

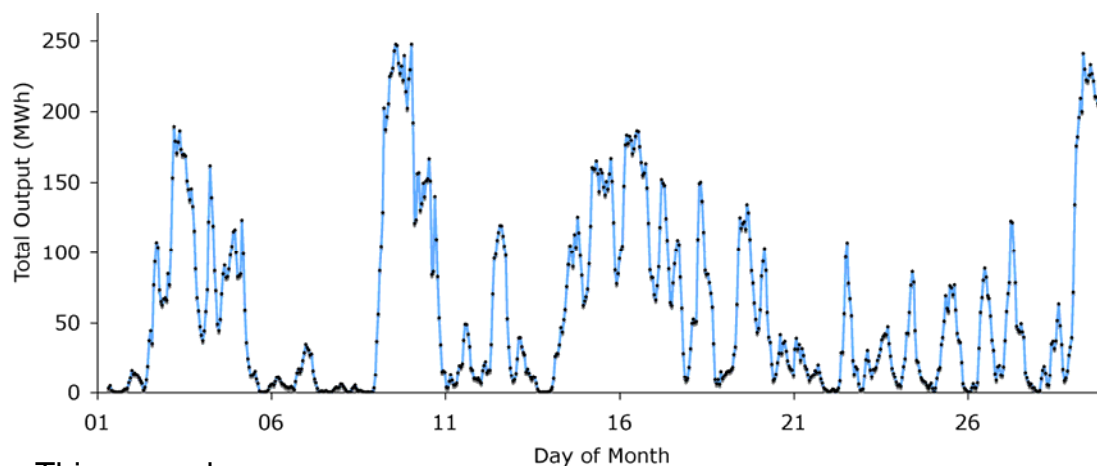
Wind Energy Forecasting 风能预测

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Wind Energy Forecasting: Predicting a variable resource to increase its value

风能预测：预测波动的风能资源以增加其价值



This example:

- Highly Variable Output 波动幅度较高的输出
- No output 10% of time 10%的时间没有输出
- Output \leq 20% of capacity half the time 输出在额定容量20%以下的占半数

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Benefits of Wind Energy Forecasting

风能预测的价值

- Forecasts can be used in many ways to benefit the industry:
很多方面都需用到预测, 为工业生产带来价值
- Better understanding of revenue
能更好的理解收益
- Possibility to operate in merchant conditions instead of accepting Power Purchase Agreements (PPAs)
市场环境下运行的可能性, 而非接受购电协议。
- Ability to better schedule maintenance – both in terms of producing more power, but also avoiding days where cranes are hired, but not used.
更好地安排检修计划——生产更多电能, 避免出现浪费情况。
- Allows better integration of wind into the power grid. This enables the installation of more wind farms!
允许电网接纳更多的风电, 这使得可建设更多的风电场。
- **BOTTOM LINE: Make wind more profitable.**
最后: 使风电利润更大

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STATE-OF-THE-ART WIND ENERGY FORECASTING 最新的风能预测方法

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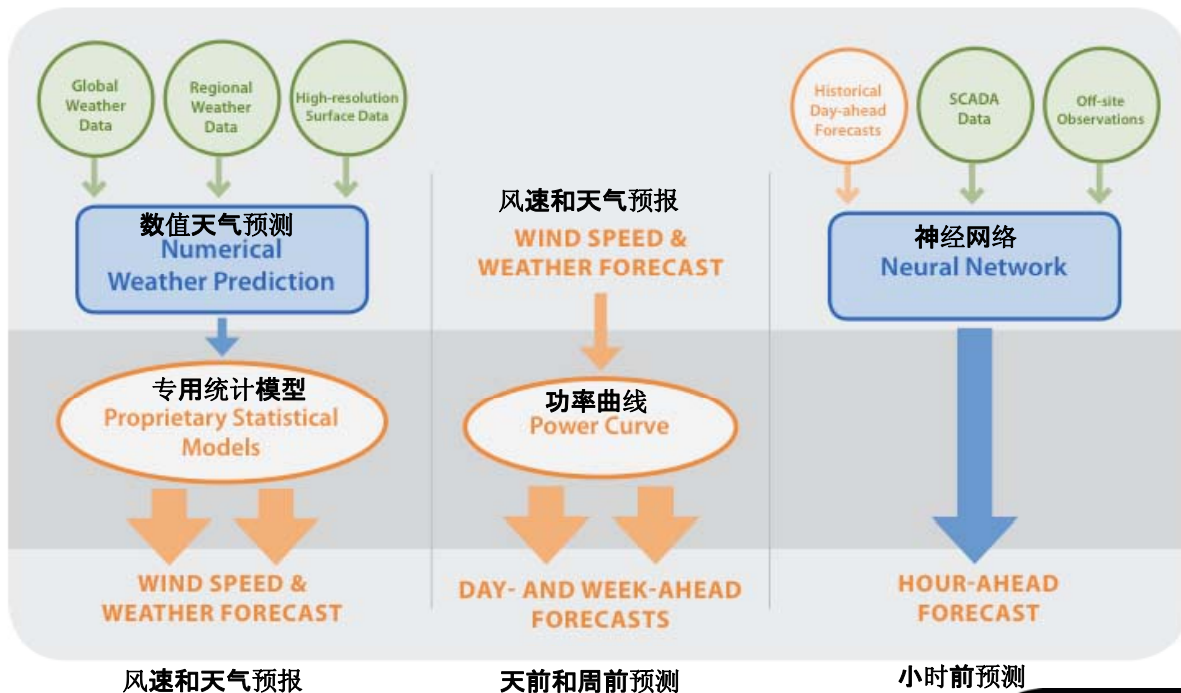


A State-of-the-art forecast system

一种最新的预测系统

全球天气数据 局部天气数据 高分辨率地表数据

历史天前预测 SCADA数据 场外观测

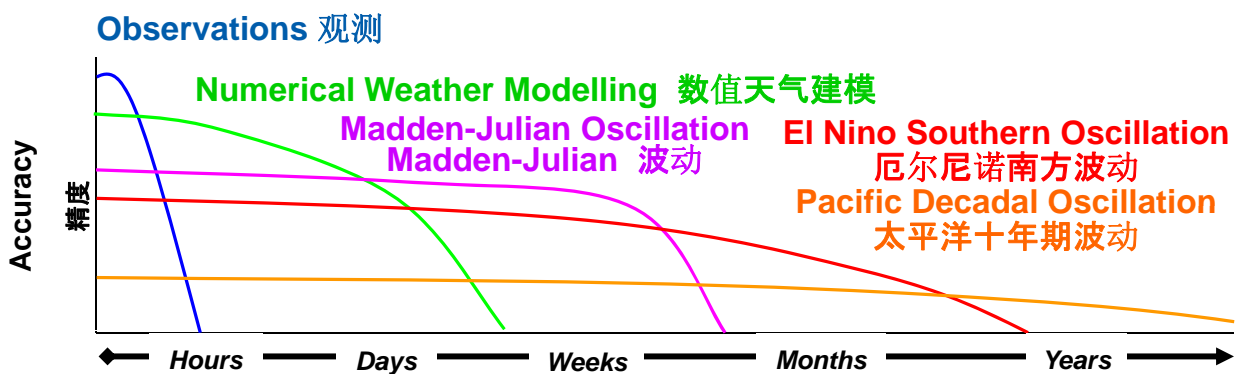


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Situational Analysis - Forecast Horizons

情况分析-预测尺度



Short-range 短期

- Spinning or firming reserves
旋转备用和固定备用
- Load following
负荷跟踪
- Spot market
现货市场

Medium-range 中期

- Transmission scheduling
输电计划
- Asset allocation
资金分配
- Day ahead market
天前市场

Long-range 长期

- Asset optimization
资产优化
- Futures market
未来市场
- Hedging
对冲(套期保值)

Assessment 评估

- Firm capacity
固定容量
- Volumetric risk
容量风险

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HOURS AHEAD FORECASTING

小时前预测

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Power Data: Key to Hours Ahead Forecasting

功率数据：对小时前预测至关重要

- » Accurate hour-ahead forecasting is essential to integration of wind energy into power systems.
精确的小时前预测是风电接入电力系统的基础。
- » One of the great challenges to hours ahead forecasting is that a large portion of the error arises from the wind speed to energy conversion.
小时前预测的一大挑战是：预测误差的很大一部分来自于从风速到风能的转换。
- » At this time frame, the wind over the project can be predicted reasonably accurately, but the effects of localised gusting (and short-term gusting) can play a very significant role in disturbing the power conversion.

在此时间尺度上，风能可以被可观地准确预测；但是，本地阵风影响（短期阵风）对功率转换会产生很大的干扰。

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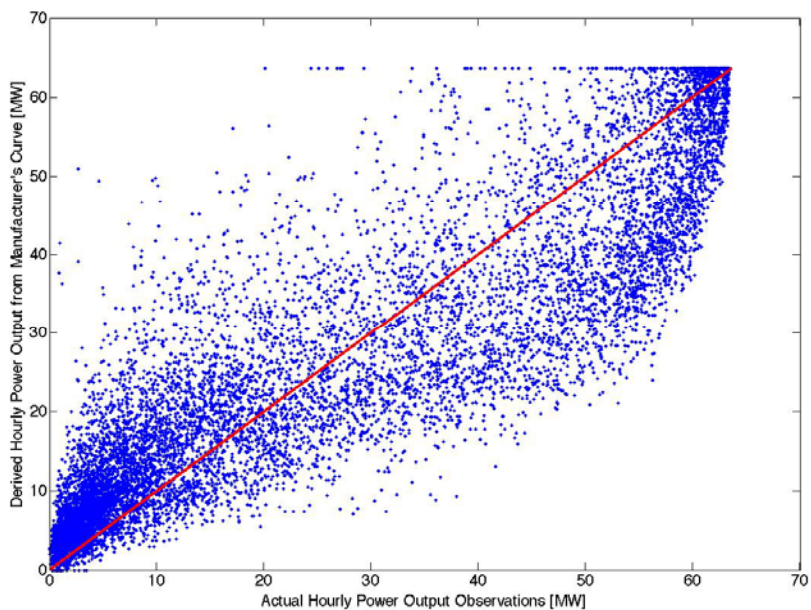


Benefits of Turbine-Level Data 风电机组数据的作用

Hourly average power converted from reference met tower wind speed
由参考测风塔风速换算而来的小时级平均功率

vs.

Actual hourly average project power
实际的小时级平均功率



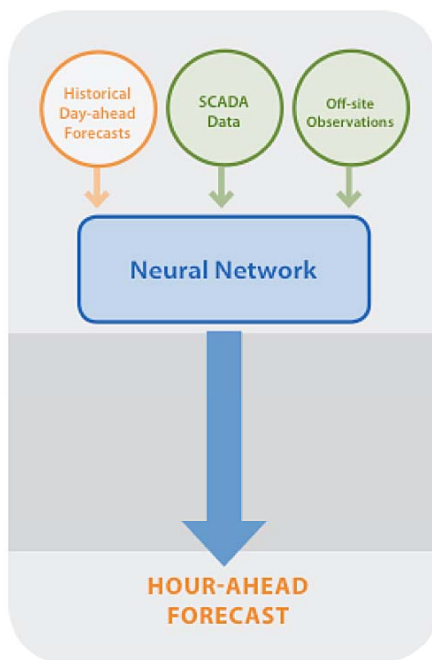
~20% MAE with a perfect wind forecast at the reference met tower
在参考测风塔的风预测较好, 20% MAE (平均绝对误差)

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Hour Ahead Forecast System 小时前预测系统

历史天前预测 SCADA数据 场外观测



神经网络

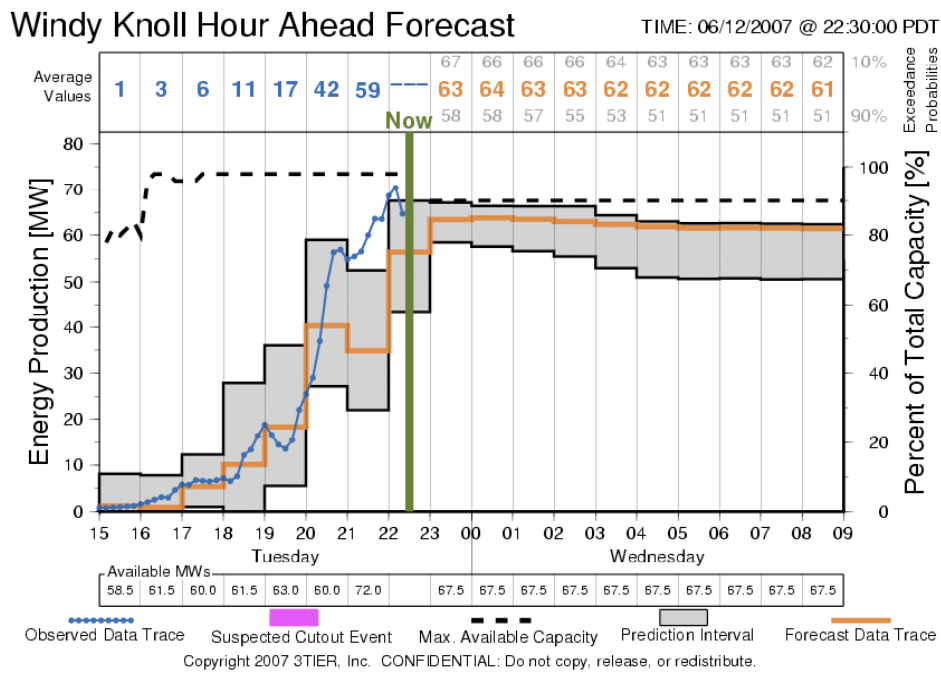
小时前预测

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Hour-Ahead Forecast Example

小时前预测案例



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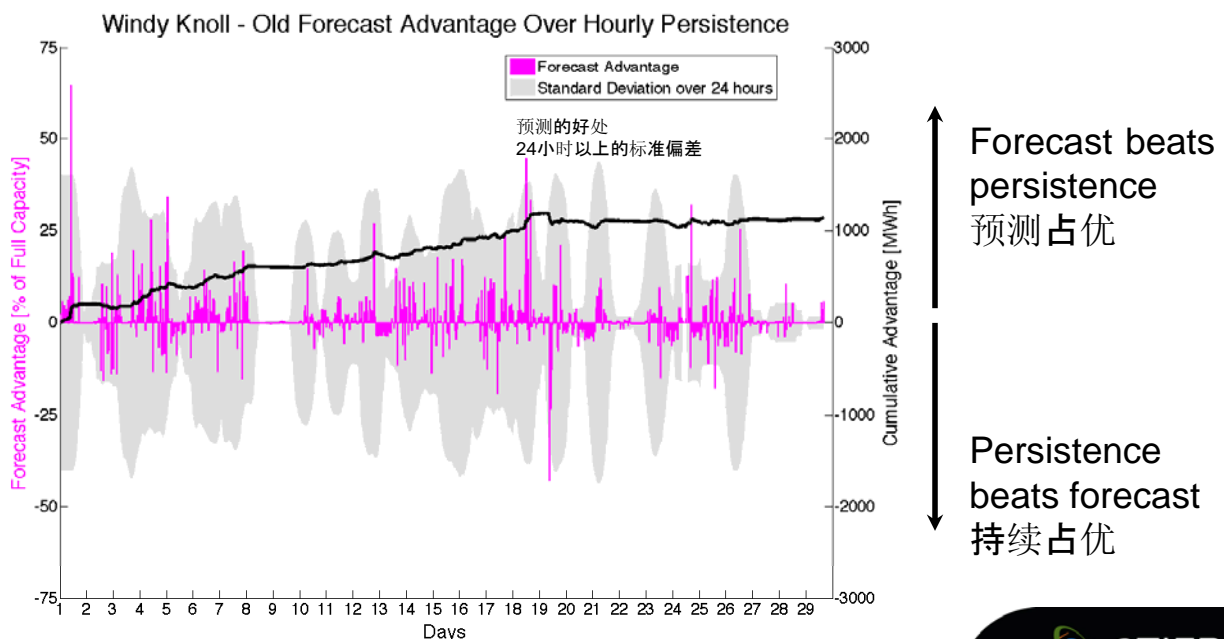


Hour Ahead Forecasting with On-Site Data

利用现场数据的小时前预测

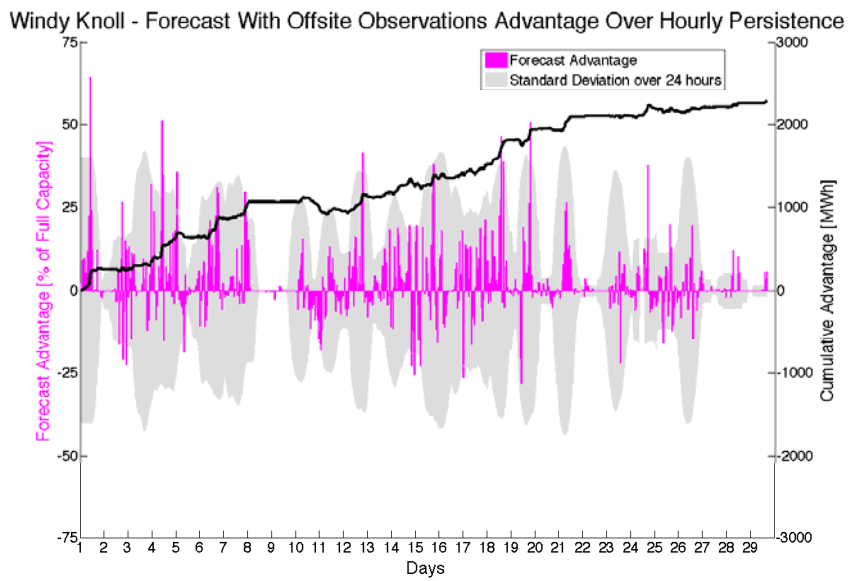
It is possible to beat persistence with an advanced model and good wind farm data.

采用先进的数学模型和准确的风电场数据得到的预测结果可能好于持续法。



Hour Ahead Forecasting including Off-Site Data 小时前预测(包括场外数据)

And Performance improves with additional data, especially from off-site
通过附加数据, 特别是场外数据, 提高性能。



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DAYS AHEAD FORECASTING 天前预测

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Value of Day Ahead Forecasting

天前预测的价值

It has been estimated that the value of using a day-ahead forecast of wind energy production to the power system as a whole can equal US\$10/MWh. (GE study for NY State)

对电力系统整体来说, 利用天前风能预测的价值可大约折合为\$10/MWh(结果来自通用对纽约州风电接入研究)

This value is obtained from setting up the power system in advance to ANTICIPATE the wind energy, which has tremendous benefit to the thermal units.

该价值来自于能够通过预知风电而提前对电力系统做好安排, 这对于火电机组有很大的效益。

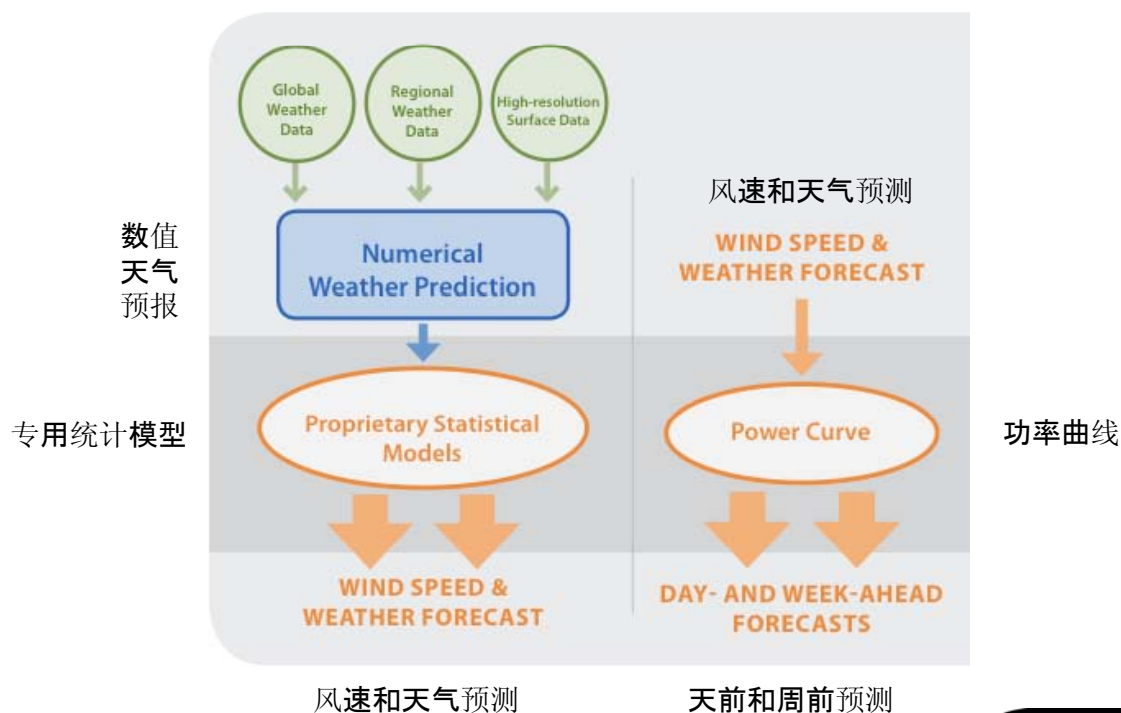
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3TIER's Days Ahead Forecast System

3TIER的天前预测系统

全球天气数据 局部天气数据 高分辨率地表数据



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Numerical Weather Prediction Methodology

数值天气预报方法

INPUTS 输入

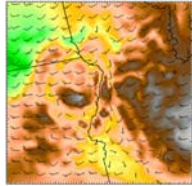
ANALYSIS 分析

OUTPUTS 输出

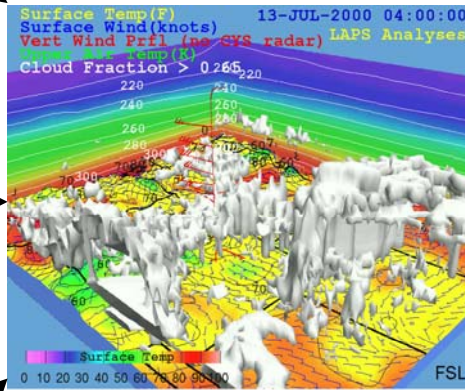
Synoptic Scale Forecast Inputs
天气尺度预测输入



High Resolution Terrain, Soil and Vegetation Data
高分辨率地形, 土壤, 植被数据



DESIRABLE:
Onsite Observations
最好有:
场址观测数据



Key weather parameters such as:
主要天气参数

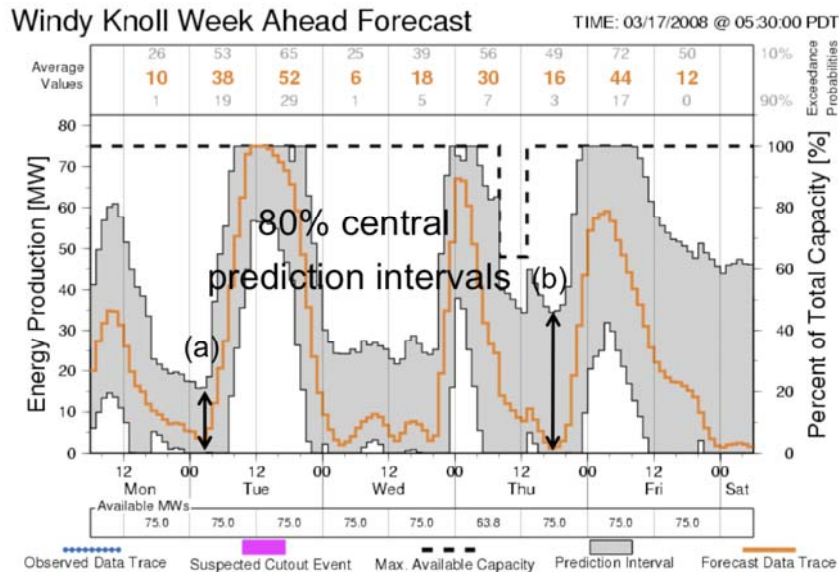
- Wind speed
风速
- Wind Direction
风向
- Pressure
气压
- Temperature
温度
- Humidity
湿度
- Etc.
等等

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Dealing with Uncertainty – Risk Tolerance

处理不确定性-风险限度



Week ahead forecast for wind project with 75 MW capacity. The grey shaded area is between the 90% and 10% exceedance probability values. The thick black dashed line is the wind project scheduled capacity. The orange line represents the P50 or value where the forecast has an equal probability of exceeding or being less than.

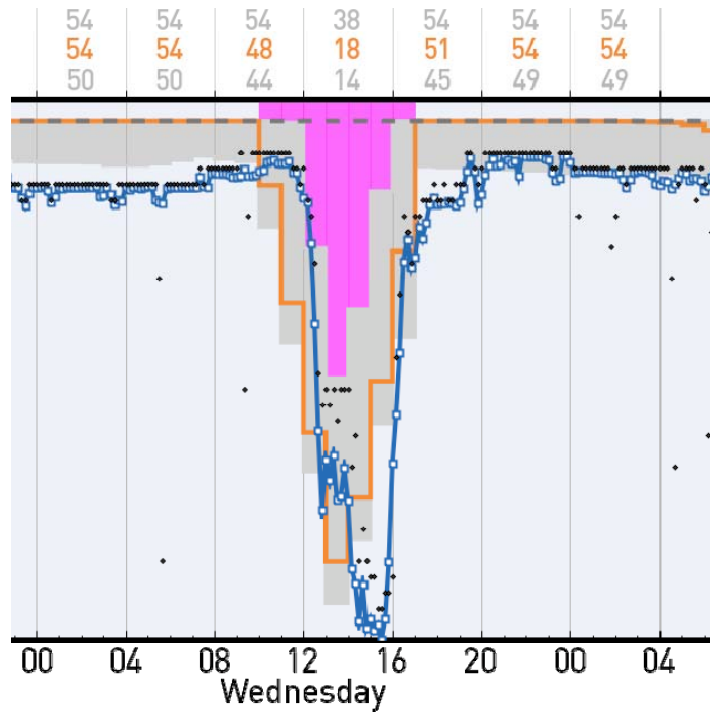
75MW容量风电项目的周前预测。灰色阴影部分介于90%和10%超标概率值。深黑色虚线是风电项目的发电计划容量。橙色线表示的是预测概率小于等于超出容量的概率。

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We can also forecast major cut-out events

同样可以预测重大的风电切机事件

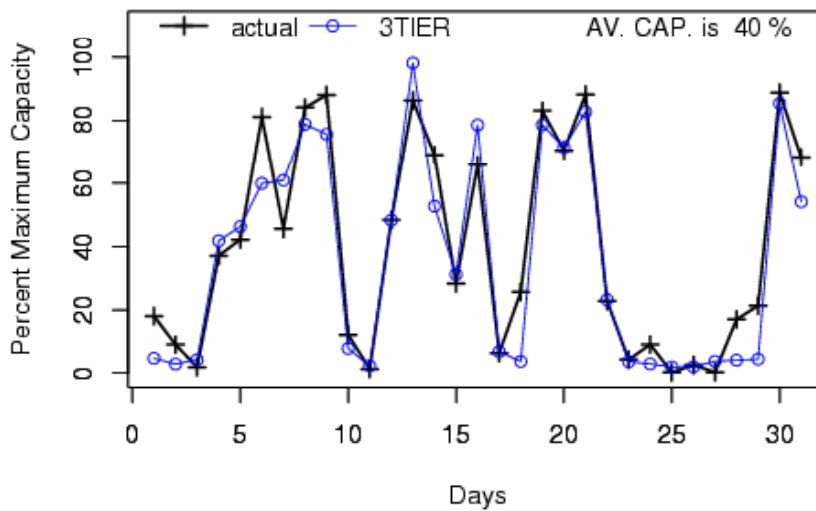


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An accurate month of wind energy prediction

风能预测精度较高的一个月



» This is why 2/3rds of the US wind market purchase 3rd party forecasts

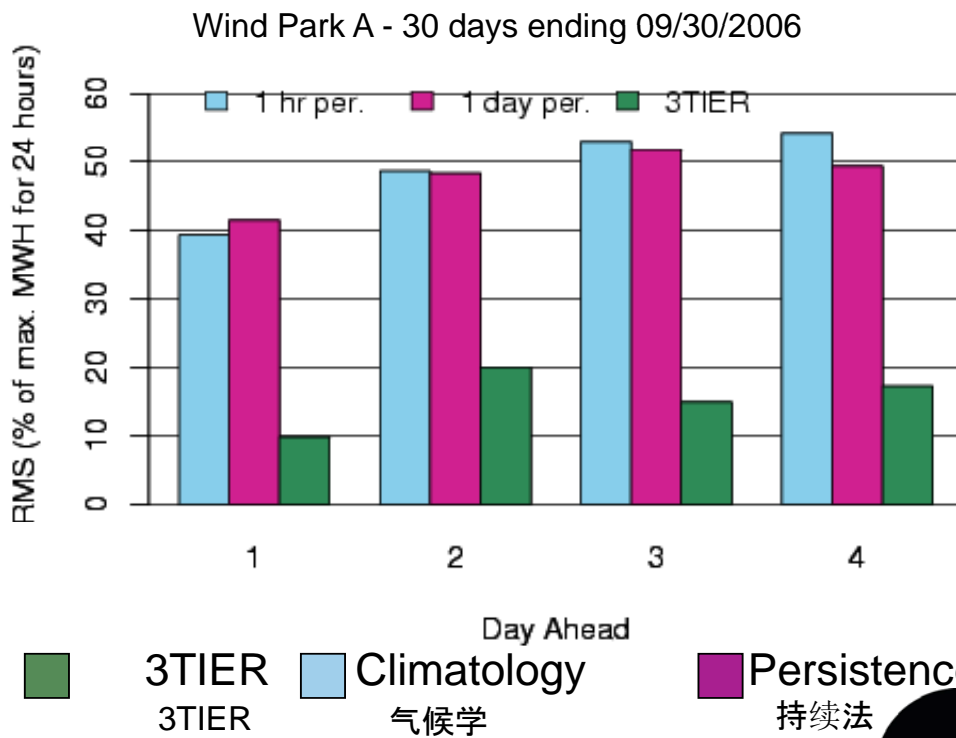
这就是美国风电市场上2/3的服务都购买第三方预测产品的原因。

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ONE TO FOUR DAY AHEAD FORECAST ACCURACY

一至四天的天前预测精度



WIND RELIABILITY

风的可靠性

Can wind energy be scheduled a day ahead reliably?

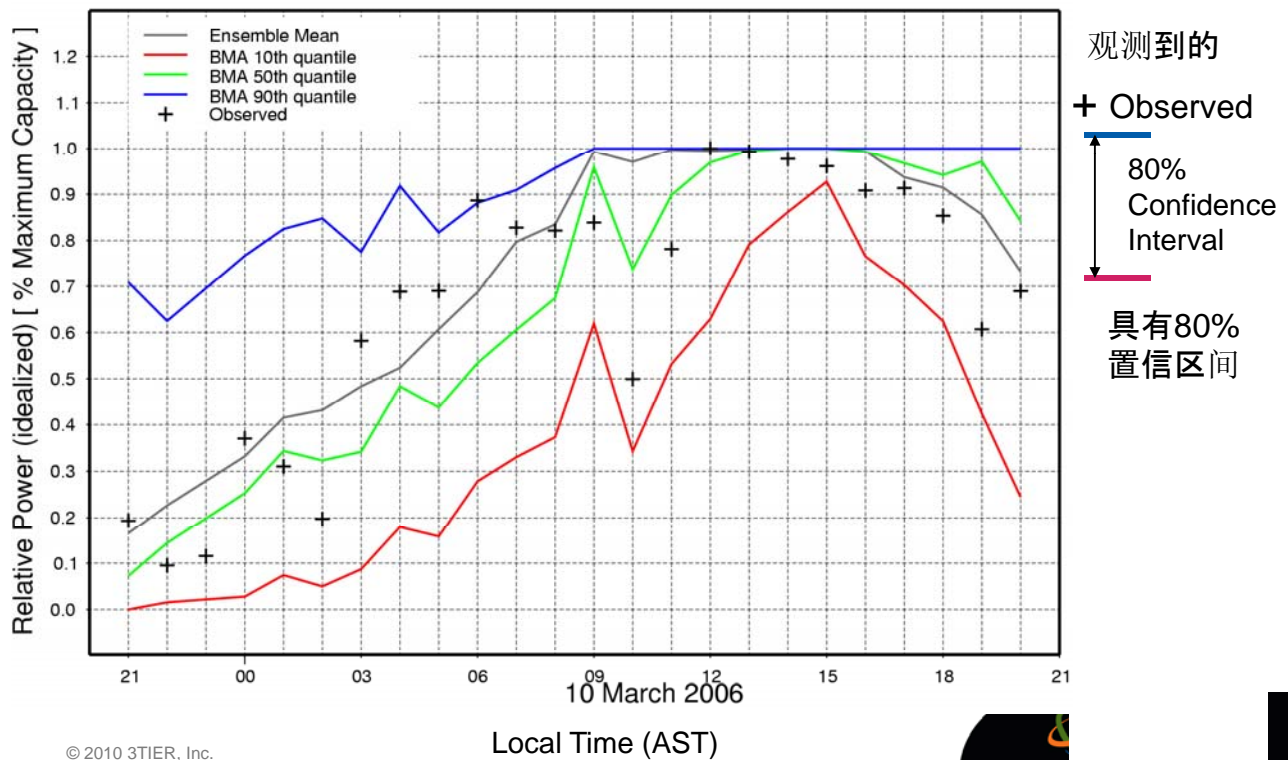
风能可以可靠地安排天前发电计划吗？

Requires a robust forecast prediction interval

需要一个鲁棒的预测区间

DAY AHEAD FORECAST (24-48 H)

天前预测(24-28小时)



Keys to a good wind energy forecast

良好风能预测的关键

- » 1. Build a good wind project. 建立一个良好的风能项目
 - » Our unhappiest client is not the one with an inaccurate forecast at a windy site, but the one with a very accurate forecast at a site that is not performing up to expectations.
客户最不满意的是风场的不精确预测，而是精确预测的风场却没有达到期望的性能。
- » 2. Take good measurements. 采取有效措施
 - » Every turbine, every 10 minutes, wind speed, direction, turbine status and power output.
每台风机，每十分钟，风速，风向，风机状态和出力
 - » Send these to your forecast provider. 将上述数据传给预测提供商
- » 3. Hire a reputable forecasting company with a proven track record.
雇一个有信誉的预测公司，有证明过的良好业绩。
- » 4. Wind energy, while variable, is predictable on an hour-ahead and day-ahead basis.
风能，虽然有波动性，但还是可以基于小时前和天前进行预测。