GLOBAL SOLUTIONS
IN ENGINEERING

GENIVAR

CanWEA 2011 Conference and Exhibition

Advanced MCP Techniques

Rob Istchenko, P.Eng.

GENIVAR Inc.

Vancouver, BC

October 4, 2011

GENIVAR

PRESENTATION OUTLINE

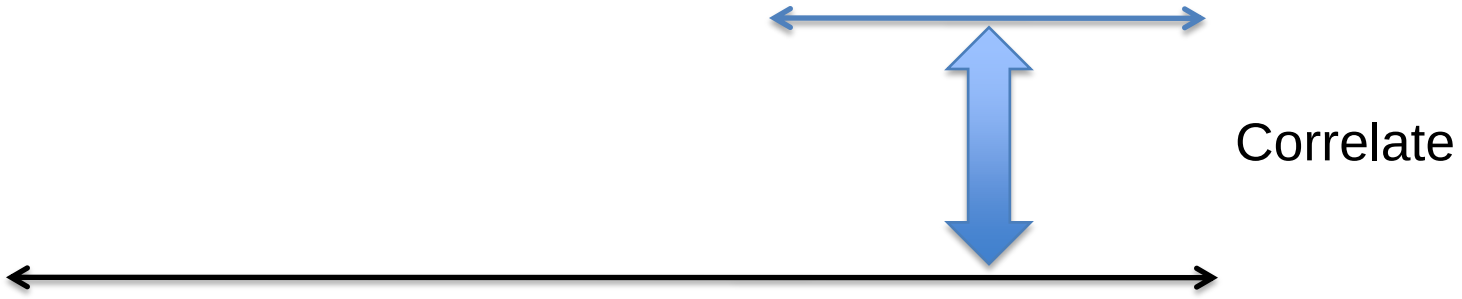
- MCP Overview
- Description of Techniques
- Evaluation Criteria
- Test Scenarios
- Results
- Summary
- Recommendations

MCP OVERVIEW

- The strength of the wind resource varies from year to year
- Long-term reference data can be leveraged to generate an estimate that incorporates multiple years of variability
- Process commonly referred to as **MCP**:
  - ***Measure*** data at the prospective project site

MCP OVERVIEW

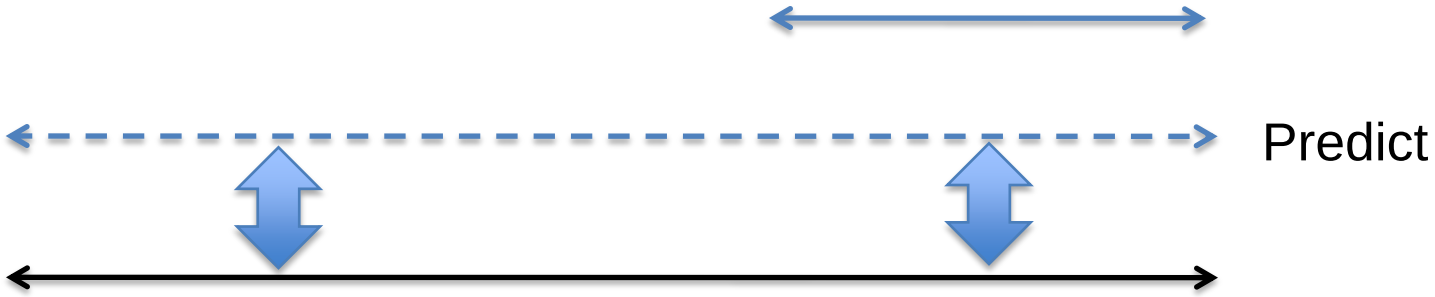
- The strength of the wind resource varies from year to year
- Long-term reference data can be leveraged to generate an estimate that incorporates multiple years of variability
- Process commonly referred to as **MCP**:
  - ***Measure*** data at the prospective project site
  - ***Correlate*** with a concurrent reference data set



GENIVAR

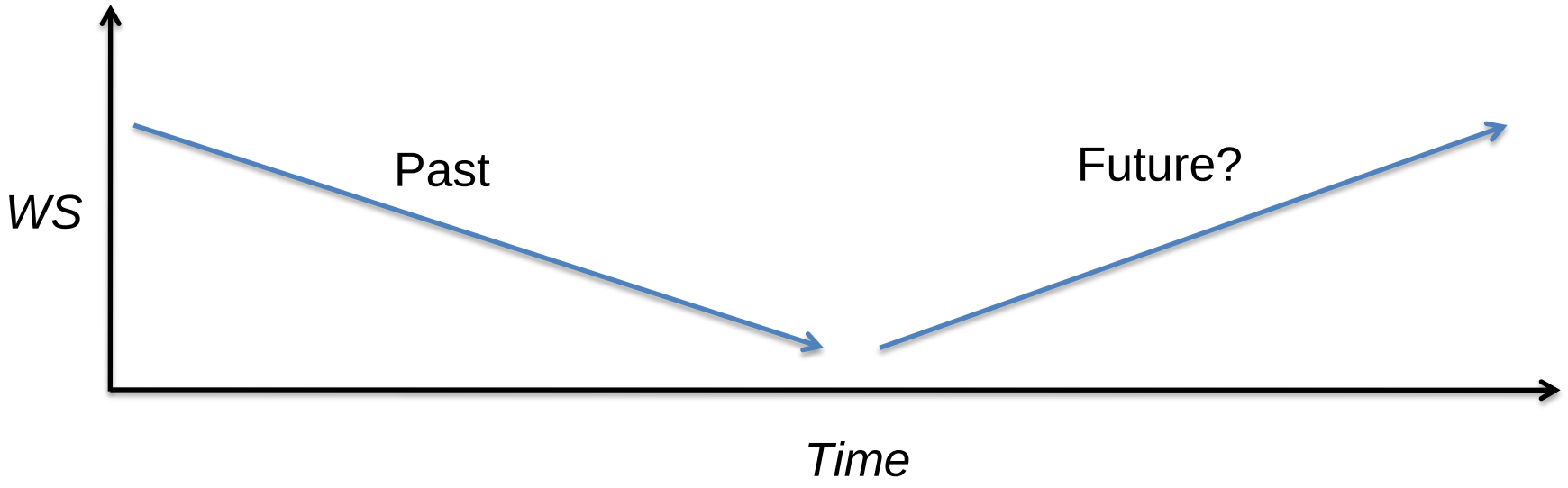
MCP OVERVIEW

- The strength of the wind resource varies from year to year
- Long-term reference data can be leveraged to generate an estimate that incorporates multiple years of variability
- Process commonly referred to as **MCP**:
  - ***Measure*** data at the prospective project site
  - ***Correlate*** with a concurrent reference data set
  - ***Predict*** a long-term data set (hindcast)



MCP OVERVIEW

- Assumes that the long-term average historical wind resource is representative of the future wind resource
- Requires ***consistent*** historical data (sensor type, placement, and orientation; tower location; exposure…)… *garbage in = garbage out*



MCP OVERVIEW

- There are a variety of MCP techniques, including:
  - Various linear regression techniques
  - Matrix method / joint probability
  - Weibull scaling
- Some techniques involve scaling the reference data, others transform the measured data
- Presentation explores 3 techniques:
  - Weighted Non-Linear Regression
  - Distribution Matching
  - Fuzzy Logic

DESCRIPTION OF TECHNIQUES

Weighted Non-Linear Regression

- Weibull distribution commonly used to characterize frequency distribution of wind speeds
- MCP regression based on non-linear relationship between cumulative Weibull distributions:

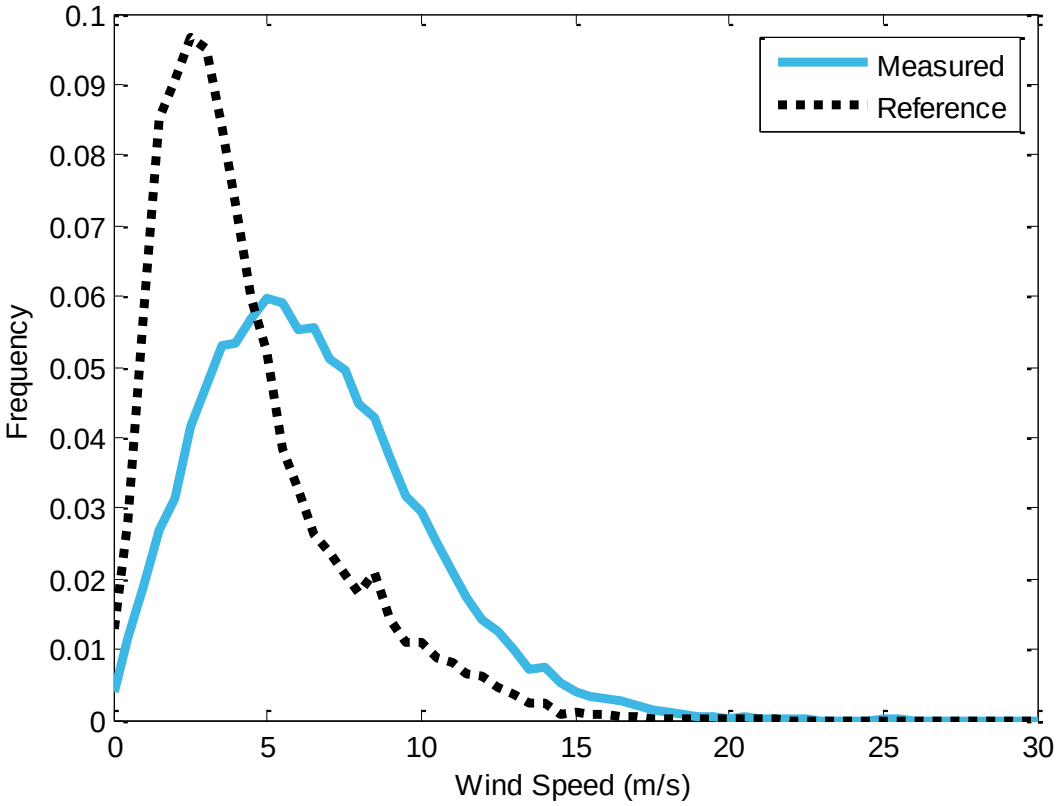
$$WS_1 = A_1 \left(\frac{WS_2}{A_2}\right)^{\frac{k_2}{k_1}} \quad \rightarrow \quad WS_1 = e^b {WS_2}^m$$

- Technique makes use of this relationship without requiring direct fitting of the data to a Weibull distribution
- Weighting adjusted based on minimizing a variety of errors, incl. wind turbine yield, distribution of wind speeds, and mean wind speed
- Technique applied on a directional basis with no data averaging

GENIVAR

DESCRIPTION OF TECHNIQUES

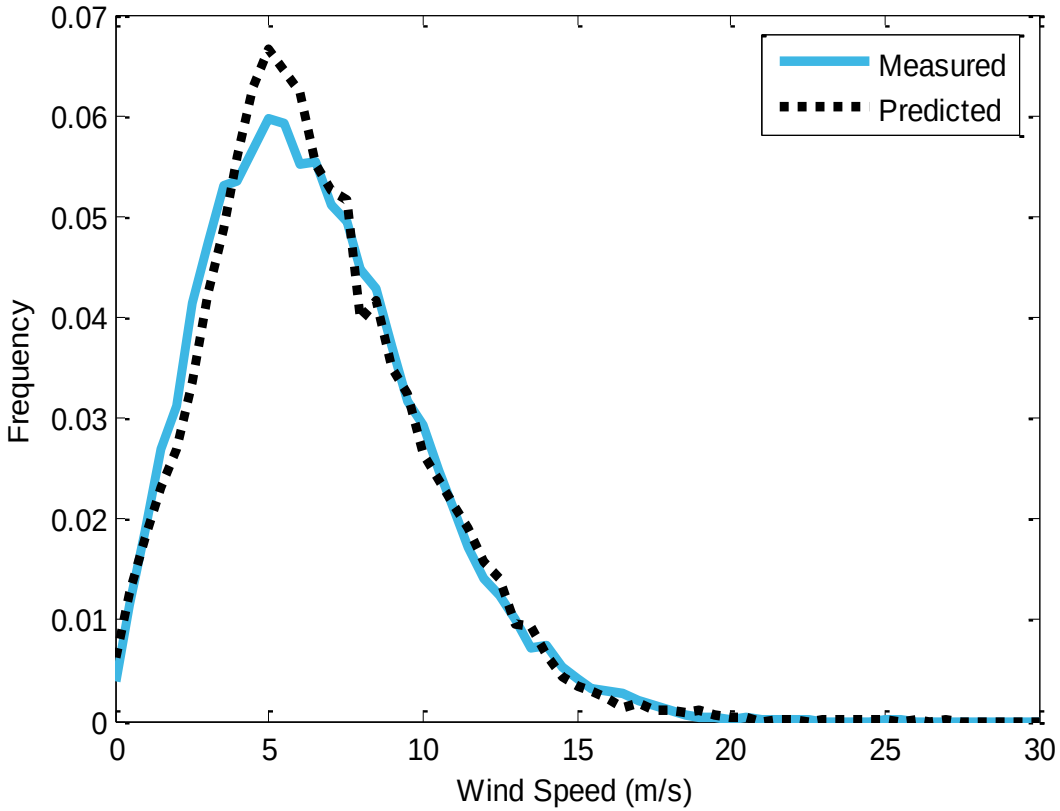
Weighted Non-Linear Regression - Example



GENIVAR

DESCRIPTION OF TECHNIQUES

Weighted Non-Linear Regression - Example



GENIVAR

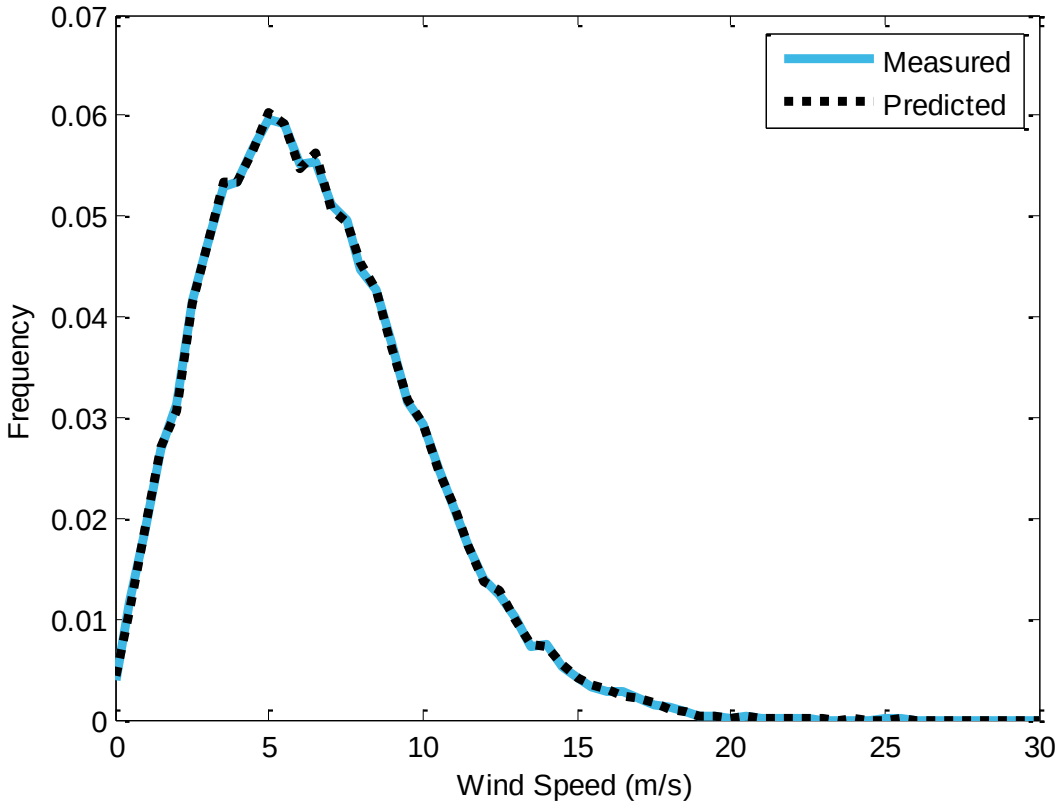
DESCRIPTION OF TECHNIQUES

Cumulative Distribution Matching

- Transformation based on equivalent wind speed percentiles in the synchronized measured and reference data
- By design, produces an exact match to the measured frequency distribution of wind speeds
- Matching of distributions ensures that mean wind speeds and production also match for the concurrent period
- Applied on a directional basis with no data averaging

DESCRIPTION OF TECHNIQUES

Distribution Matching - Example

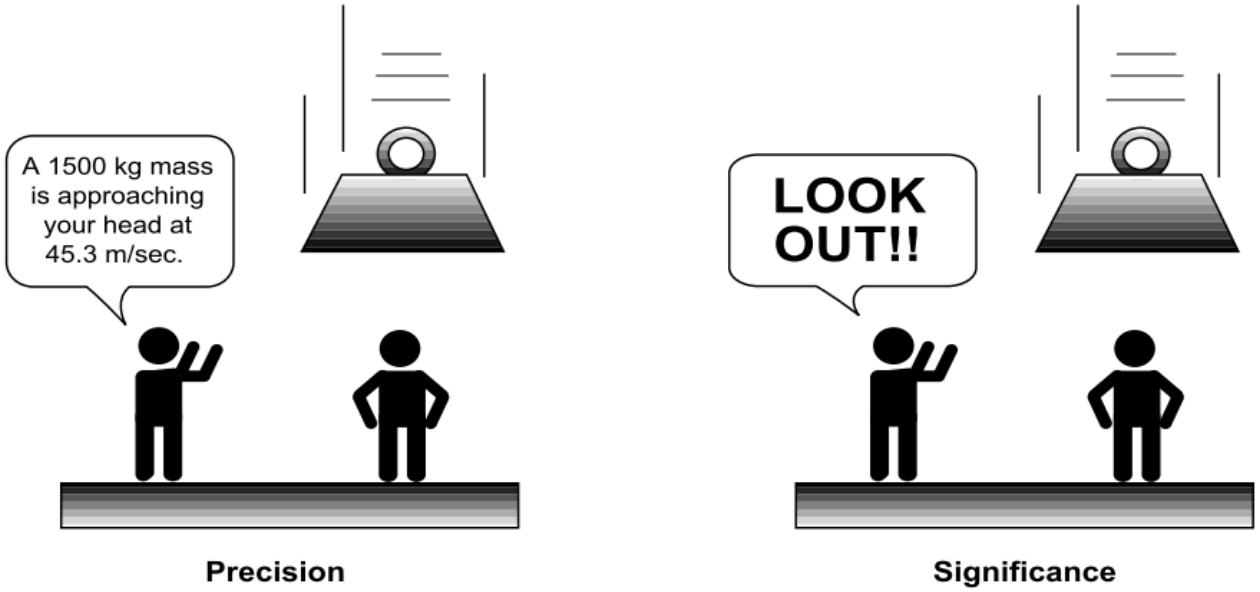


GENIVAR

DESCRIPTION OF TECHNIQUES

Fuzzy Logic

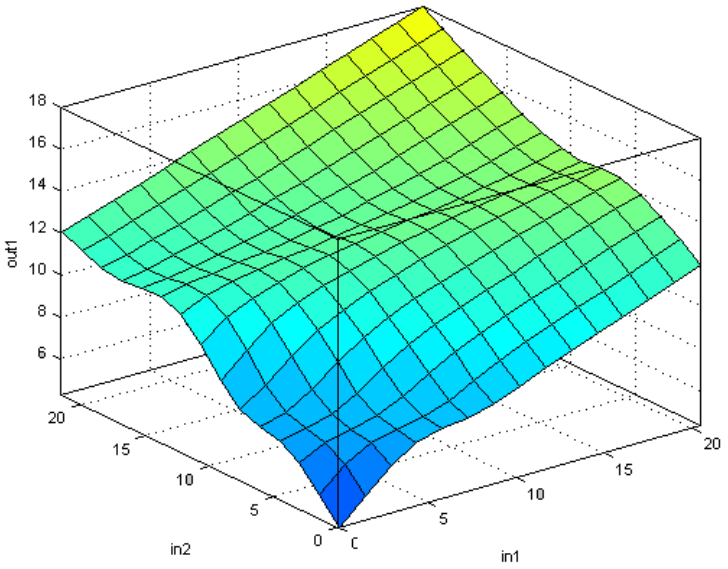
- Although the name isn't particularly confidence-inspiring… Can be an efficient way of handling complex problems since it allows for uncertainty / "fuzziness" in relationships



DESCRIPTION OF TECHNIQUES

Fuzzy Logic Technique

- Training data (concurrent measured and reference data) used to define rules
- Can incorporate multiple input datasets (multiple reference wind speeds, wind directions etc.)
- Can evaluate inputs in order to use only the most useful
- Objectives can be tailored – for example, can include matching of diurnal and seasonal wind speed patterns

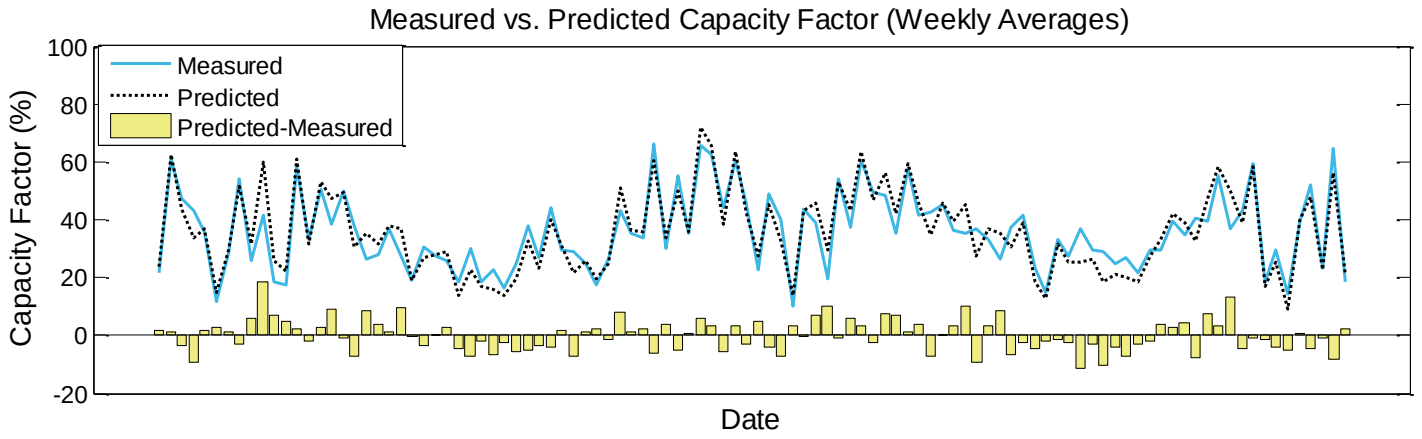


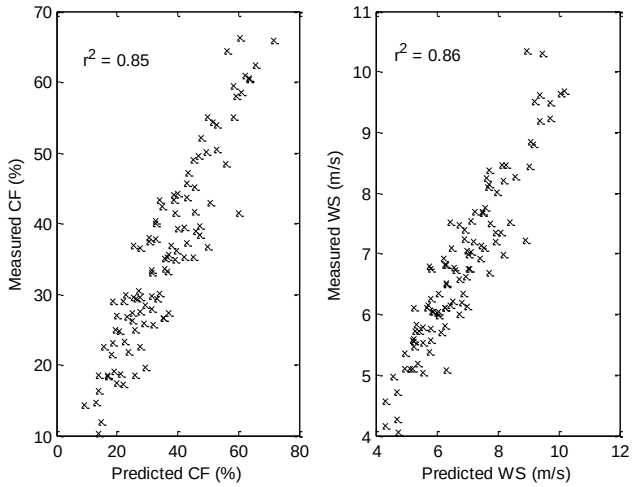
GENIVAR

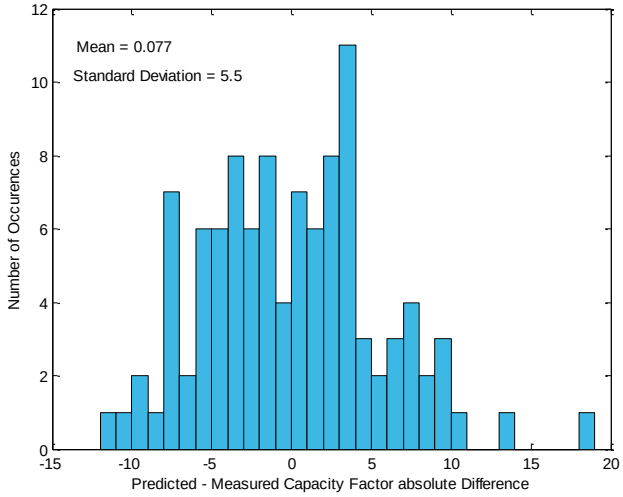
EVALUATION CRITERIA

- How do we evaluate the predictions? What to compare?
- Compare concurrent measured and predicted data sets:
  - Correlations
  - Mean wind speed
  - Distribution of wind speeds
  - Calculated yield
  - Temporal variability (record-by-record, weekly, time-of-day, season…)
- Blind trials – there are various techniques for using “training” and “checking” subsets of the prediction

EVALUATION CRITERIA







GENIVAR

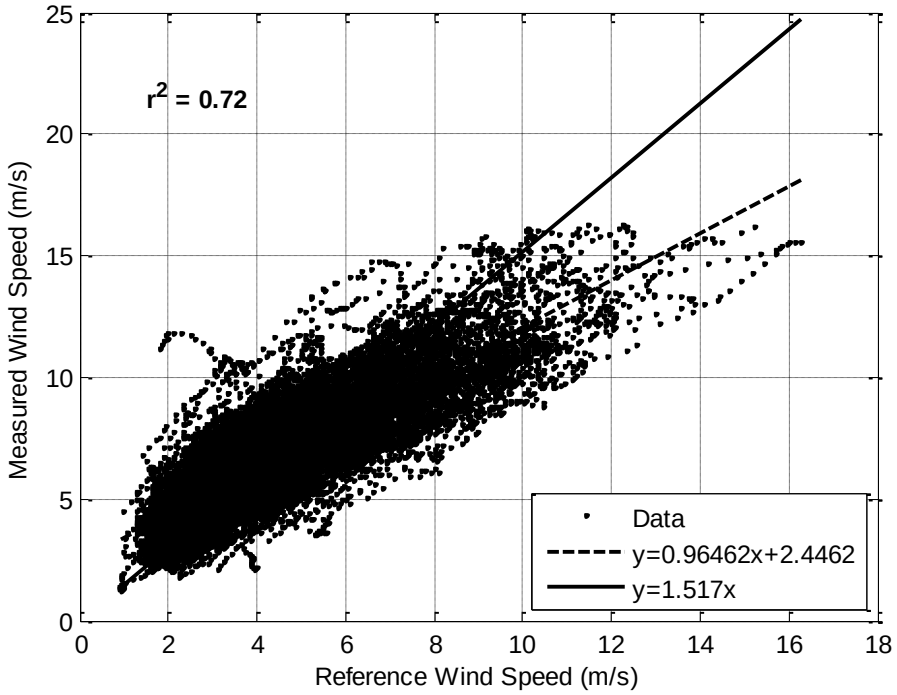
TEST SCENARIOS

- We would like to test the consistency and stability of the various prediction techniques under different plausible scenarios
- Two common challenges in MCP:
  - Short period of measured data available
  - Weak correlation with reference data

RESULTS – CASE 1

→ Case 1:

- Reference data set with good correlation
- 2 years of measured data



GENIVAR

RESULTS – CASE 1

→ Case 1:

- Reference data set with good correlation
- 2 years of measured data

	Concurrent Period (2 Years)			1-Year Validation Period			LT Period	
Prediction Technique	**Mean Wind Speed Error**	**Yield Error**	**Stdev of Weekly CF Error (abs)**	**Mean Wind Speed Error**	**Yield Error**	**Stdev of Weekly CF Error (abs)**	**Mean Wind Speed (m/s)**	**CF**
Weight Non-Lin	0.1%	0.0%	5.5%	0.9%	2.0%	5.1%	6.64	33.9%
Dist Match	0.0%	0.0%	5.5%	1.2%	2.0%	5.2%	6.63	33.8%
Fuzzy Logic	-0.1%	-0.8%	4.9%	1.8%	3.4%	4.3%	6.72	34.6%

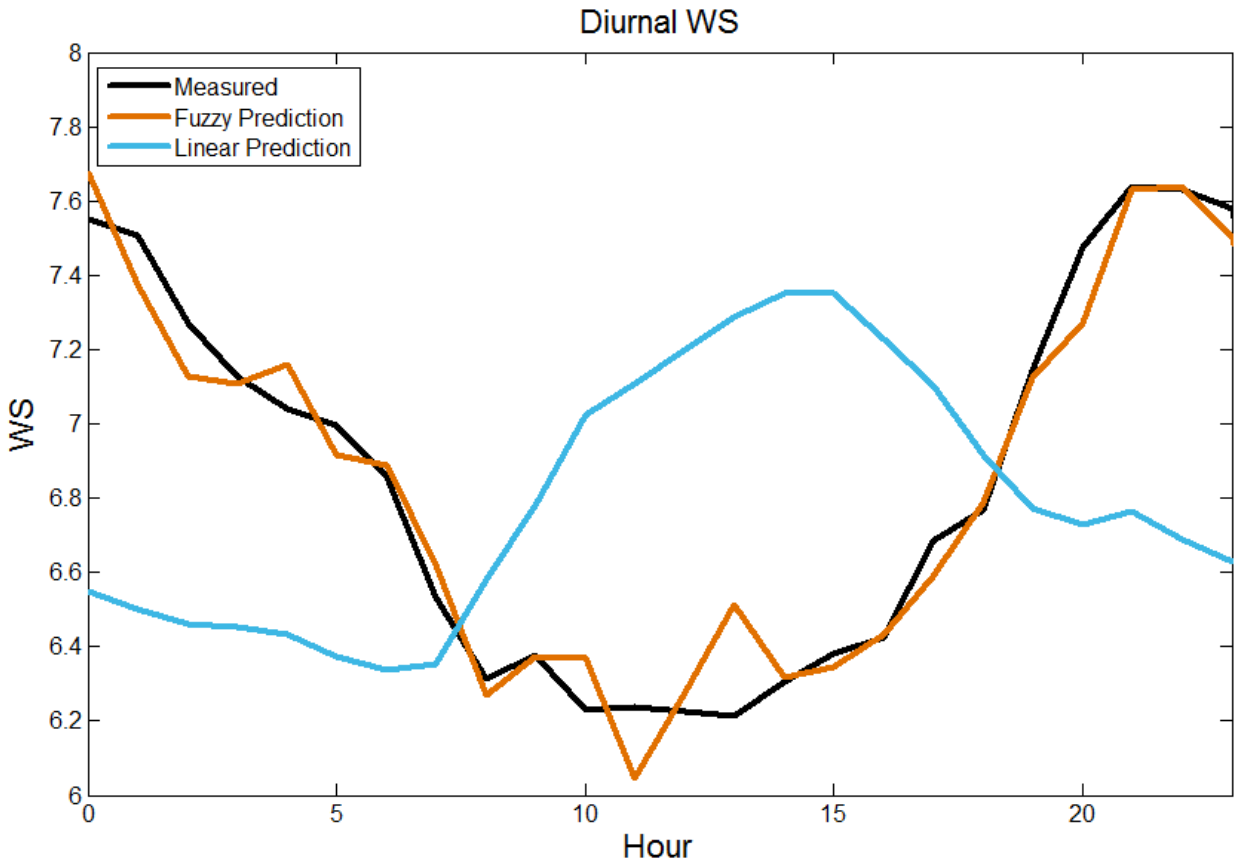
RESULTS – CASE 1

- Case 1:
  - Reference data set with good correlation
  - 2 years of measured data

		Concurrent Period (2 Years)			1-Year Validation Period			LT Period	
	Prediction Technique	Mean Wind Speed Error	Yield Error	Stdev of Weekly CF Error (abs)	Mean Wind Speed Error	Yield Error	Stdev of Weekly CF Error (abs)	Mean Wind Speed (m/s)	CF
	Weight Non-Lin	0.1%	0.0%	5.5%	0.9%	2.0%	5.1%	6.64	33.9%
	Dist Match	0.0%	0.0%	5.5%	1.2%	2.0%	5.2%	6.63	33.8%
	Fuzzy Logic	-0.1%	-0.8%	4.9%	1.8%	3.4%	4.3%	6.72	34.6%
Established Approaches	Lin Reg	-0.7%	-9.7%	4.7%	0.3%	-8.2%	4.2%	6.65	30.7%
	Modified Lin Reg	-1.2%	-1.1%	6.1%	-0.4%	0.8%	4.6%	6.63	34.2%
	Matrix Method	-1.5%	-2.2%	5.7%	-0.9%	-1.1%	5.6%	6.61	33.9%

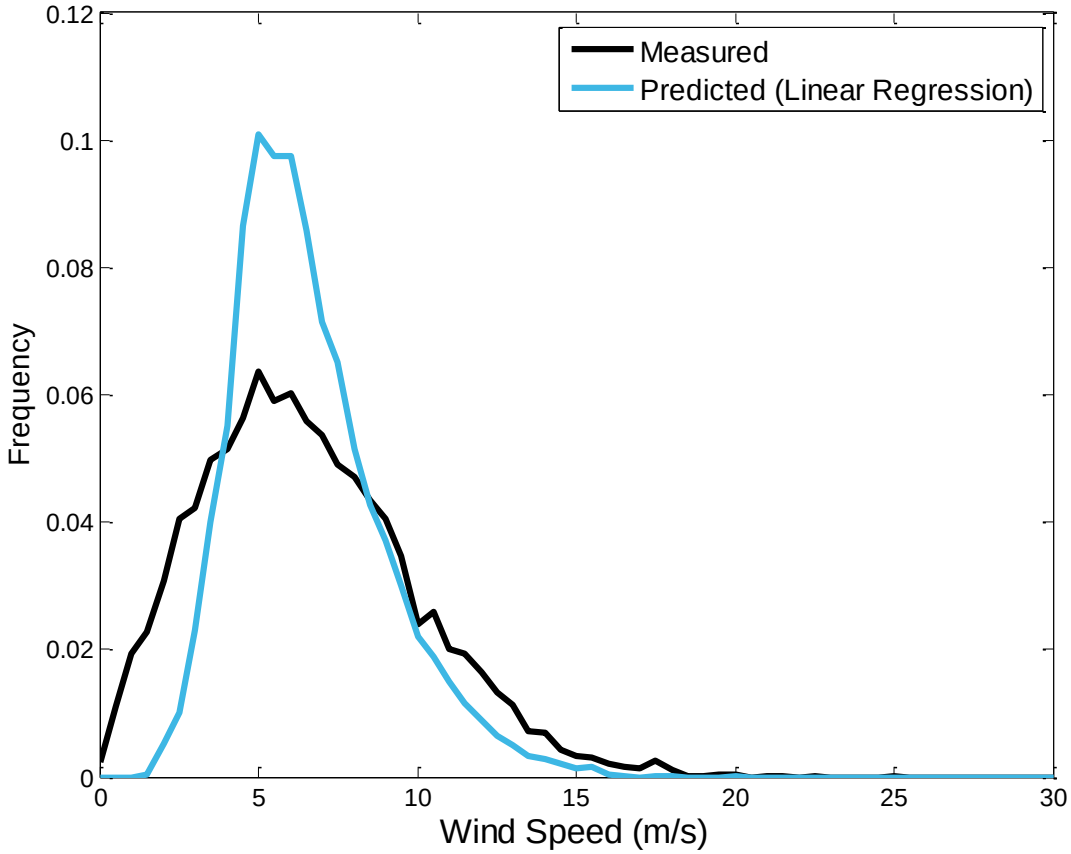
GENIVAR

RESULTS – CASE 1



GENIVAR

RESULTS – CASE 1



GENIVAR

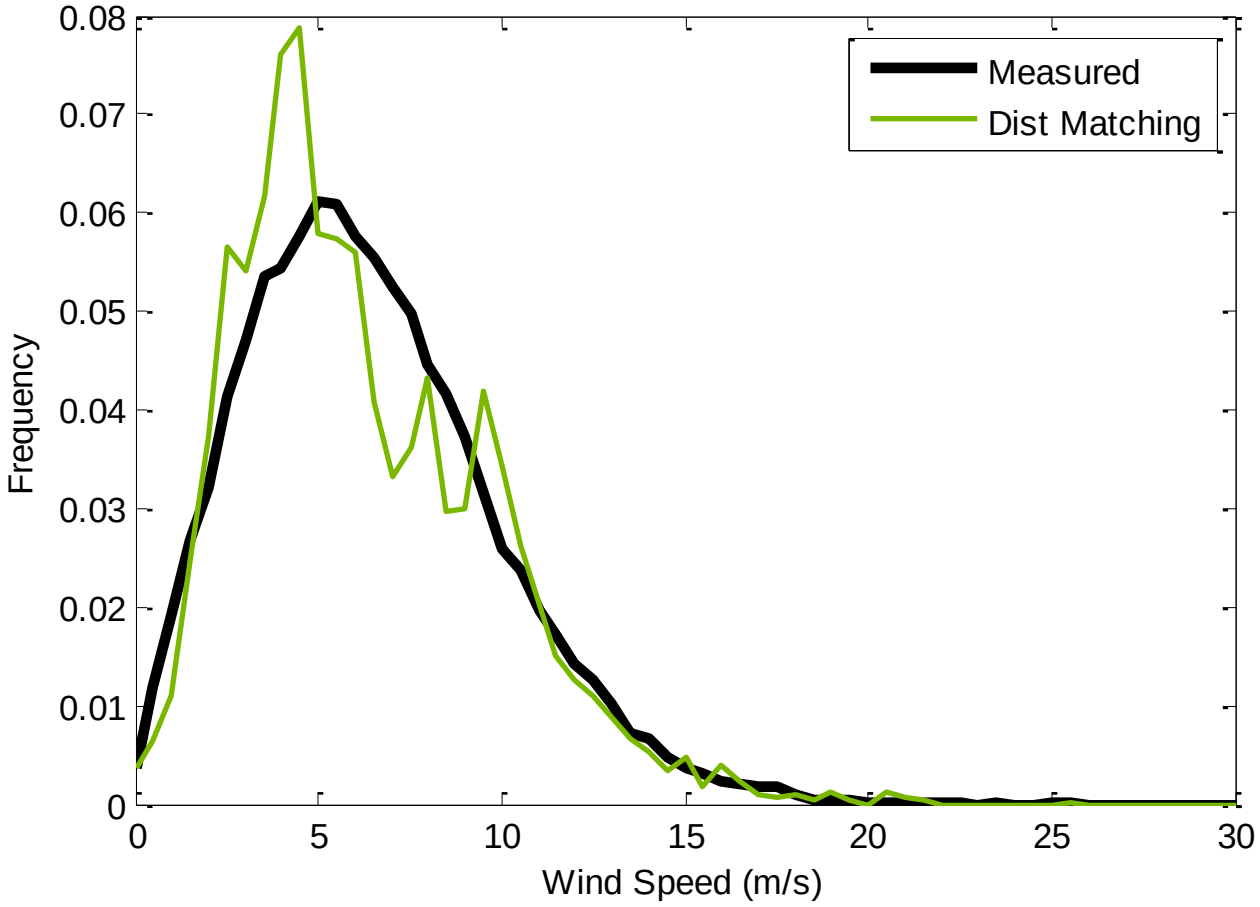
RESULTS – CASE 2

→ Case 2:

- Reference data set with good correlation
- 3 months of measured data

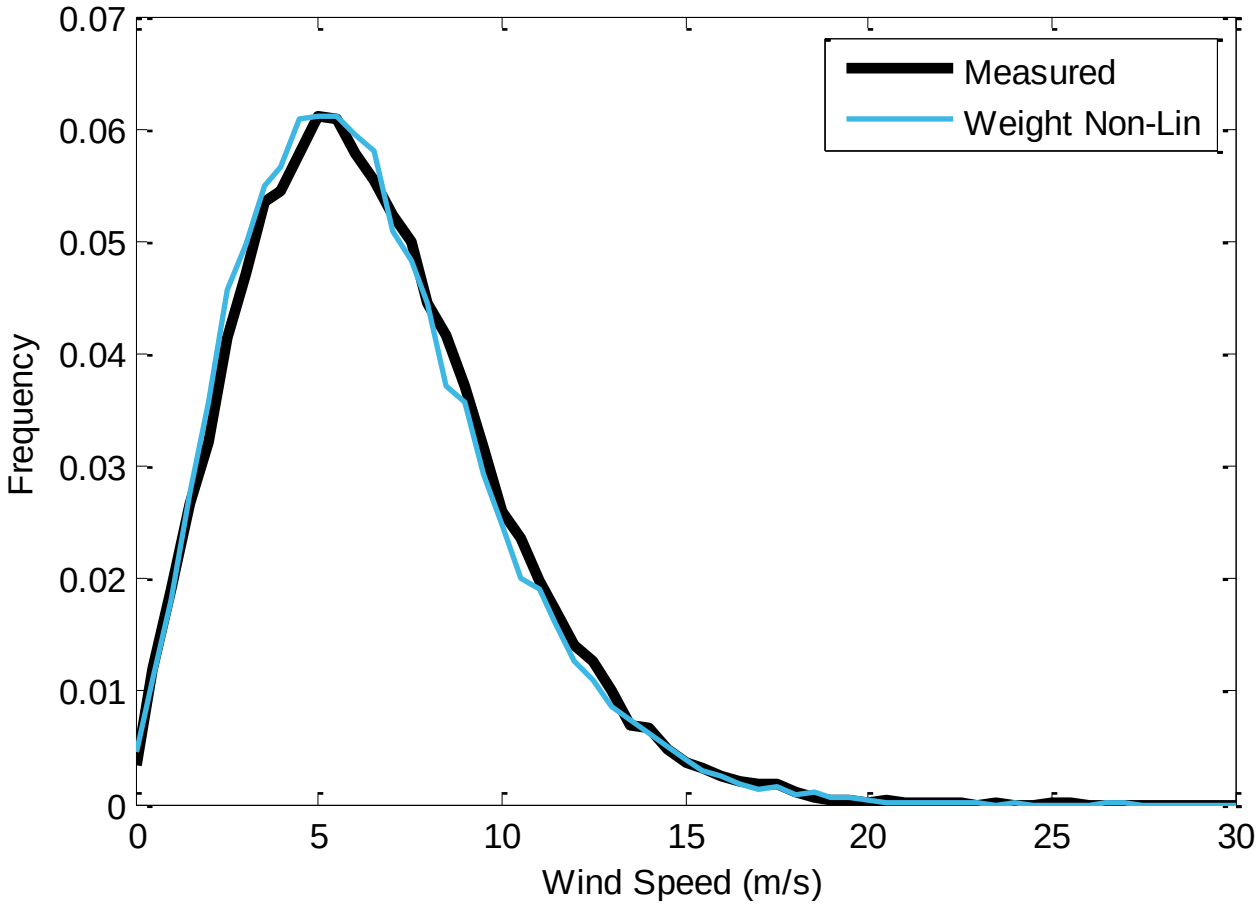
	4-Year Validation Period			LT Period	
Prediction Technique	**Mean Wind Speed Error**	**Yield Error**	**Stdev of Weekly CF Error (abs)**	**Mean Wind Speed (m/s)**	**CF**
Weight Non-Lin	-2.0%	-4.4%	5.2%	6.49	32.0%
Dist Match	-2.6%	-5.0%	5.6%	6.42	31.7%
Fuzzy Logic	0.7%	3.8%	6.9%	6.66	35.1%

RESULTS – CASE 2



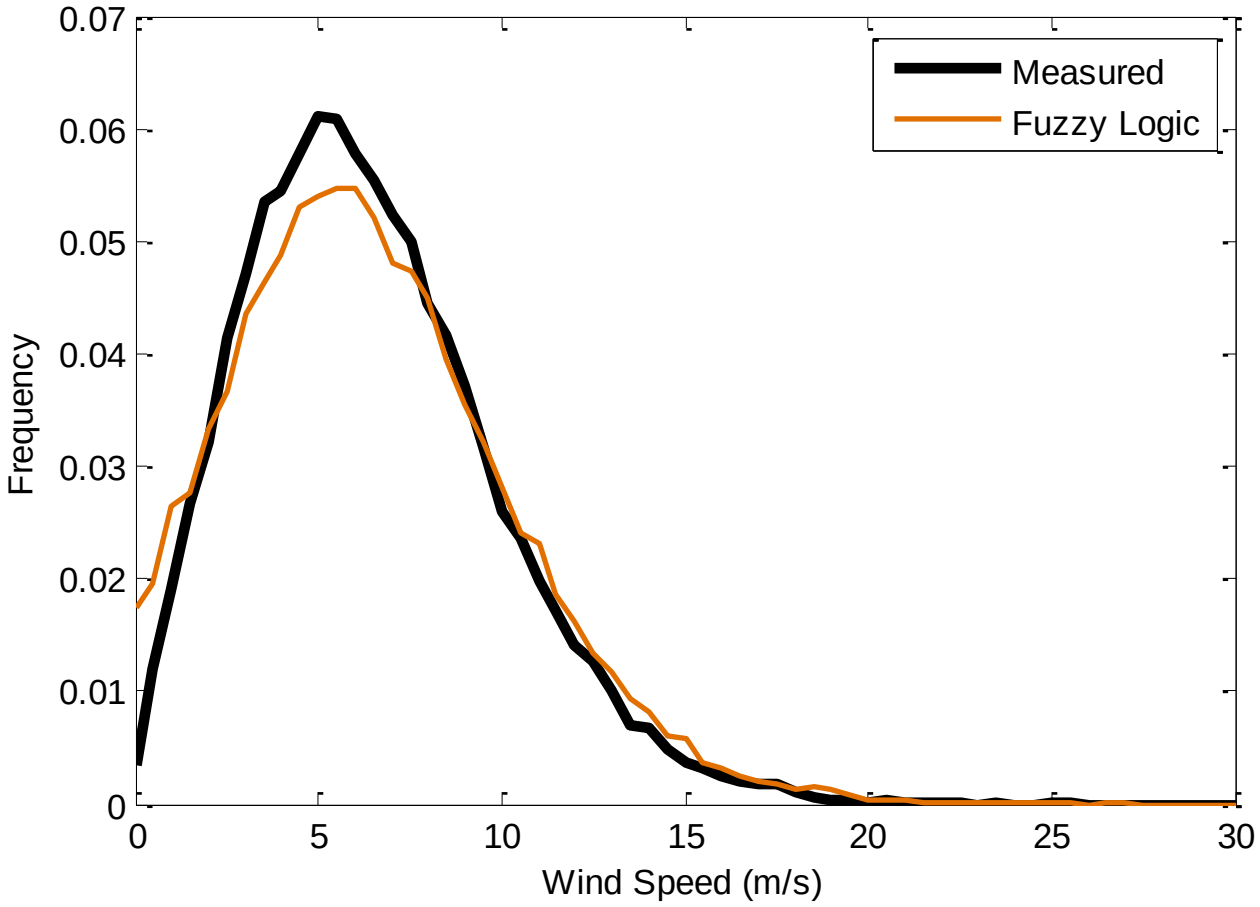
GENIVAR

RESULTS – CASE 2



GENIVAR

RESULTS – CASE 2

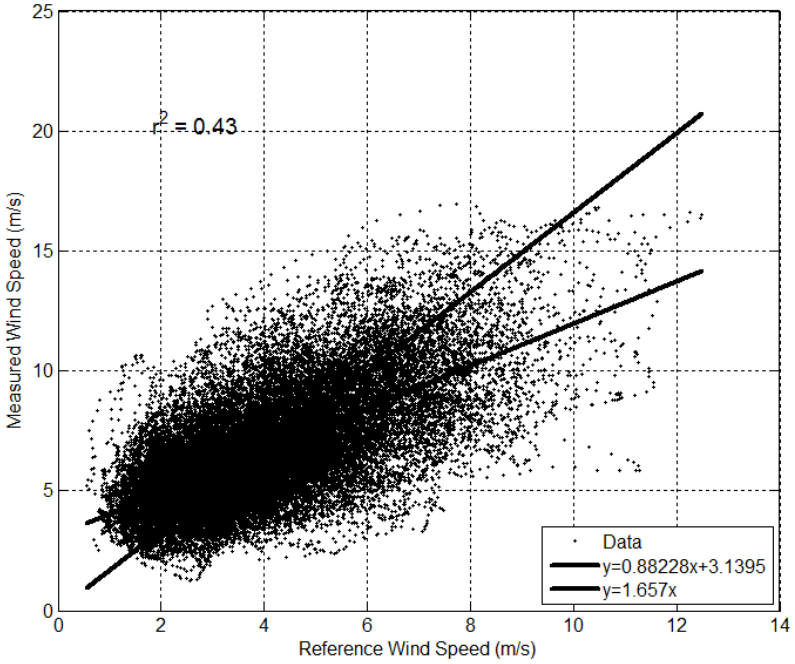


GENIVAR

RESULTS – CASE 3

→ Case 3:

- Reference data set with poor correlation
- 2 years of measured data



GENIVAR

RESULTS – CASE 3

→ Case 3:

- Reference data set with poor correlation
- 2 years of measured data

	2-Year Validation Period			LT Period	
Prediction Technique	**Mean Wind Speed Error**	**Yield Error**	**Stdev of Weekly CF Error (abs)**	**Mean Wind Speed (m/s)**	**CF**
Weight Non-Lin	-4.4%	-5.8%	8.2%	6.35	31.7%
Dist Match	-3.8%	-5.8%	8.3%	6.36	31.7%
Fuzzy Logic	2.1%	6.3%	8.5%	6.72	35.3%

SUMMARY

- Weighted non-linear regression and distribution matching are fairly stable under challenging circumstances
- Distribution matching eliminates bias in the concurrent period, but can produce a more discretized distribution when it is defined using a short period of record
- Fuzzy technique is quite adaptable and demonstrates good temporal validation; however…
- Current implementation is less stable than other techniques
- Convergence between techniques when there is a strong relationship between the reference and local data

RECOMMENDATIONS

- No technique can overcome poor quality reference data
- Evaluate using a portfolio of techniques, including possibility of using measured data only – disagreement can be revealing
- Consider a variety of validation metrics – beyond mean wind speed and r^2
- Preference of technique may vary depending on the particular situation and the intended use of the output data set
- Presentation focuses on prediction of wind speeds, similar approaches are relevant to other variables (wind direction, temperature…)
- Utilize validation results to inform uncertainty analysis
- Consider bypassing MCP and using on-site data only

Thank You

Special thanks to contributors:

Carlos Ferreira, P.Eng., TransAlta Wind
and
Barry Turner, Ph.D., ACM, GENIVAR

GENIVAR