Wind Flow Modeling Software Comparison

John Vanden Bosche
Chinook Wind

AWEA Wind Resource Assessment Workshop
Minneapolis, MN
September 30, 2009

Chinook Wind

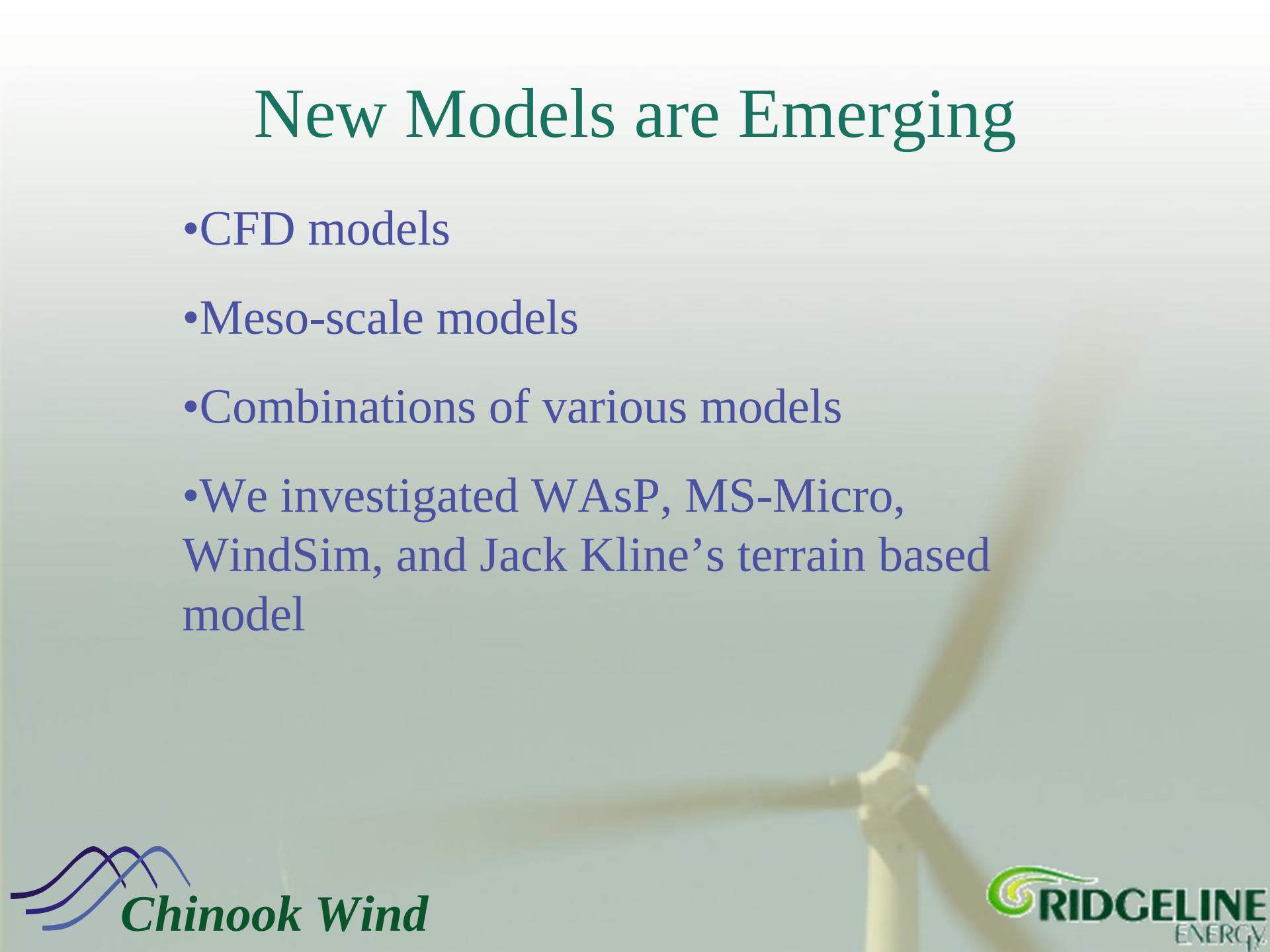
RIDGELINE ENERGY

Issues With Wind Flow Modeling

- Impractical to measure the wind at the location of each wind turbine, so *some* model is necessary
- Conceptual flow models were used historically – relied heavily on the analyst's skill
- WAsP became a de-facto industry standard over the past 10 to 15 years
- WAsP is a linear model that is not ideal. Can we do better?

New Models are Emerging

- CFD models
- Meso-scale models
- Combinations of various models
- We investigated WAsP, MS-Micro, WindSim, and Jack Kline's terrain based model



Chinook Wind

RIDGELINE ENERGY

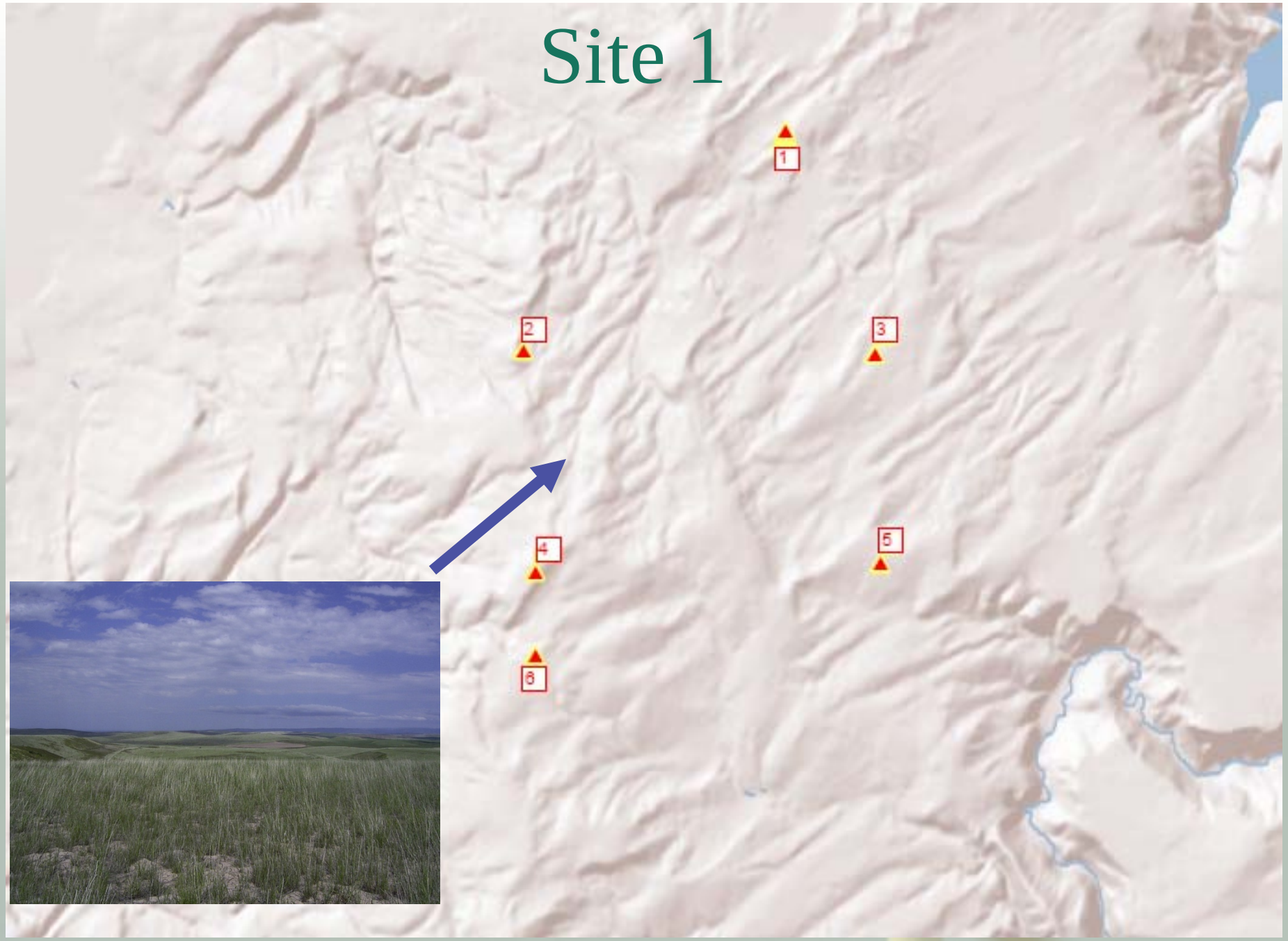
Methodology

- Compared models at two sites with different terrain and climate characteristics
- Utilized ONLY concurrent wind data at a consistent height in the comparison
- Eliminated potential bias from MCP or wind shear adjustments
- Utilized “best practices” for use of each software
- Jack Kline modeled the sites for us – we provided data and he provided results

Sites

- Test sites provided courtesy of Ridgeline Energy
- Intermountain western US
- Both have moderately complex terrain
- Atmospheric stability is important in wind flow
- Site names and average wind speeds have been obscured to ensure confidentiality

Site 1



Site 2

WAsP

- Oldest model considered
- Linear flow model
- Industry standard
- Well known

MS Micro 3

WindFarm

- Part of optimization software ‘WindFarm’
- Linear flow model
- Very fast calculations
- Low cost $$$
- Effective tutorials

Chinook Wind

RIDGELINE ENERGY

WindSim

windsim

- CFD
- Combines results from multiple met towers
- Visual error results
- Exportable 3D data
- Possible to investigate convergence

Jack Kline's Model

- Empirical model – presented at the 2007 WRA workshop
- Utilizes proprietary upwind and downwind exposure indices
- Measured wind speeds are regressed with exposure indices and elevation
- Regression results can be used to predict wind speeds at other met tower locations (or turbine locations)

Results Comparison

- Combined results from multiple initialization met towers for WAsP and MS-Micro to create a composite wind flow grid
- WindSim treats multiple met towers simulteously
- Leave 1 met tower out from composite grid
- Compare predicted result for “left out” tower to measured wind at that tower

Results Table – Site 1

Met Tower	Jack Kline	MS Micro	WindSim	WAsP
1	0.1%	1.6%	-7.1%	-4.5%
2	0.0%	0.9%	1.3%	-3.7%
3	-1.8%	6.3%	-3.4%	-2.4%
4	-0.6%	-5.1%	2.1%	2.2%
5	1.9%	-1.8%	3.2%	3.6%
6	-0.5%	3.6%	3.0%	-0.9%
RMS Error	**1.1%**	**3.8%**	**3.8%**	**3.1%**
Bias	**-0.6%**	**2.9%**	**-3.1%**	**-3.5%**

Chinook Wind

RIDGELINE ENERGY

Results Table – Site 2

Met Tower	Jack Kline	MS Micro	WindSim	WAsP
1	-1.8%	0.8%	-2.9%	3.3%
2	1.4%	3.2%	5.3%	1.2%
3	-2.2%	-2.1%	-8.9%	1.4%
4	-1.8%	1.4%	4.6%	-4.7%
5	1.5%	-2.5%	3.7%	2.3%
RMS Error	**1.8%**	**2.2%**	**5.5%**	**2.9%**
Bias	**-0.6%**	**0.2%**	**0.4%**	**0.7%**

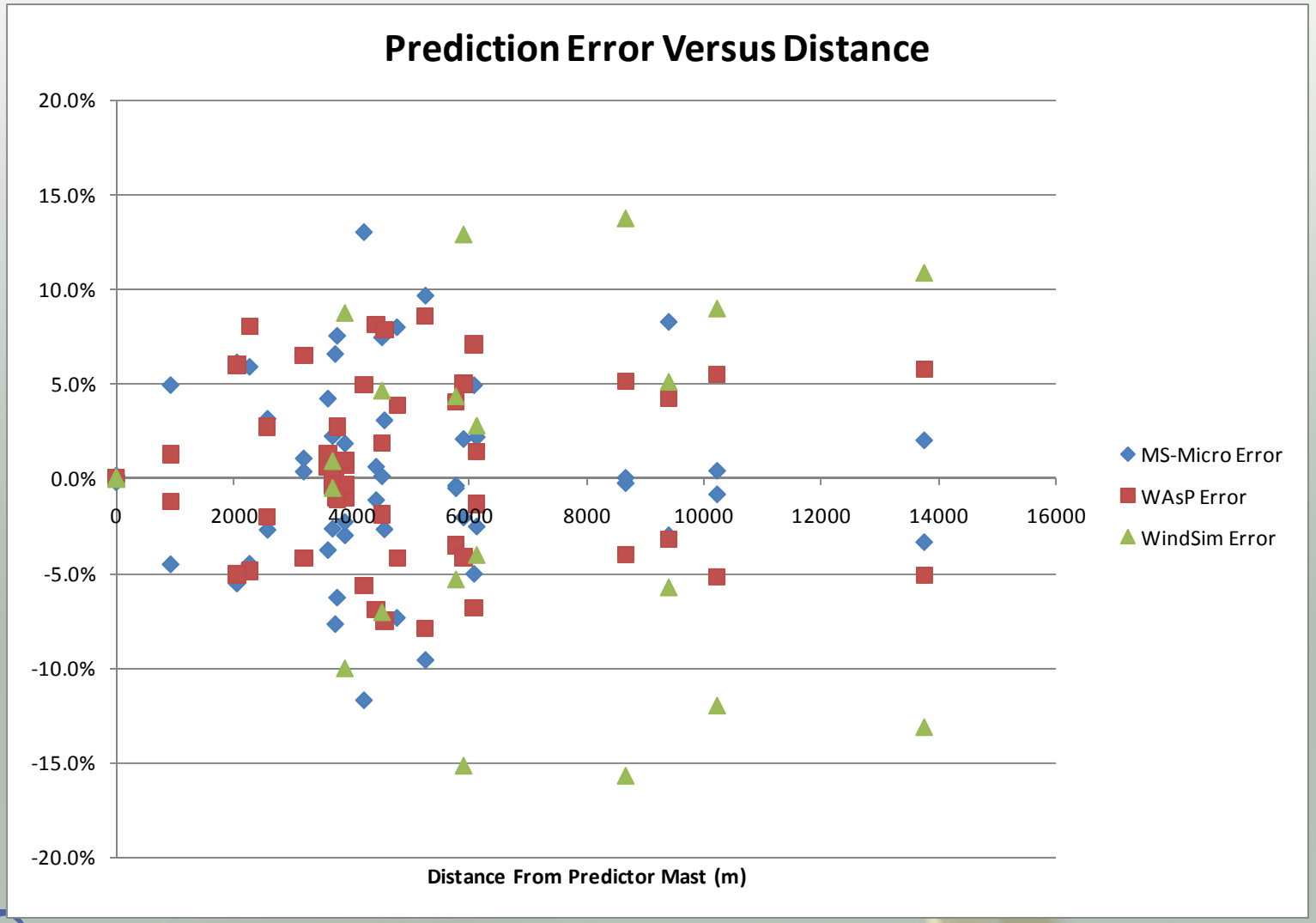
Chinook Wind

RIDGELINE ENERGY

What does error correlate to?

- Tells us something about how the models work
- We may be able to apply correction factors
- To examine error correlation, we re-ran the models with 1 tower predicting all other towers – the opposite of “leave one out”
- Compare error to distance, elevation change, upwind and downwind exposure change, and RIX

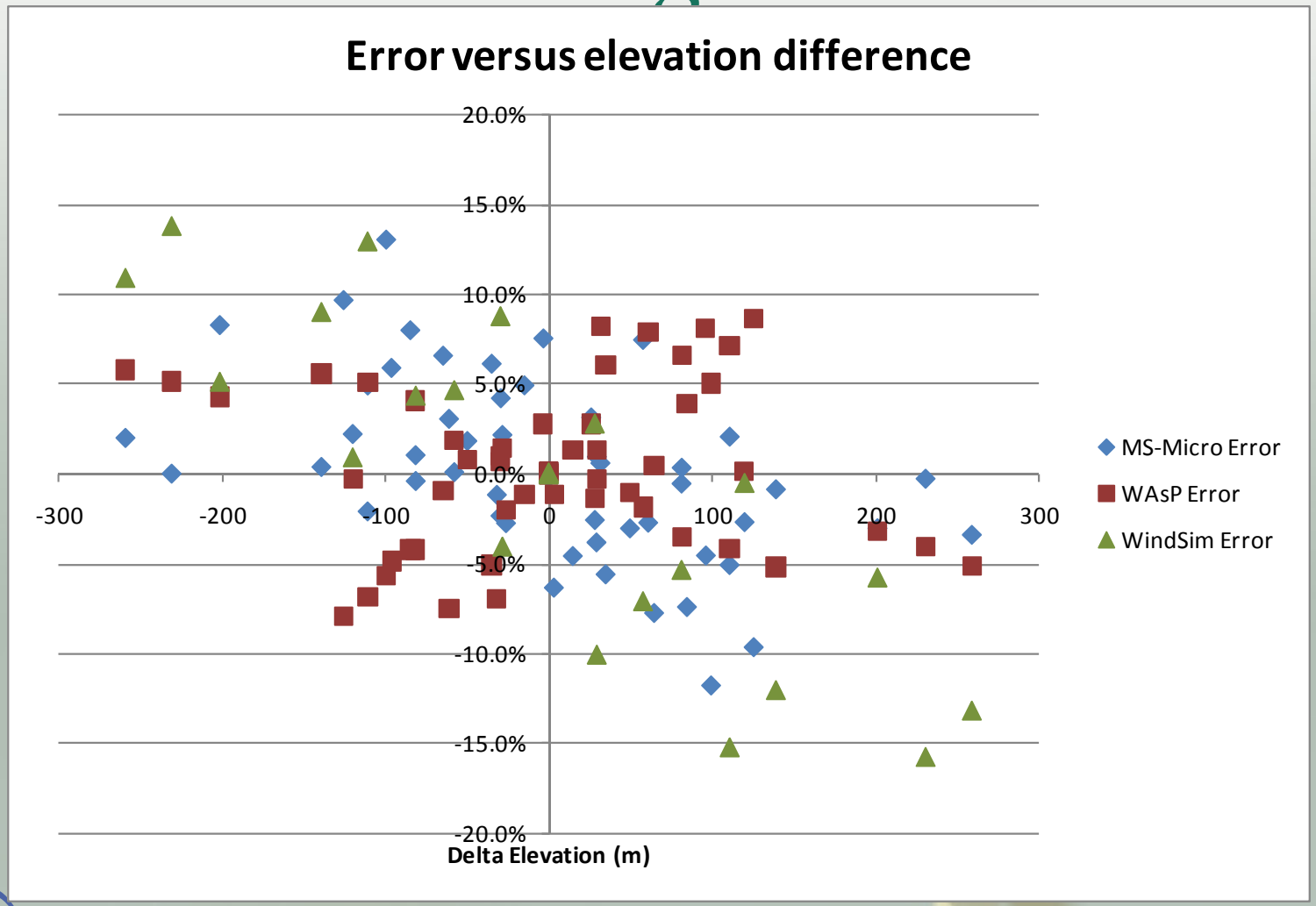
Is error correlated to distance?



Chinook Wind

RIDGELINE ENERGY

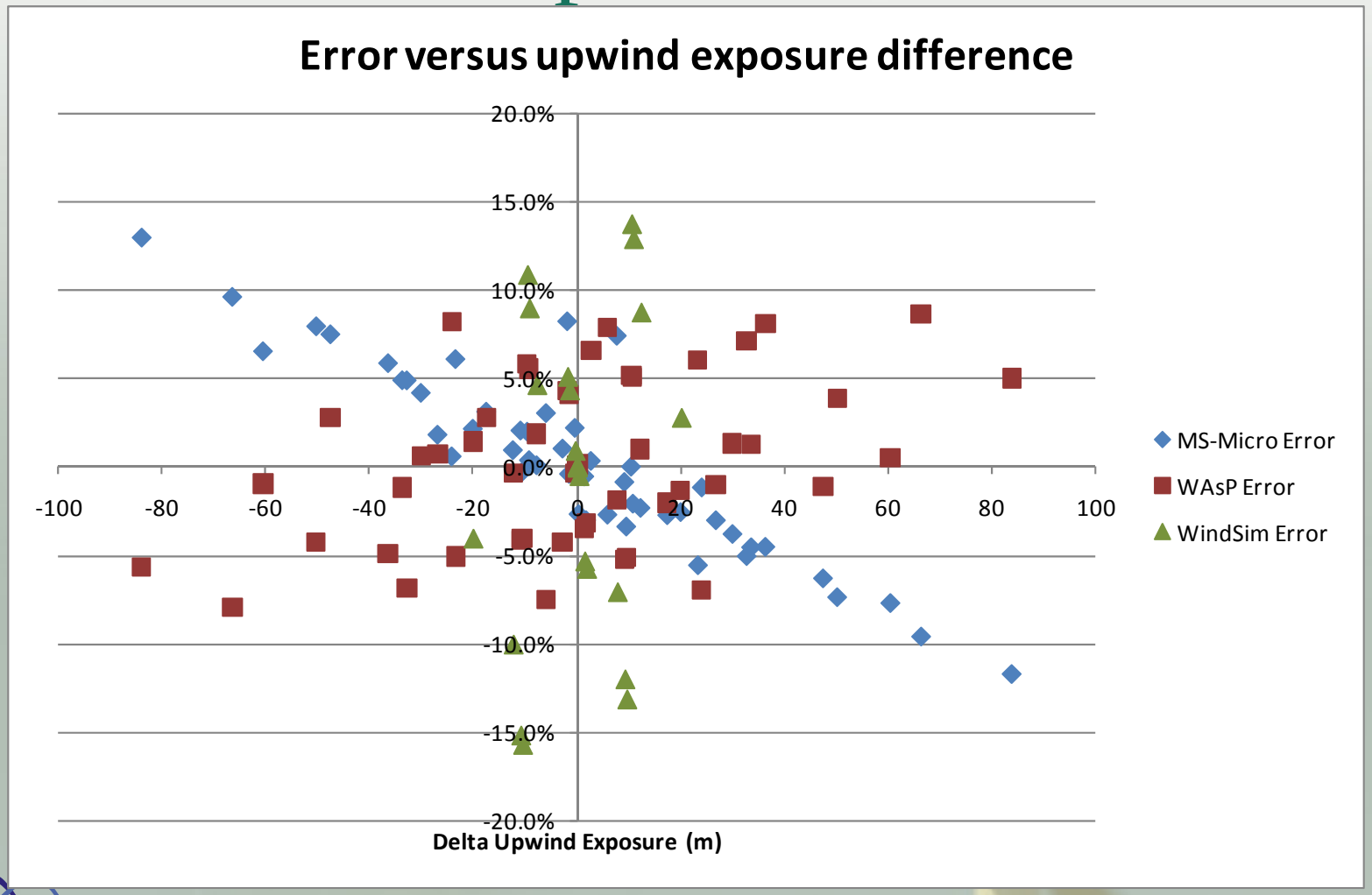
Is error correlated to elevation change?



Chinook Wind

RIDGELINE ENERGY

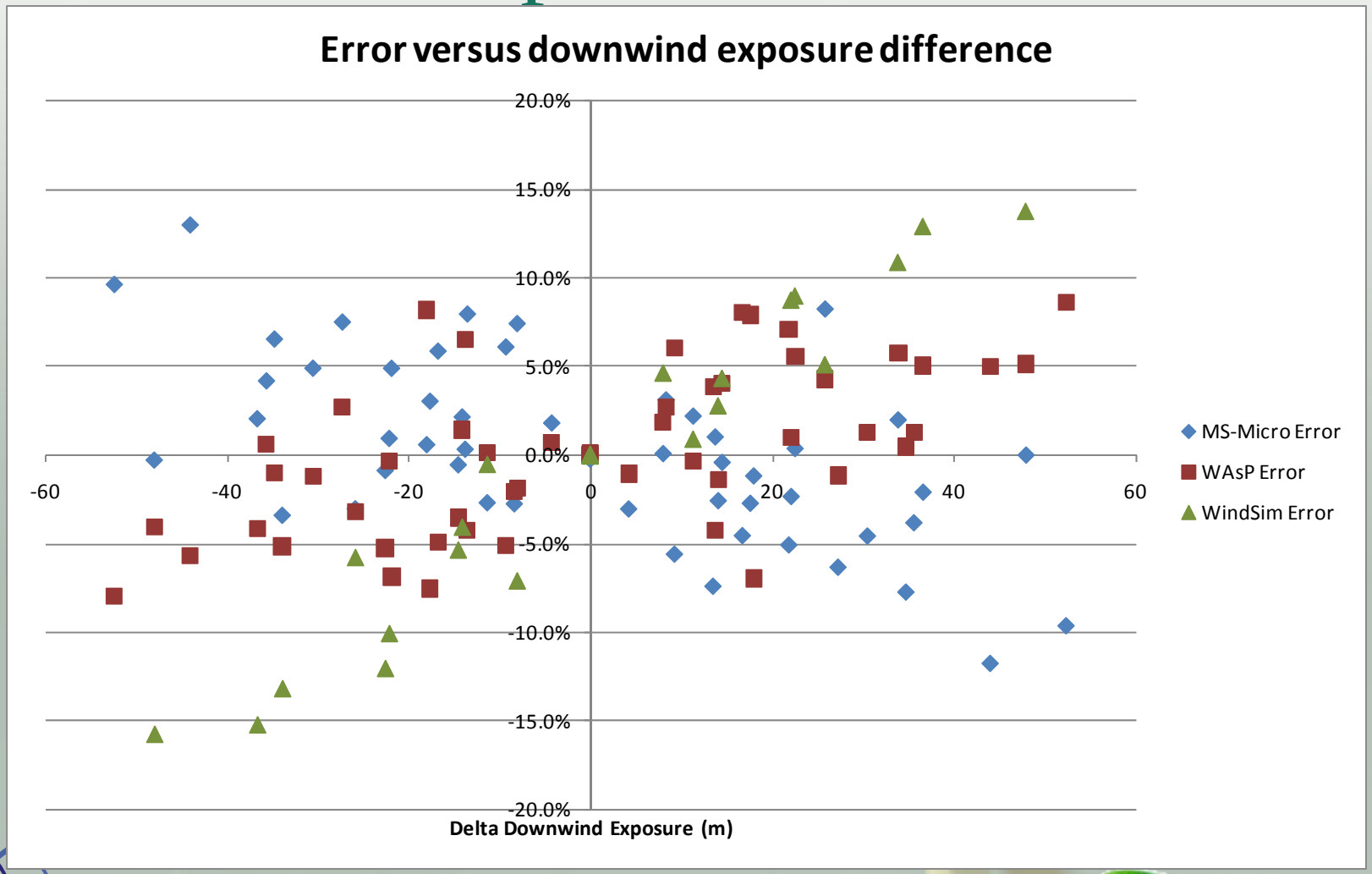
Is error correlated to upwind exposure?



Chinook Wind

RIDGELINE ENERGY

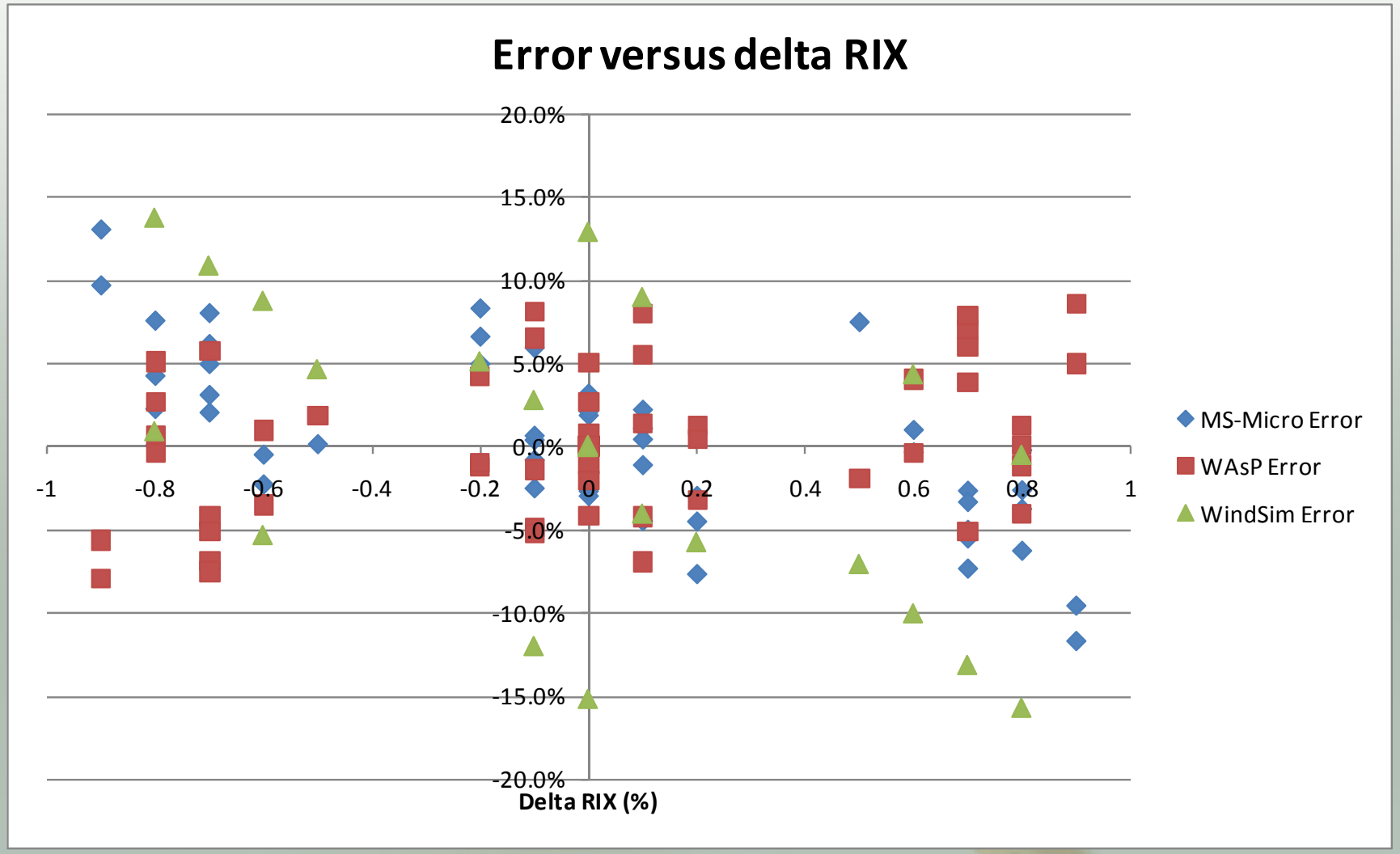
Is error correlated to downwind exposure?



Chinook Wind

RIDGELINE ENERGY

Is error correlated to delta RIX?



Chinook Wind

RIDGELINE ENERGY

What Do the Results Mean?

- The commercially available software performs reasonably well, but there is a possibility to have big errors
- Care is needed in designing a measurement campaign
- More met towers are better, in a wide variety of terrain
- Jack is onto something with his exposure-based model!

Acknowledgements

- Thanks to Ridgeline Energy for access to their sites and data
- Thanks to Nathaniel Vandal, Mike Burghart, and Regina Sweet for help with help with processing data and running models
- Thanks to Jack Kline for modeling the sites
- Thanks to Arne Gravdahl at WindSim for his excellent technical support