WEATHER MODELING FOR WIND INTEGRATION STUDIES
用于风电接入研究的天气建模

Weather Modeling is Integration Study Standard
天气建模是接入研究的基础

"A state-of-the-art wind-integration study typically devotes a significant effort to obtaining wind data that are derived from large-scale meteorological modeling that can re-create the weather corresponding to the year(s) of load data used."

最新的风电接入研究在获取风资源数据方面做了很大努力：这些风资源数据来自于大尺度气象模型，该模型可用于重建与多年用电负荷数据同步的天气数据。

J.C. Smith et al., "Utility Wind Integration and Operating Impact State of the Art", IEEE Transactions on Power Systems - Special Section on Wind Energy, 2007.

Importance of Modeling 建模的重要性

Wind Integration Studies are performed BEFORE the projects are built and often BEFORE any wind data is collected.

风电接入研究往往在工程建设和风资源数据收集之前开始；

Large Scale Wind Integration Studies typically consider many GigaWatts of potential wind energy installation. Even if observations are available, they are not at every potential project location.

大规模风电接入研究通常要考虑多个GW容量的潜在风电装机。即使观察数据是可以获得的，也不能在所有可能的工程所在地进行观察。

Wind Integration Studies often extrapolate from existing patterns of load, therefore they require wind energy data that are coincident (overlap in time) with the load data.

风电接入研究经常从已有的负荷模式进行外推，因此需要获得与负荷数据同步的风能数据。

It is extremely important to adequately model and capture the effect of geographic diversity on wind farm behaviour at short and long time-scales (10 minutes to seasonal).

充分模拟并且获取在长时间和短时间尺度上地理分布差异对风电场行为的影响尤为重要。

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TYPICAL DATA REQUEST
典型数据要求

Simulate the energy output of hundreds of projects . . .
模拟仿真数百个风电项目的功率输出

Every ten minutes . . .
每10分钟

For a specific set of years in the past . . .
针对过去一些特定年份集合

Spread out over a large region . . .
分布在大片区域

And provide forecasts too!
提供预测

Observational data, by themselves, are not sufficient to satisfy this request.
观测数据，他们自己获取的，不能充分满足这个要求。

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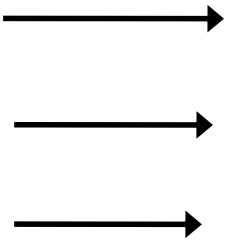
The Importance of Weather Modeling
天气建模的重要性

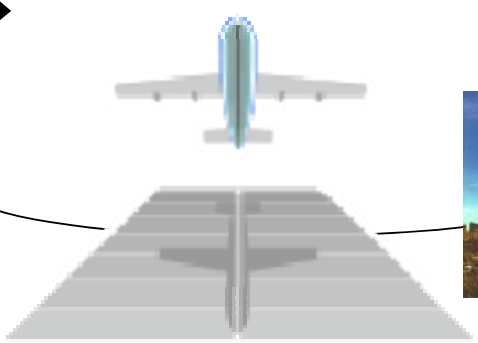
Measure-Correlate-Predict (MCP) is not a reliable way to evaluate weather at another site.
测量－关联－预测(MCP)不是估计另一个地方天气的可靠方法。

Meteorological processes causing the wind at the project site and the long-term reference location can be quite different!
气象过程会造成项目位置的风能情况和长期作为参考点位置的风能情况很不一样。



warm

cold



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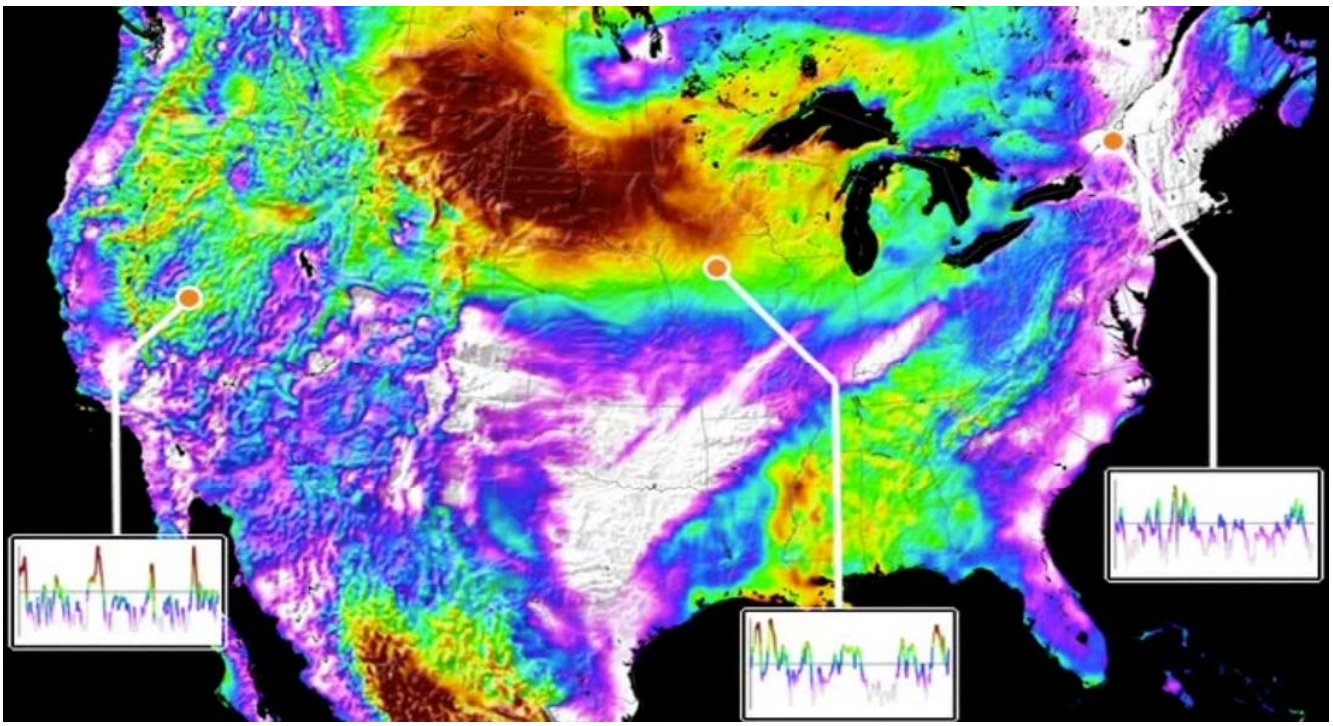
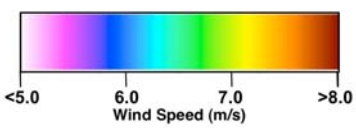
Weather Simulation for short-term variability
短期变化的天气仿真

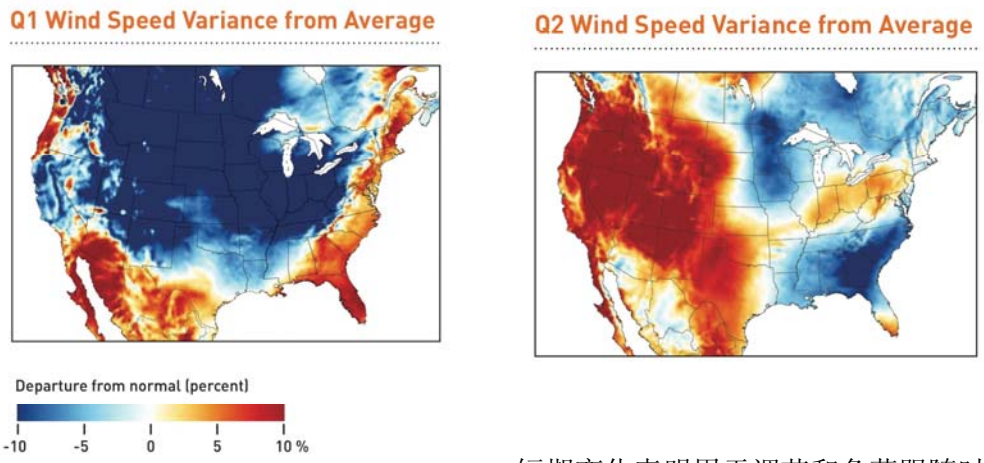


April 2010 hourly wind variability across U.S.A.
2010年4月，美国境内风速的小时级变化



Weather Simulation for long-term variability
长期变化的天气仿真

Departures from Normal (2010): Red is Higher, Blue is Lower
与正常的偏离(2010):红色代表高出，蓝色代表低于。



Short-term variability informs integration costs in regulation and load following time frames. What does a ramp look like from one project, ten projects, 100 projects?

Longer term variability quantifies the value of the energy resource.

短期变化表明用于调节和负荷跟随时间尺度上的并网成本；1个项目，10个项目，100个项目的变化率会是怎样的呢？

Is it windy, and where, during a drought?
长期变化能够量化风能资源的[illegible]够多吗，在哪儿？即使是在

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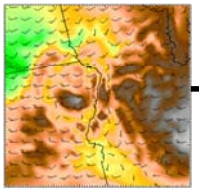
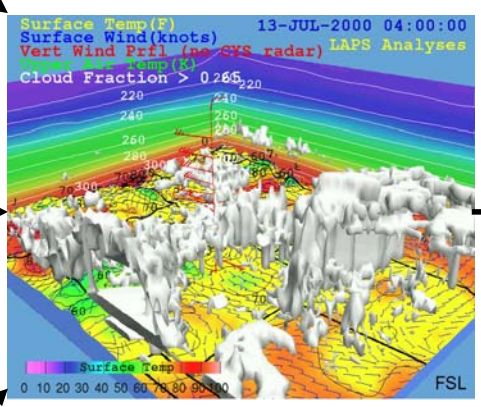
Weather Modeling Framework
天气建模框架

Global Weather Archive 1948-present
全球天气档案 1948年－至今

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



Onsite Observations
现场观测



Understanding of wind characteristics
理解风的特性

Long-term variability assessments
长期变化评估

Spatial wind maps
空间风能地图

INPUTS 输入 ANALYSIS分析 OUTPUTS 输出

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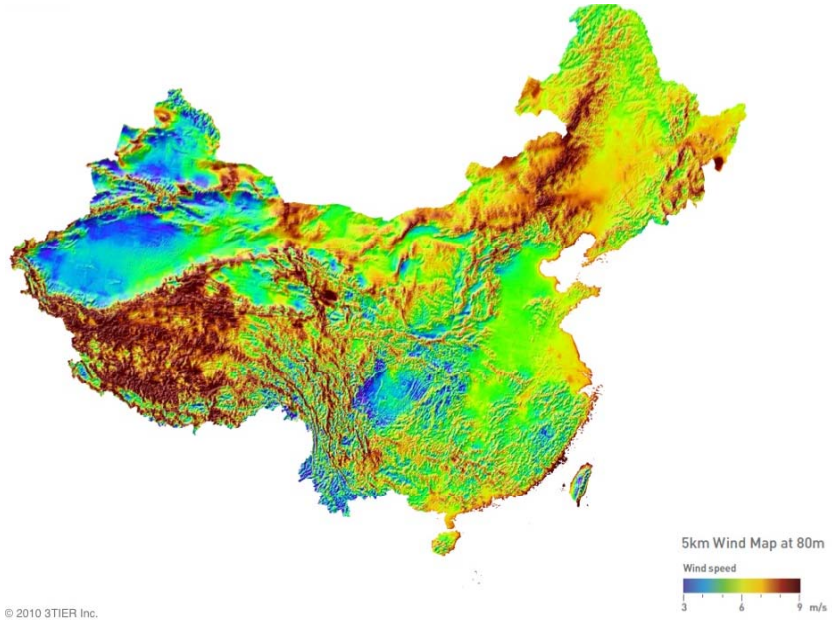
Can this approach be used in China?
这个方法能在中国应用吗？



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Case Study: NREL WEST STUDY OBJECTIVES
案例研究：美国可再生能源实验室西部风电研究目的

1) Create a 4D meteorological data set that covers the entire western United States at:
- a spatial resolution of 2km (2D),
- multiple heights above the ground (1D),
- every ten minutes for a period of 3 years (1D)
- The order of these (D's) matter.

2) Provide this entire data set to NREL.

3) Estimate 900 GW of potential wind energy output from this meteorological data set by modelling 30,000 locations each with a nameplate capacity of 30 MW. This includes forecasts too!

4) Provide this entire data set to NREL.

5) Build an interface so that users can access the data from #3

1) 建立涵盖整个美国西部的4维气象数据集
- 2公里(2维)空间分辨率
- 距离地面多个高度(1维)
- 3年每10分钟的数据(1维)
- 按照上述顺序

2) 将整个数据集提供给美国可再生能源实验室。

3) 借助整个气象数据集，并通过对30，000个位置的风能建模(每个地点30MW的容量)，估计出有900GW的潜在风能开发量。这些也包含了预测！

4) 将整个数据集提供给美国可再生能源实验室。

5)建立交互界面，这样用户可从第3步中获取数据。

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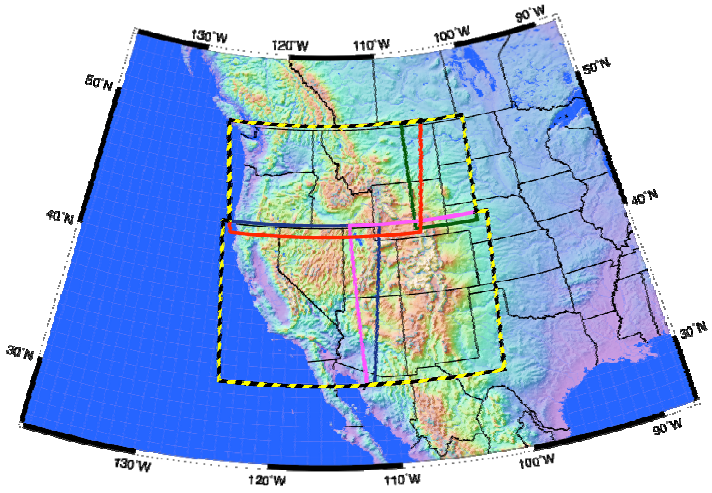
Creating the WWSIS Dataset
建立WWSIS数据集

- The final WWSIS wind dataset was a large dataset to create (and post-process)

  最终建立的WWSIS风数据集是巨大的(需后期处理)。



- Total area was over 1.2 million grid points.

  整个区域面积覆盖多于120万个网格节点。
- Each grid point had a three year, ten-minute time series equal to 157,680 data points.

  每个网格节点都包括3年的10分钟时间序列数据，相当于有157,680个数据点。
- Each time series was comprised of 21 modeled variables.

  每个时间序列包括21个模型变量。

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Creating the WWSIS Dataset
建立WWSIS数据集

- The following data was developed for each grid point:
  - Wind speed and direction at 10 m, 20 m, 50 m, 100 m, and 200 m
  - Temperature at 0 m, 2 m, 20 m and 50 m above the surface
  - Specific humidity at 2 m above the surface
  - Pressure at the surface
  - Precipitation at the surface
  - Downwelling radiation (longwave and shortwave) at the surface
- 以下是每个网格节点的数据：
  - 10m, 20m, 50m, 100m和200m的风速和风向
  - 距离地表0m, 2m, 20m和50m处的温度
  - 距地表2m处的湿度
  - 地表压力
  - 地表降水量
  - 地表下降辐射(长波和短波)

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Creating the WWSIS Dataset

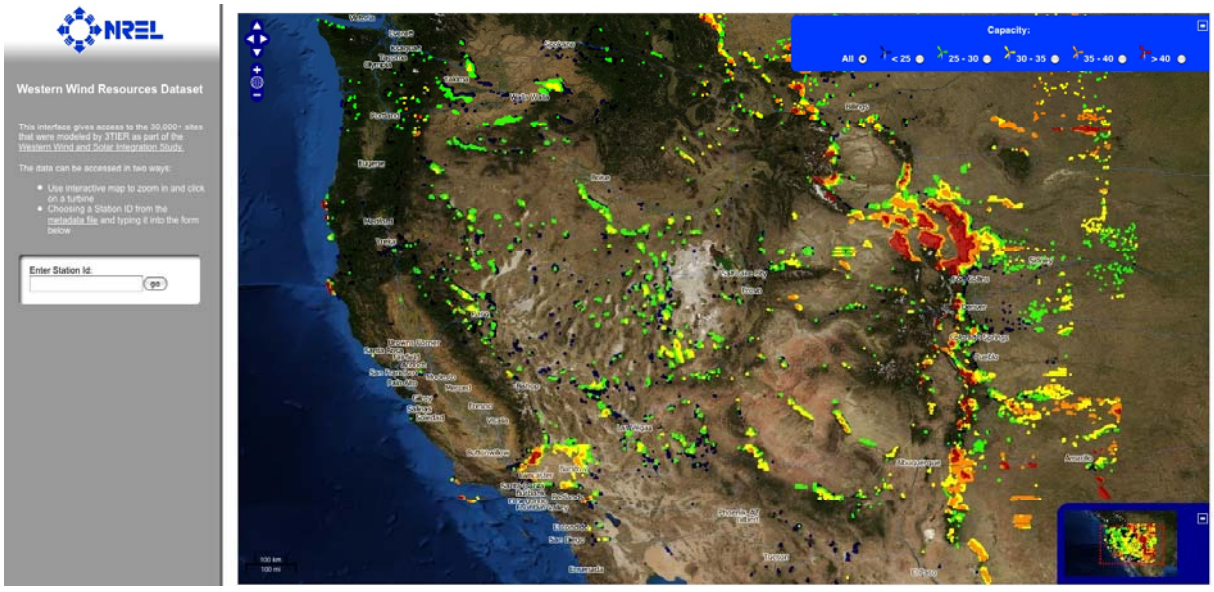
- To perform the integration study, synthetic wind projects had to be developed.
- The first task was to identify which sites were most practical; sequentially:
  - Selection of Pre-Existing/Pre-Proposed Sites
  - Proximity to Transmission (in study area)
  - Load Correlation (# sites per state from NREL)
  - Wind Power Density (# sites per state from NREL)
- Over 32,000 possible locations were selected.

建立WWSIS数据集

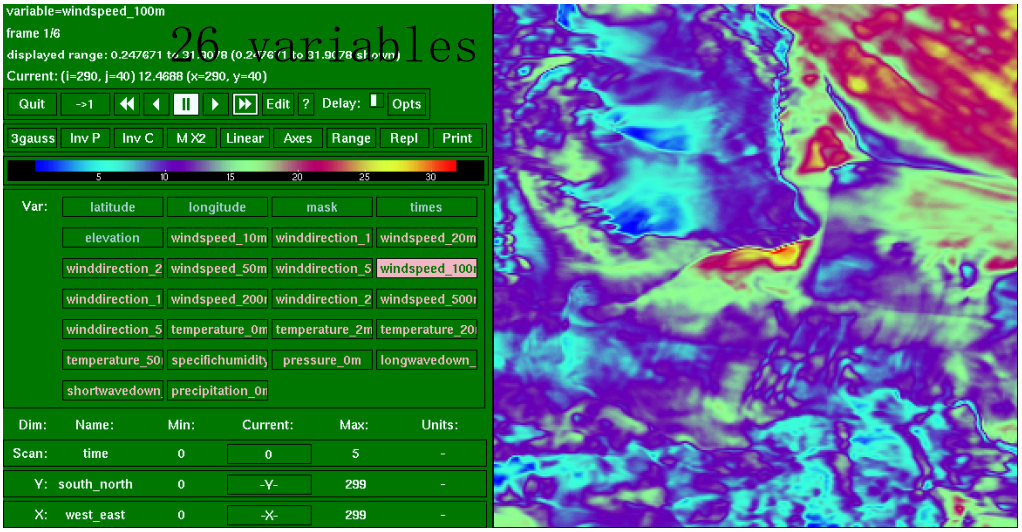
- 为了进行风电接入研究，必须要建立综合性风电项目模型
- 首要任务是确定最实际可行的地点，顺序如下：
  - 选择已存在/已建议的地点
  - 靠近输电线路(在研究地区)
  - 负荷相关性(NREL提供的每个州的地点)
  - 风能密度(NREL提供的每个州的地点)
- 多于32000个可能地点供选择

3TIER NREL Wind Integration Study
3TIER NREL风电接入研究

http://www.nrel.gov/wind/integrationdatasets/western/data.html



ISSUES: How much data is too much?
问题：多少数据算太多？



26 variables

5.1 TBytes per year:
15.3 TBytes total

DOWNLOAD IT ALL in 283 DAYS (5Mbps) AND
store it on a US$20k High Capacity RAID Storage system

每年有5.1T字节数据，总共为15.3T字节数据。

下载时间为283天（5Mbps），储存在2万美元的大容量RAID存储系统中

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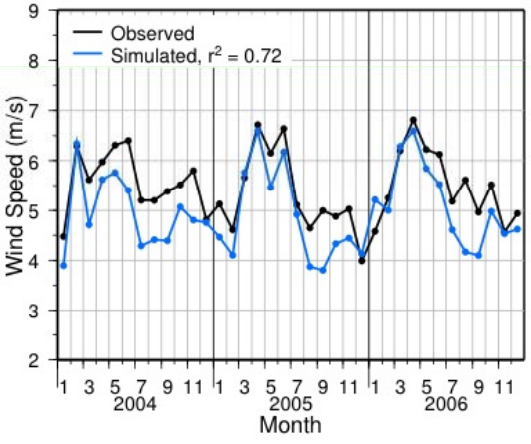
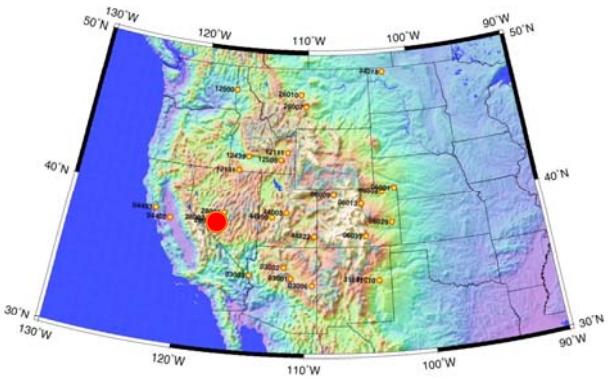
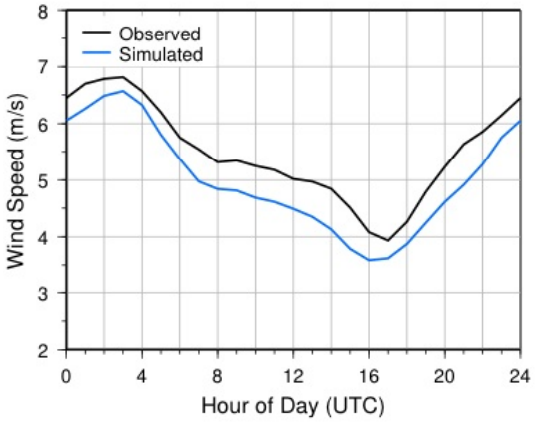
Validation (Nevada)
验证（内华达州 ）







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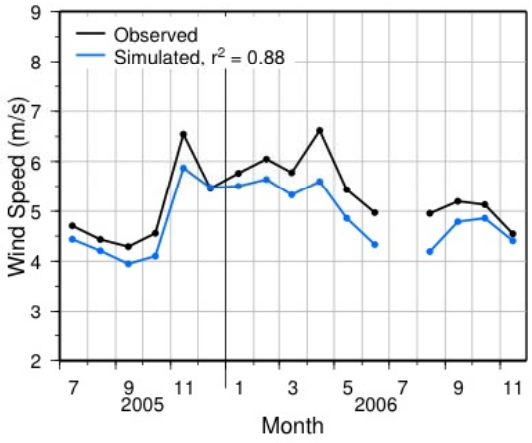
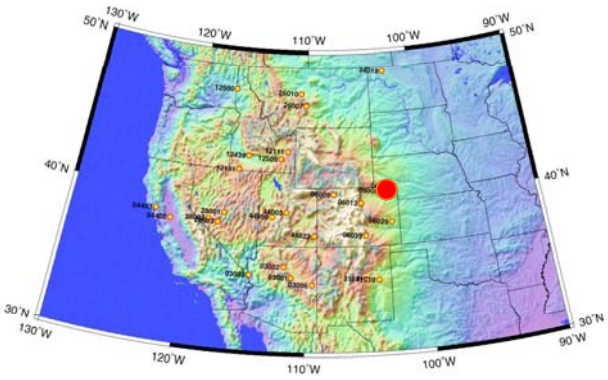
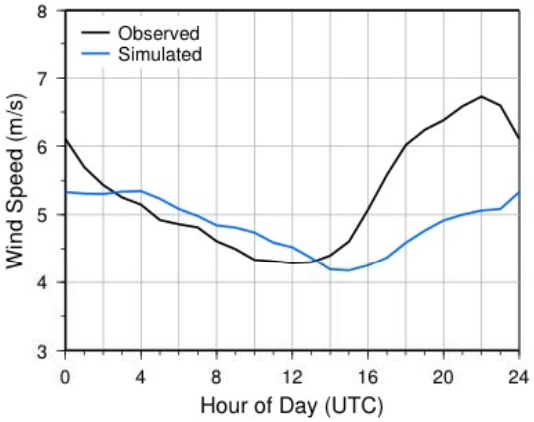
Validation (Colorado)
验证（科罗拉多州）







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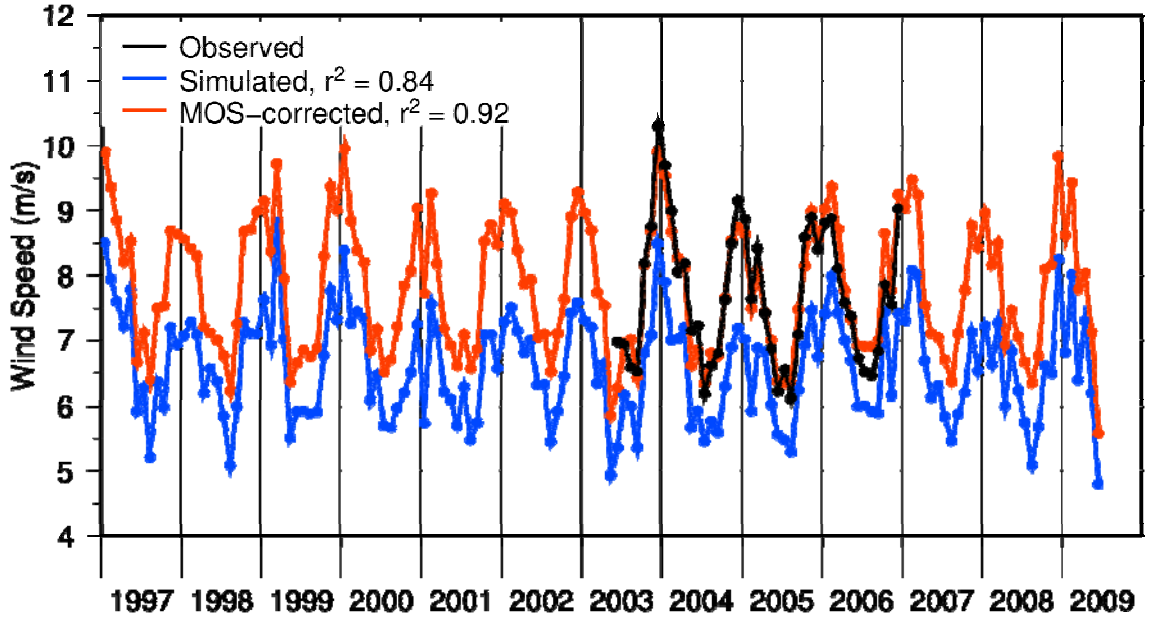
Observations can be used to improve results
观测可用来改善结果



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Conversion to Power
转化为功率

» Weather Modeling provides only weather data
天气建模仅提供天气数据。

» These data still need to be converted to power to estimate project output.
这些天气数据仍需转化为功率后才能估算项目功率输出。

Simulation of Synthetic Projects

- The other process is SCORE (Statistical Correction to Output from a Record Extension).
- Why is SCORE required? Modeled wind speeds are often too persistent
  - Simple upscaling of manufacturer's rating curves does not model farm-wide smoothing relationships.
  - "Farm-wide" rating curves are developed from empirical data for an entire farm and are subject to farm specifics such as project size and turbine layout.
  - Wind speed to power conversion is not deterministic

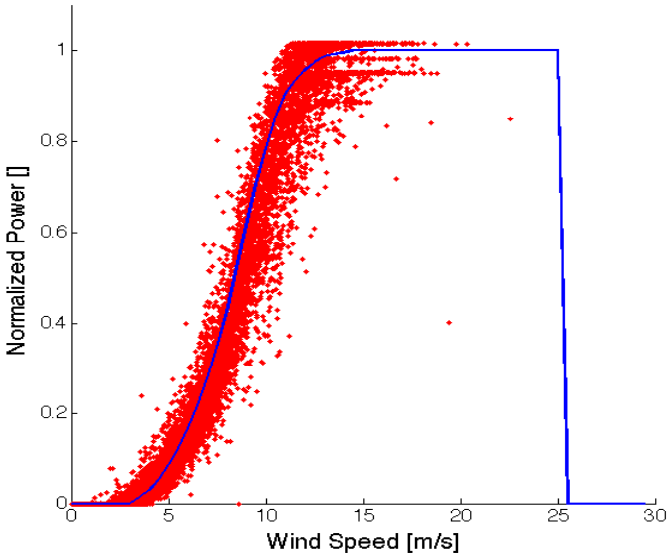
综合项目仿真

- 另一种过程是SCORE（记录数据扩充输出的统计校正）
- 为什么需要SCORE？模拟的风速经常是非常固定的
  - 简单放大机组制造商的额定功率曲线不能模拟出风场范围的平滑效应关系。
  - 风场范围额定功率曲线是从整个风场的经验数据中得到的，并受到风场细节比如风场的大小和风机布局的影响。
  - 风速转换为功率是非确定性的。

Simulation of Synthetic Projects
综合项目仿真

- The relationship between wind speed and power output is not fully deterministic

  风速和功率输出之间不是完全确定性的关系。

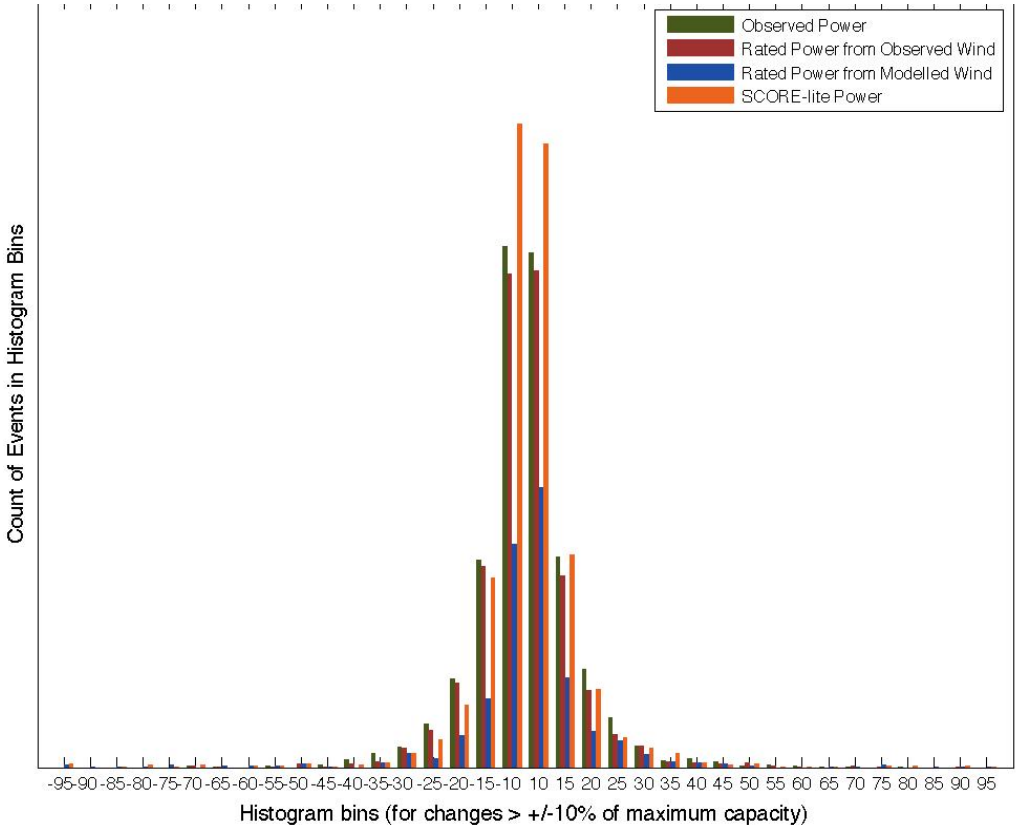


Simulation of Synthetic Projects

- How does SCORE work?
- Accurately modeling an individual turbine (or string of turbines) will result in a more accurate representation of the entire wind farm.
  - SCORE is based on empirical experience with wind speed to power output - related directly to the size of the grid spacing used in the mesoscale model.
  - However, it is important to note that SCORE is designed to operate in a probabilistic manner and so it may not be right at any given moment. Instead it is designed to provide statistically correct data。

综合项目仿真

- SCORE是如何工作的?
- 单个(多个)风机的精确建模有助于更加准确地描述整个风场。
  - SCORE 方法是基于风速到功率输出的经验，与用于中尺度建模的网格空间尺寸大小直接相关。
  - 但是，必须说明的是，SCORE是用于概率理论下的运行计算，因此在任意给定时刻其运行结果可能不正确。事实上它是用于提供统计的正确数据。



Conclusions
结论

- Getting good information is key to understanding and operating a power system - and weather-driven renewables can only be understood by understanding the weather.

  获得正确的信息是理解和运行电力系统的关键所在，只有理解天气才能理解受天气驱动的可再生能源。

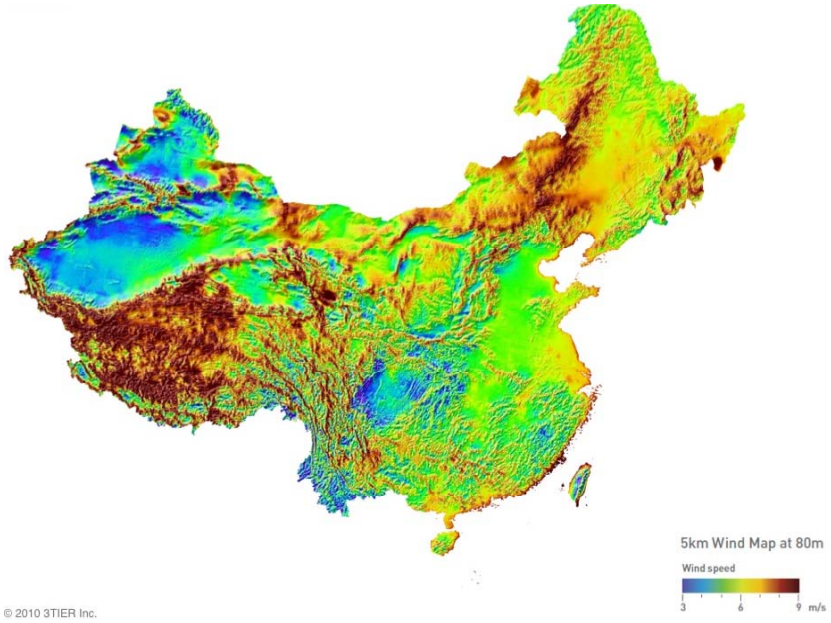
- It is possible to produce accurate forecasts or backcasts anywhere in the world, using a numerical weather prediction model.

  利用数值天气预报模型可以准确预测或回测世界任何地方的天气。

- Care must be taken in validating the weather data as well as in converting the weather data to synthetic project output.

  在验证天气数据以及将天气数据转换为综合项目输出时必须要谨慎

Can this approach be used in China?
这个方法能在中国使用吗？



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