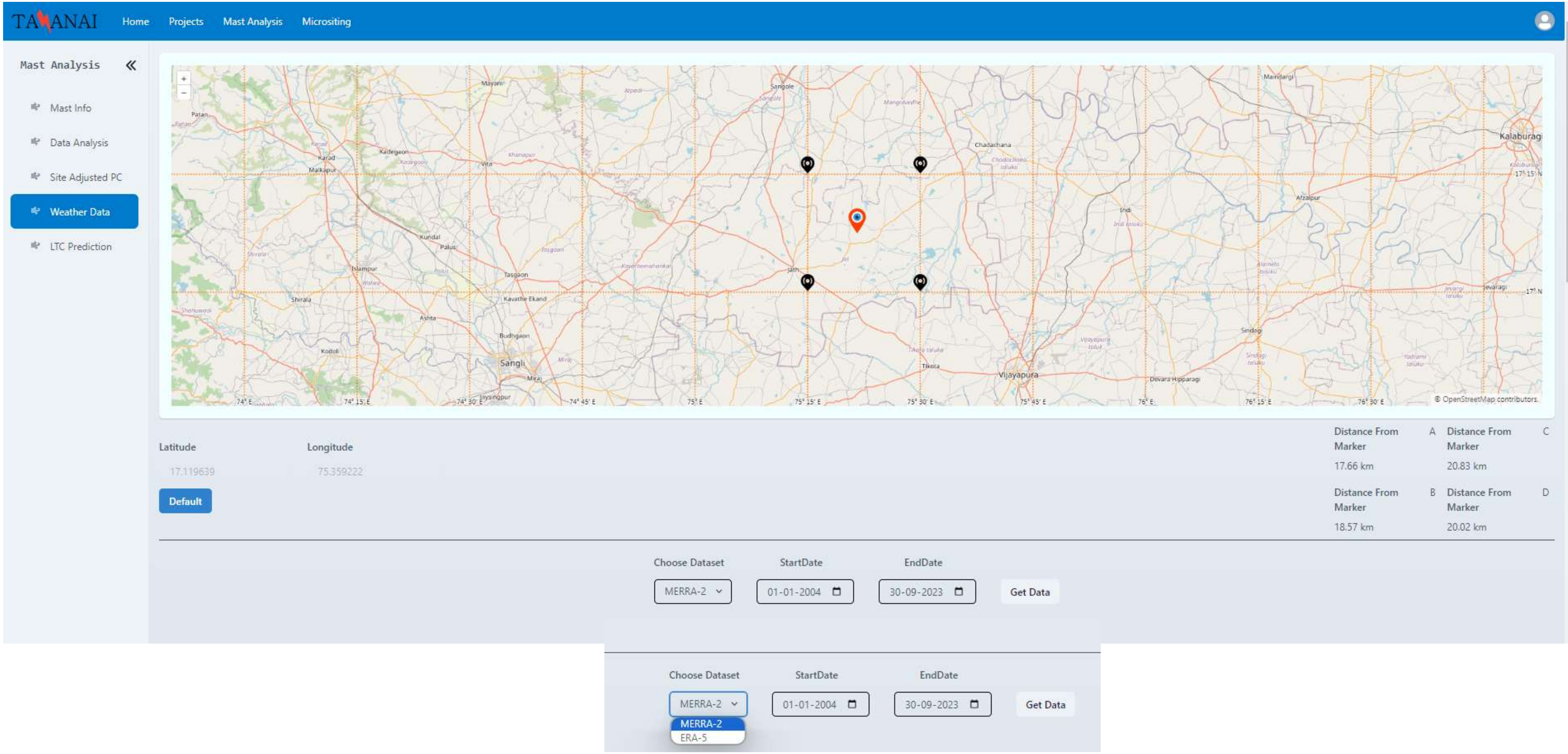
AI-Enhanced Wind Pattern Prediction for Optimal Turbine Placement

- Traditional Wind Resource methods lack precision and the ability to carry out long-term analysis
- AI algorithms analyze vast datasets, including historical weather data, assimilated and reanalysis data, and satellite imagery.
- Machine learning models can identify complex patterns and correlations in wind behavior, leading to more accurate predictions.
- Optimal Turbine Placement: AI-driven predictions guide the strategic placement of wind turbines to maximize energy production.
- Increased Energy Yield: Improved understanding of wind patterns results in higher energy yields from wind farms.
- AI enables turbines to adapt in real-time to changing wind conditions.
- Dynamic adjustments to parameters such as blade pitch and turbine speed optimize energy capture.

Demo



TAWANAI
Home
Projects
Mast Analysis
Micrositing
Mast Analysis
Mast Info
Data Analysis
Site Adjusted PC
Weather Data
LTC Prediction
Wind Speed
Windspeeds (m/s)
0
5
10
15
Nov 2004
Jan 2005
Mar 2005
May 2005
Jul 2005
Sep 2005
Timestamps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Data Analysis
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Weather Data
LTC Prediction
Sangli
Vijayapura
Kalaburagi
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Latitude
Longitude
17.119639
75.359222
Default
Distance From Marker A
17.66 km
Distance From Marker C
20.83 km
Distance From Marker B
18.57 km
Distance From Marker D
20.02 km
Choose Dataset
StartDate
EndDate
MERRA-2
01-01-2004
30-09-2023
Get Data
Choose Dataset
StartDate
EndDate
MERRA-2
01-01-2004
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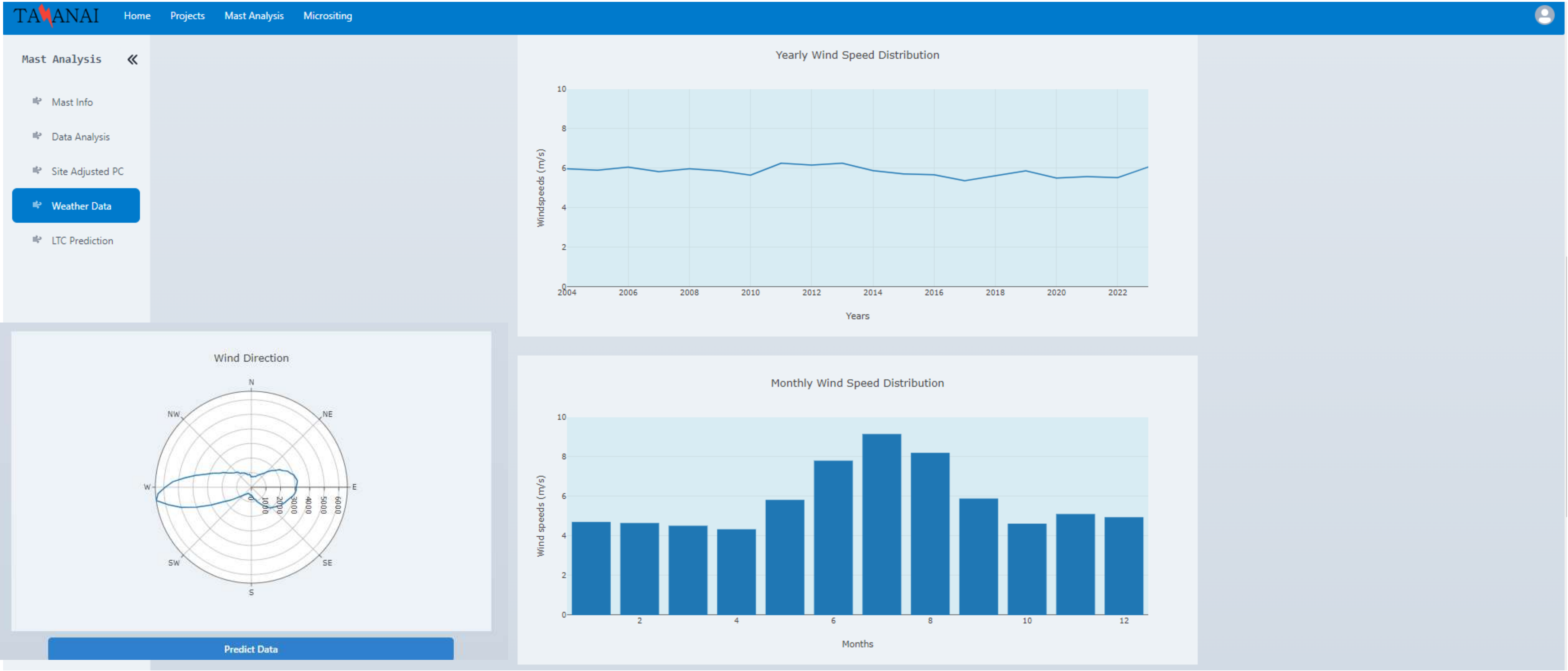
Get Data
MERRA-2
ERA-5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Mast Analysis
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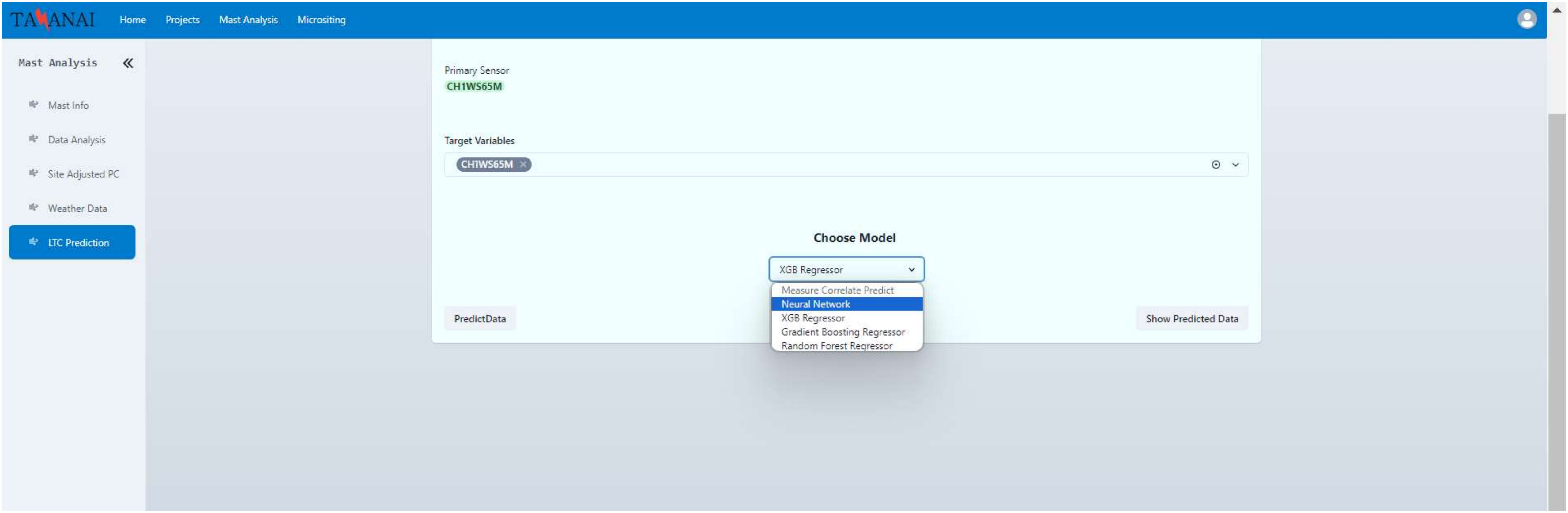
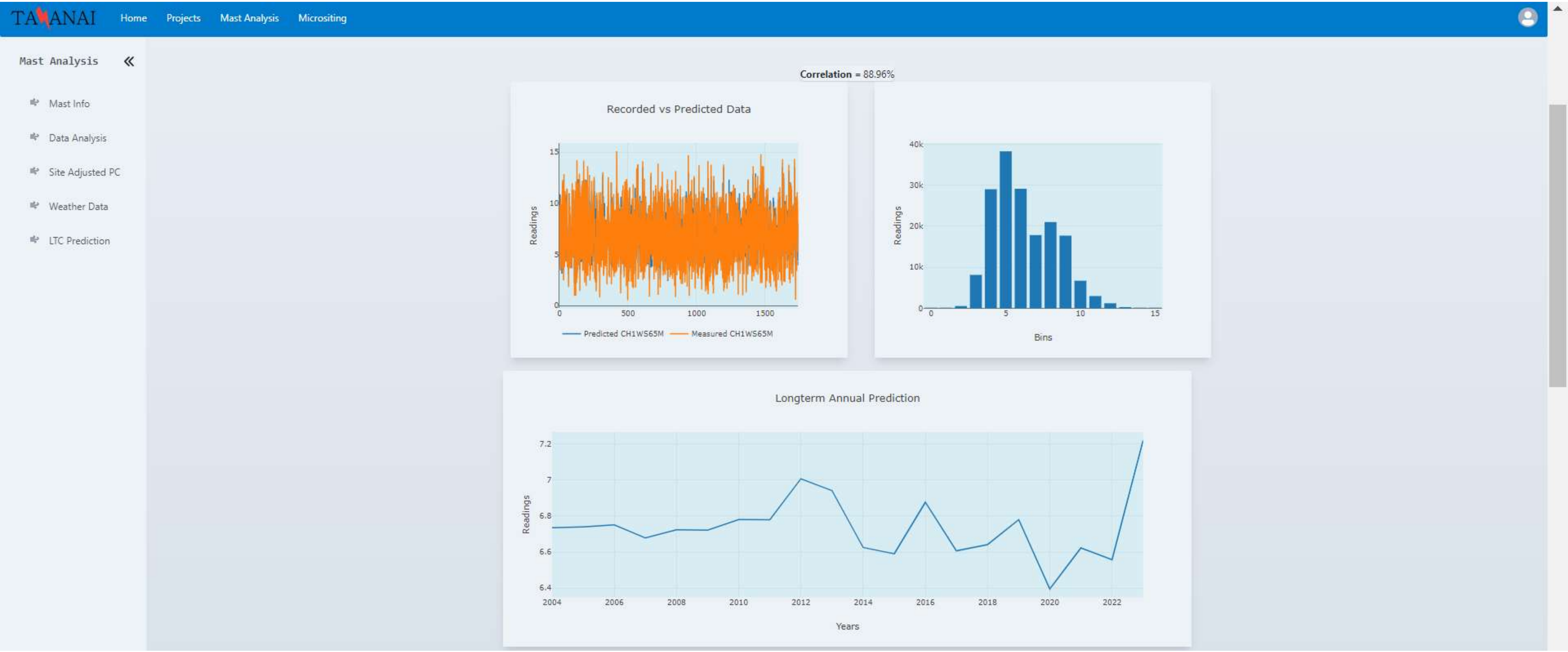
Data Analysis
Site Adjusted PC
Weather Data
LTC Prediction
Yearly Wind Speed Distribution
Windspeeds (m/s)
Years
Wind Direction
N
NE
E
SE
S
SW
W
NW
Monthly Wind Speed Distribution
Wind speeds (m/s)
Months
Predict Data



XGB = Extreme Gradient Booster

Gradient boosting is a method standing out for its prediction speed and accuracy, particularly with large and complex datasets. From **Kaggle** competitions to machine learning solutions for business, this algorithm has produced the best results. Errors play a major role in any machine learning algorithm. There are mainly two

Gradient boosting in AI is a machine learning ensemble technique that combines the predictions of multiple weak learners, typically decision trees, sequentially. It aims to improve overall predictive performance by optimizing the model’s weights based on the errors of previous iterations, gradually reducing prediction errors and enhancing the model’s accuracy.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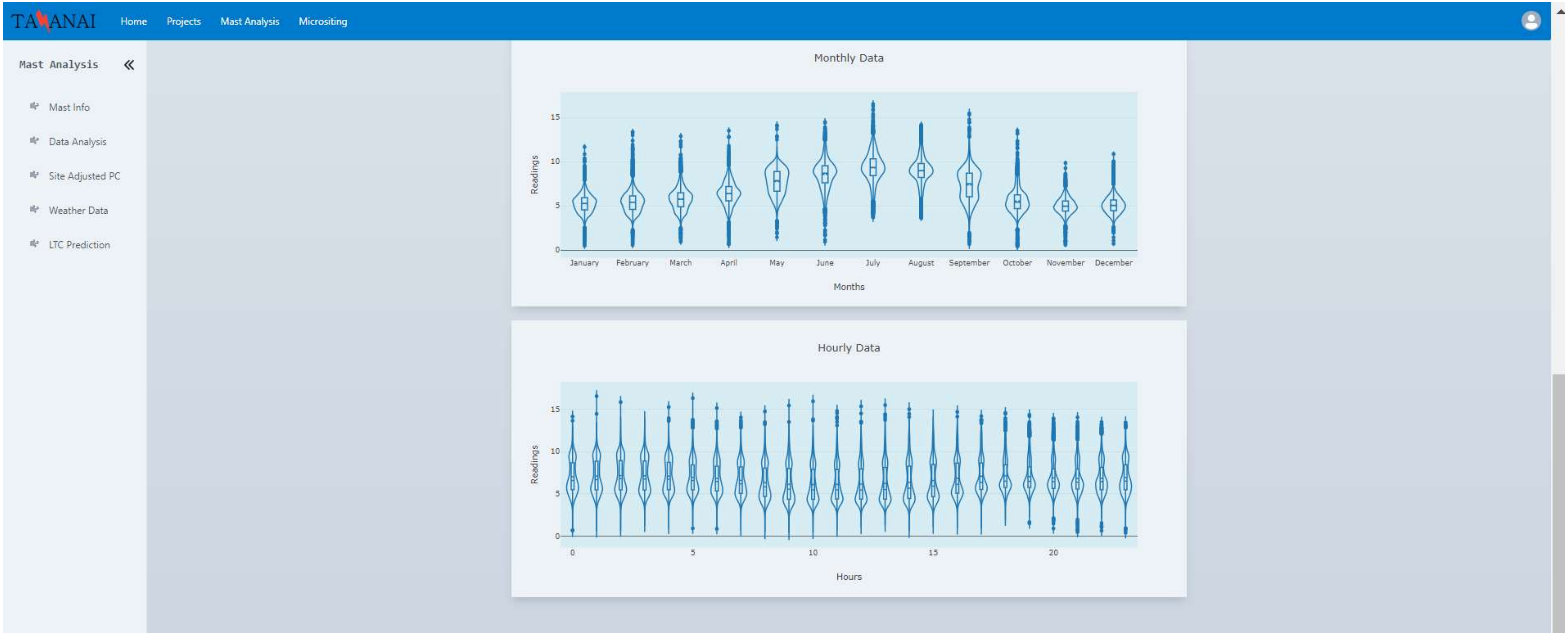
Weather Data
LTC Prediction
Correlation = 88.96%
Recorded vs Predicted Data
Readings
Predicted CH1WS65M
Measured CH1WS65M
Readings
Bins
Longterm Annual Prediction
Readings
Years


Home
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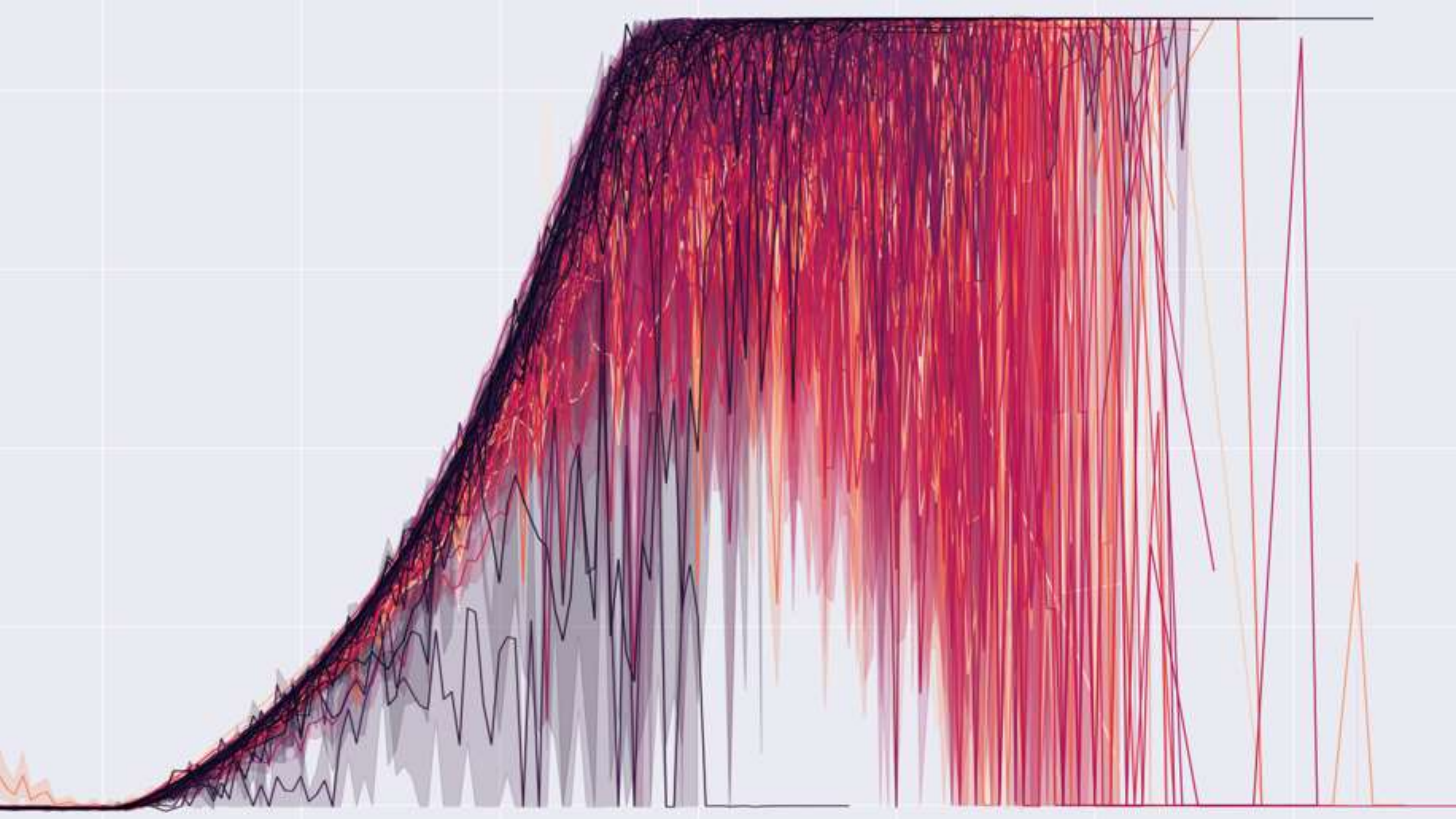
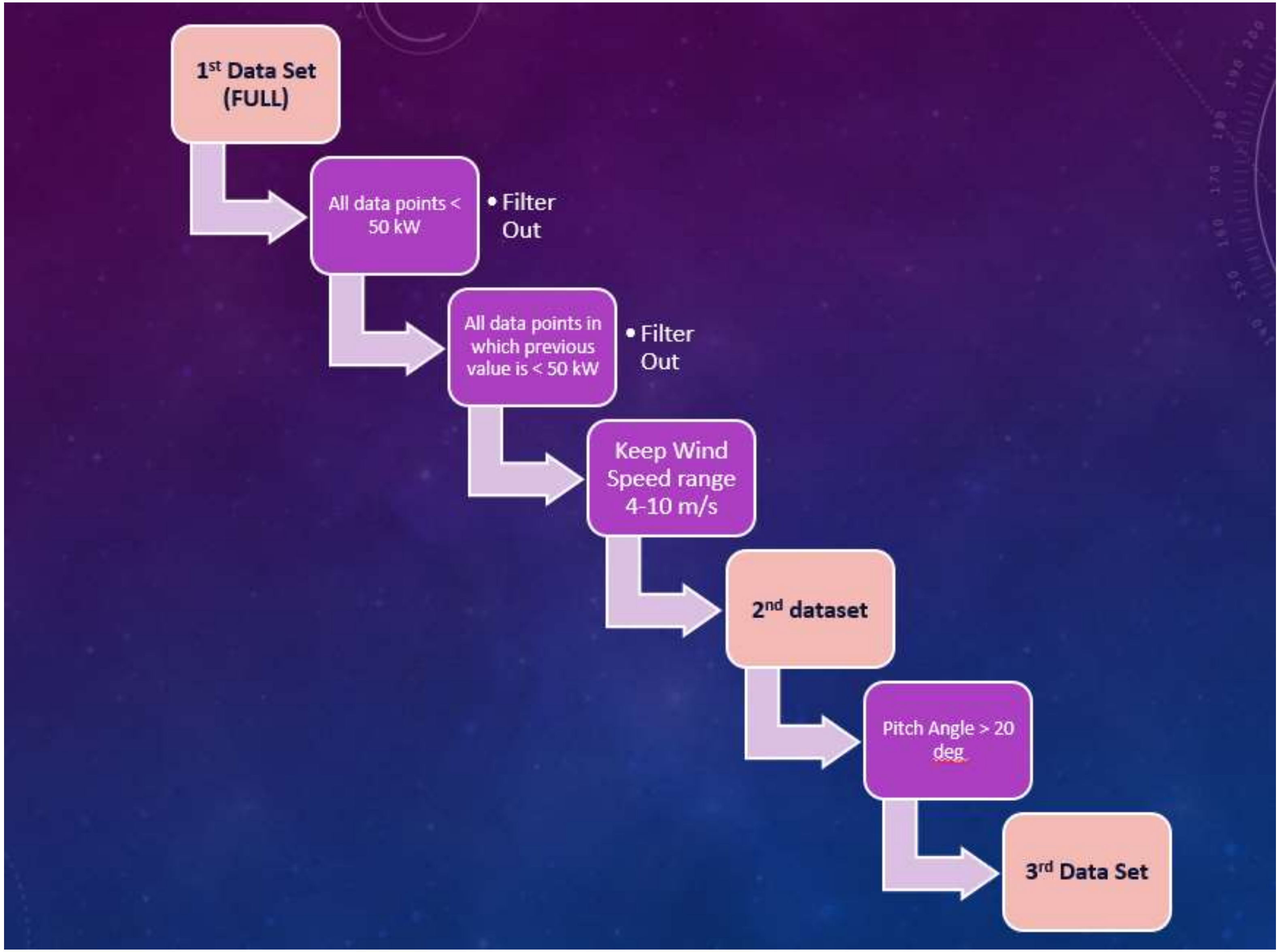
Mast Analysis
Mast Info
Data Analysis
Site Adjusted PC
Weather Data
LTC Prediction
Monthly Data
Readings
0
5
10
15
January
February
March
April
May
June
July
August
September
October
November
December
Months
Hourly Data
Readings
0
5
10
15
0
5
10
15
20
Hours

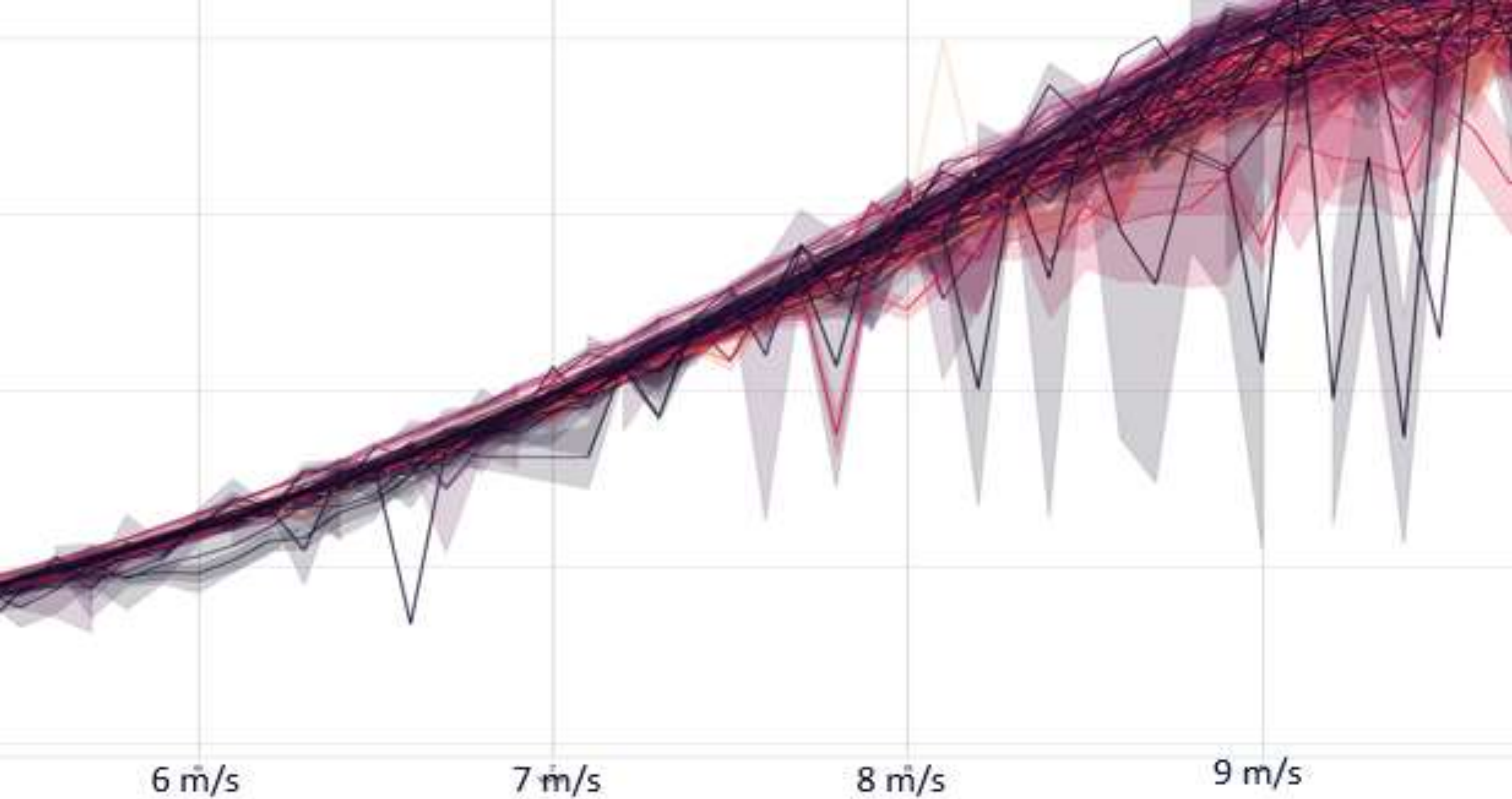
Performance Diagnostics

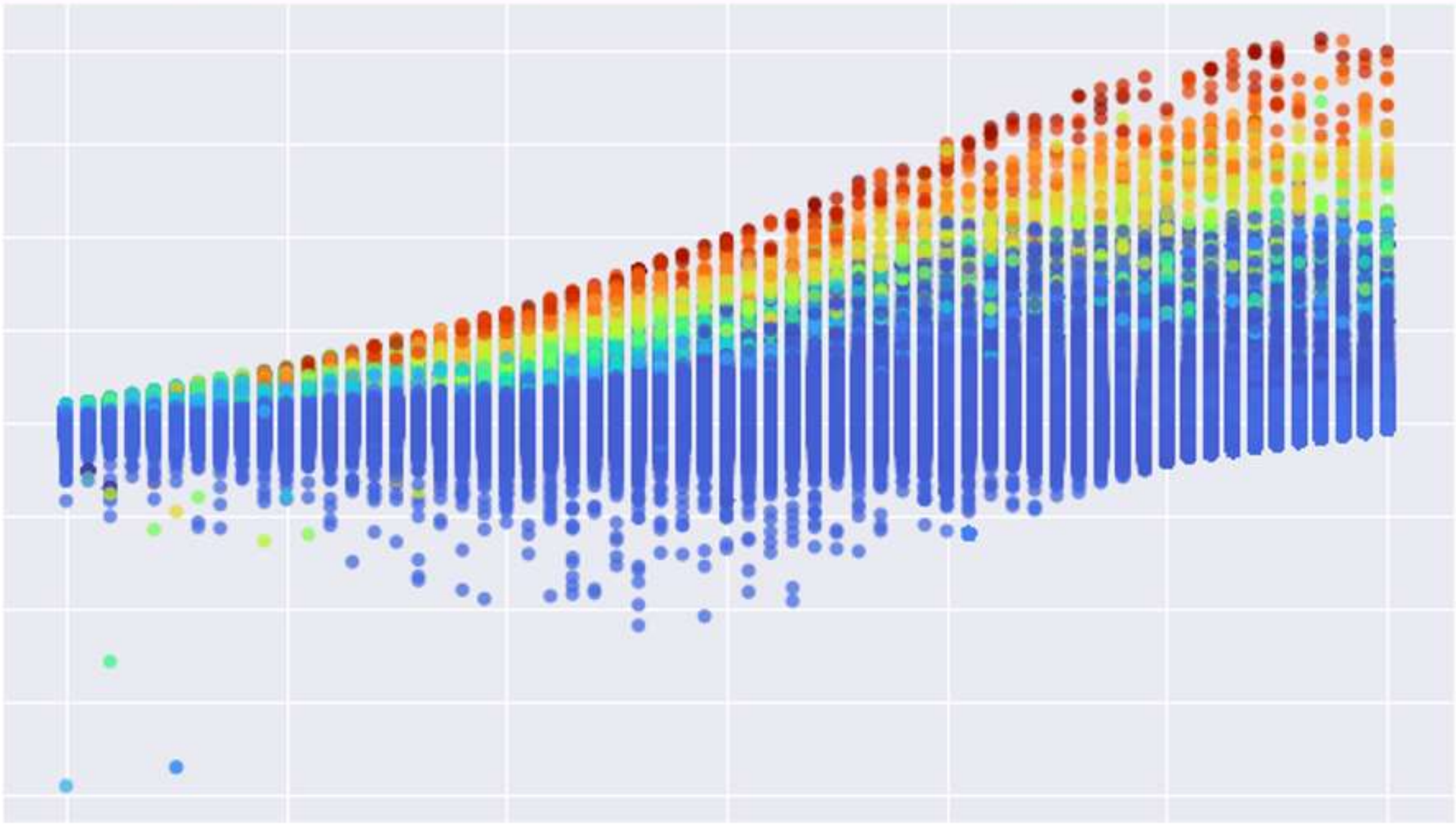
- Wind Turbines operate in a range of operational parameters
- It is often very difficult to figure out if they adhere to specifications or not
- It is difficult to assess if the machine is underperforming or not.
- Big Data generated by the SCADA system can be used with AI to assess or pin point the parameters or areas sub-systems that are forcing the wind turbine to under perform





1st Data Set (FULL)
All data points < 50 kW
• Filter Out
All data points in which previous value is < 50 kW
• Filter Out
Keep Wind Speed range 4-10 m/s
2nd dataset
Pitch Angle > 20 deg
3rd Data Set


6 m/s
7 m/s
8 m/s
9 m/s



Reliability Improvement through AI

AI enables continuous and real-time monitoring of various parameters crucial to the health of wind turbines.

AI systems can adapt and improve over time by learning from new data. As the system encounters different scenarios and conditions, it refines its algorithms, leading to more accurate predictions and a higher level of confidence in the condition monitoring process.

AI systems integrate data from a multitude of sources, including vibration sensors, temperature gauges, and performance indicators.

One of the key strengths of AI in condition monitoring is its ability to detect anomalies or irregularities in the data. Machine learning algorithms can learn normal operating patterns and identify deviations, signaling potential issues. This proactive approach allows for early intervention before problems escalate.

AI systems can act as early warning systems, alerting operators to any abnormalities or signs of impending failures. This capability is especially crucial in preventing catastrophic failures and minimizing downtime.

Predictive Maintainance with AI

- Predictive maintenance is a proactive approach enabled by AI algorithms that leverage real-time data and historical patterns to predict potential issues before they result in equipment failure.
- AI algorithms continuously analyze the streaming data from sensors on the wind turbines. This analysis involves pattern recognition, statistical modeling, and machine learning techniques to identify trends and deviations from normal operating conditions.
- By studying historical data, AI can identify patterns associated with previous failures. This enables the system to recognize early warning signs and predict potential issues, allowing for timely intervention.
- Predictive maintenance, powered by AI, shifts the maintenance paradigm from fixed-schedule to condition-based. Instead of adhering to rigid maintenance schedules, actions are triggered based on the actual condition of the equipment.
- predictive maintenance systems improve over time. As they encounter new scenarios and data, the algorithms learn and adapt, leading to more accurate predictions and enhanced reliability.

AI in Design

- AI excels in processing vast datasets related to wind patterns, topography, and turbine performance.
- By leveraging machine learning algorithms, AI identifies patterns and iteratively refines designs for optimal efficiency.
- Wind turbine design involves intricate systems with interdependent components.
- AI excels in optimizing these complex systems, considering factors such as blade design, tower height, and generator efficiency to maximize overall performance.

Smart Grid Integration:

AI facilitates the integration of wind energy into smart grids by optimizing the distribution and consumption of electricity. This helps balance supply and demand, improving grid stability and efficiency.

Data Analytics for Performance Improvement:

AI can analyze vast amounts of operational data from wind turbines and farms to identify patterns and optimize performance. This includes factors such as blade pitch, turbine speed, and generator settings.

Remote Monitoring and Control:

AI enables remote monitoring and control of wind turbines, allowing operators to manage and optimize their performance without physical presence. This is particularly useful for offshore wind farms.

Autonomous Inspection and Maintenance:

Drones equipped with AI can be used for autonomous inspection of wind turbines, identifying structural issues or damage. This can enhance safety, reduce costs, and improve the efficiency of maintenance operations.

Grid Balancing and Demand Response:

AI can help balance fluctuations in wind energy production by predicting output and adjusting other energy sources accordingly. Additionally, AI can contribute to demand response strategies by optimizing energy consumption patterns based on real-time data.

Simulation and Design:

AI algorithms can assist in the simulation and design of wind farms, optimizing layout, turbine placement, and other parameters to maximize energy production.

Thanks and Welcome to the age of AI

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