

Assessment of wind energy for Nevada using towers and mesoscale modeling

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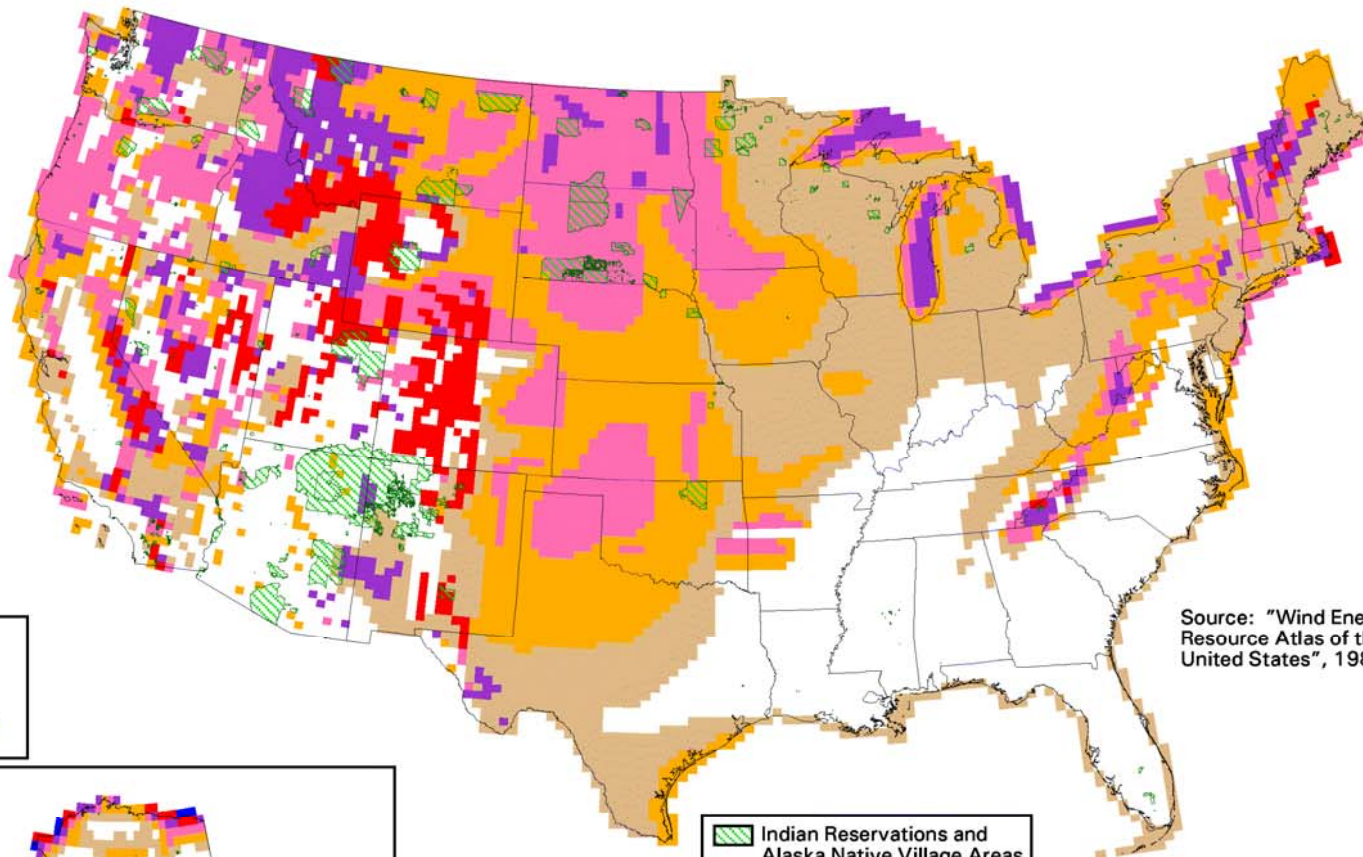
Background (I)

- Nevada imports virtually all energy
 - Nevada legislature mandates utilities (Nevada Power and Sierra Pacific companies) to produce 15% of energy by 2015 from renewable sources
 - Nevada is 21st state by the wind energy potential
 - Wind resource in Nevada is highly variable in time and space
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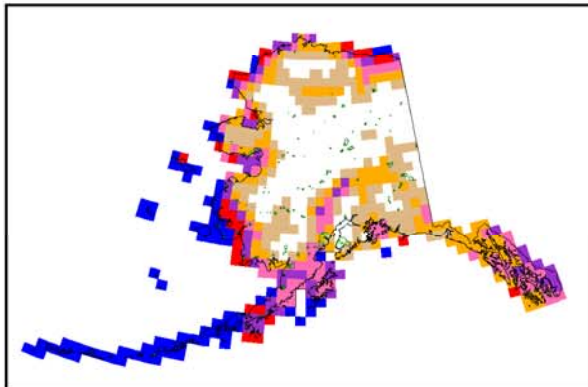
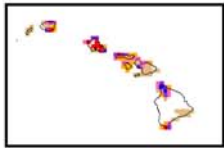
Background (II)

- Nevada's Congressional Delegation initiated assessment of Nevada's renewable energies.
 - Desert Research Institute of the Nevada System of Higher Education was funded through the Department of Energy – National Renewable Laboratory to estimate wind power density in Nevada using meteorological tower measurements and computer modeling.
 - Sierra Pacific Resources – industry partner.
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United States - Wind Resource Map



Source: "Wind Energy Resource Atlas of the United States", 1987



Indian Reservations and Alaska Native Village Areas

Wind Power Classification				
Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m ²	Wind Speed ^a at 50 m m/s	Wind Speed ^a at 50 m mph
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

^a Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory



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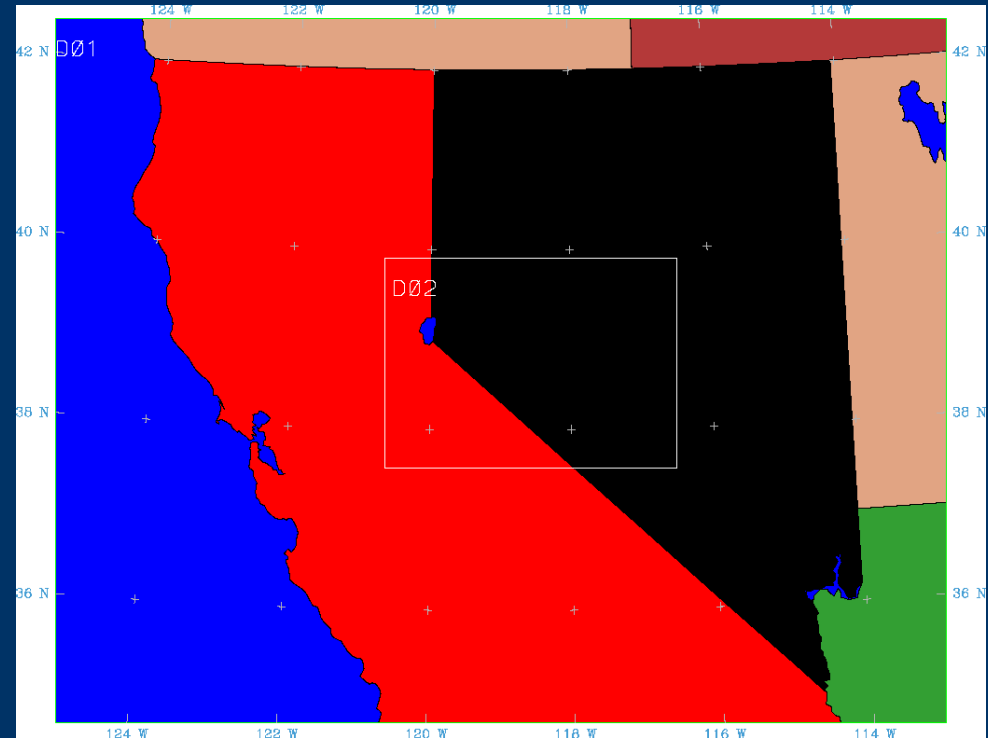
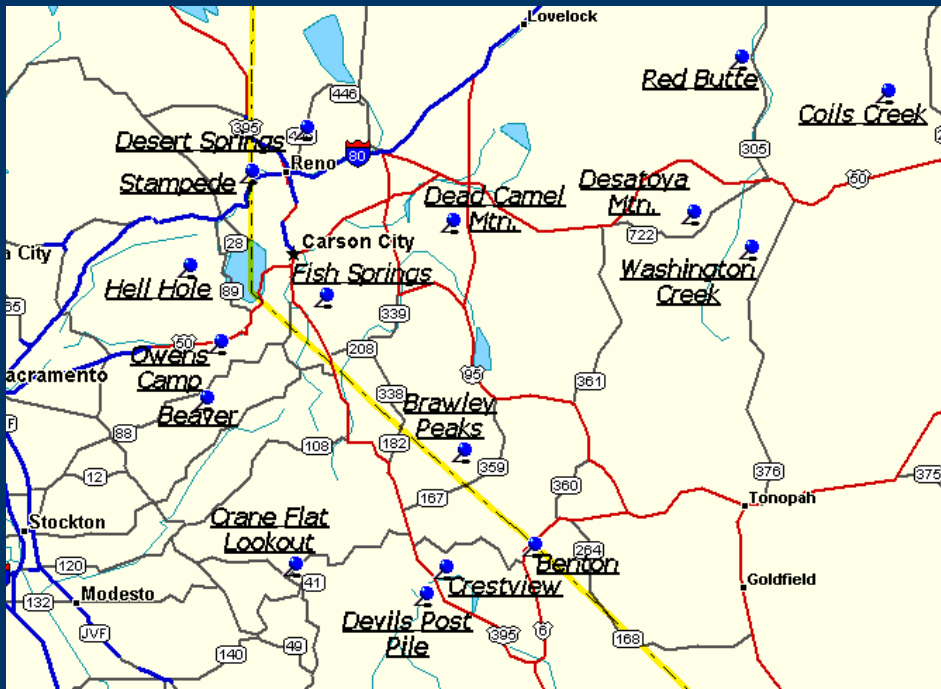
Reference – existing Wind Resource Map
(TrueWind/DOE NREL)

DRI Wind Energy Projects – DOE/NREL Funding

- (1) Nevada Wind Assessment

Analysis of 80 Remote Automated Weather Stations

Mesoscale modeling – annual cycle (2001/2002) with 9 and 3 km resolution over Nevada.

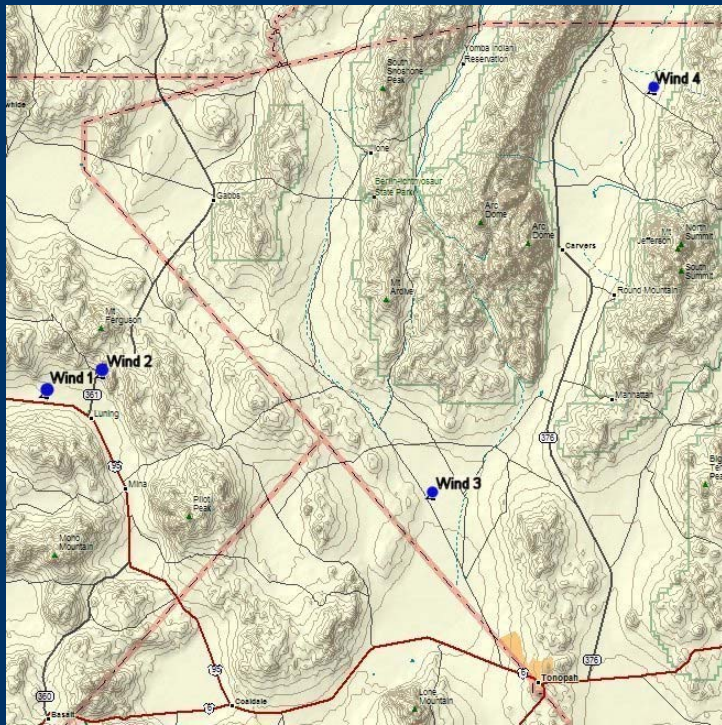


Period: Sep 2001 – Aug 2002

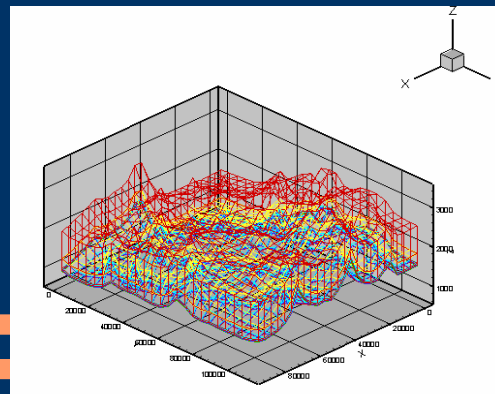
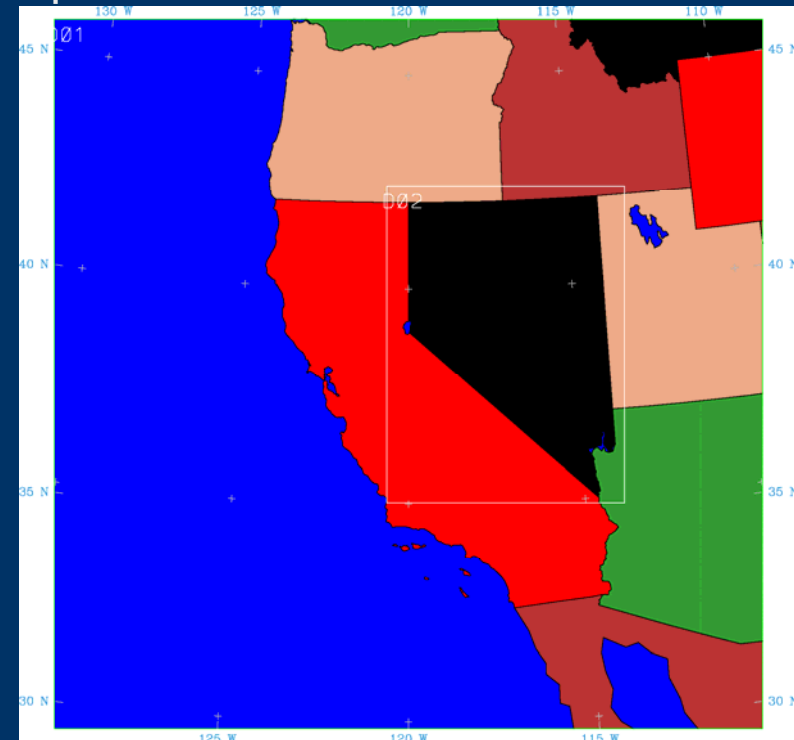
DRI Wind Energy Projects – DOE/NREL Funding

• (2) Nevada Wind Assessment (II)

(a) Four 50m wind towers installed in western Nevada near Tonopah



(b) Mesoscale modeling – annual cycle (2001/2022) with 2 km resolution over Nevada.- improving wind power density maps



(c) UNLV – Microscale modeling

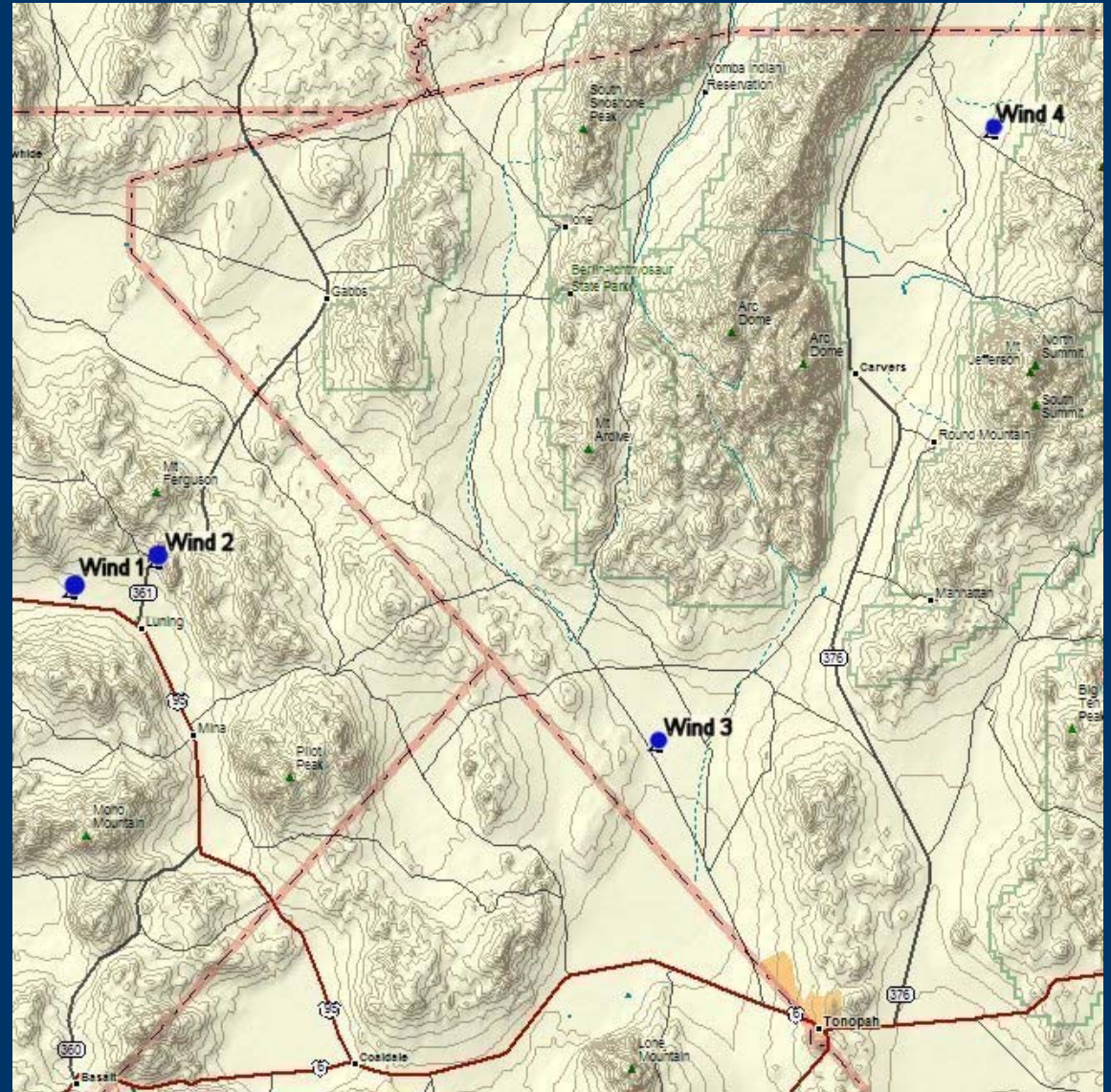
(D. Pepper)

Period: Aug 2003 – July 2004

Meteorological towers

Topographical map of the area around the four 50 m towers near Tonopah, Nevada.

Wind speed measurements are at five levels (10, 20, 30, 40, and 50m)



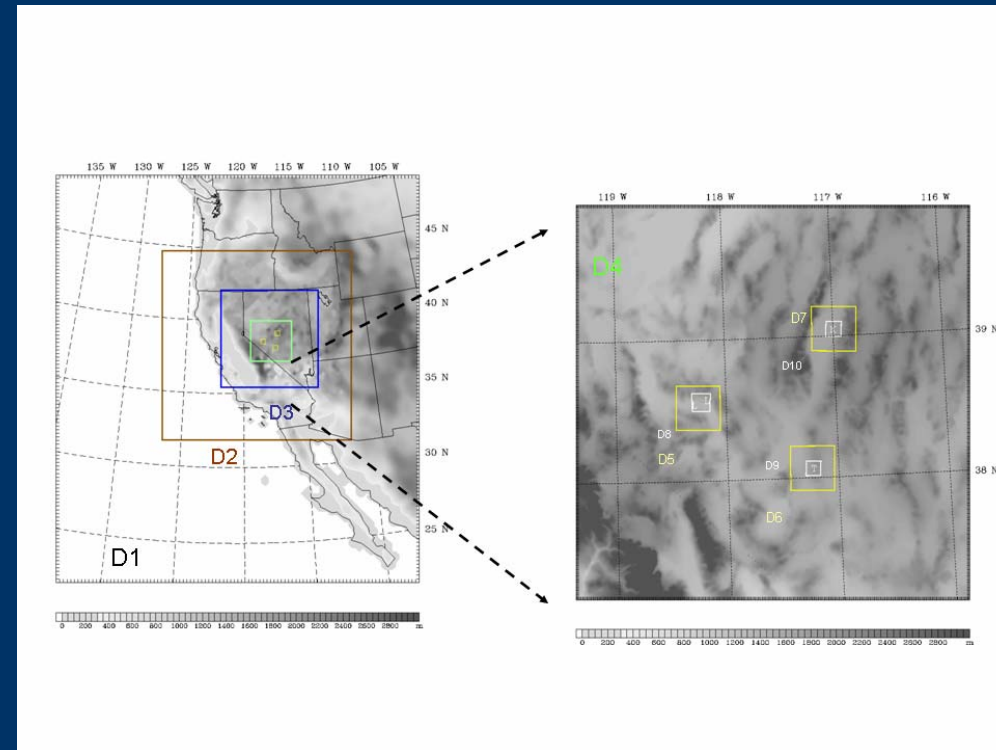
*Use: Direct wind speed measurements at hub and blade heights;
model evaluation*

DRI Wind Energy Projects – DOE/NREL Funding

- (3) Tall wind tower deployment

(a) A 80m communication tower equipped with standard and sonic anemometers at three levels near Tonopah.

(b) Mesoscale modeling – b1) Turbulence measurements and modeling; b2) Downscaling of wind forecasts from 30 km to several hundred meters resolution.



DRI Wind Energy Projects – DOE/NREL Funding

(4a) Wind towers in southern Nevada

Proposal approved, but funding is not available yet.

- One 120 m wind tower (Searchlight)
 - Four 50m towers (Bullfrog Mountain, Amargosa Valley, Indian Springs, and Goodsprings)
 - Mesoscale modeling – Model evaluation: winds, turbulence, downscaling
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DRI Wind Energy Projects – DOE/NREL Funding

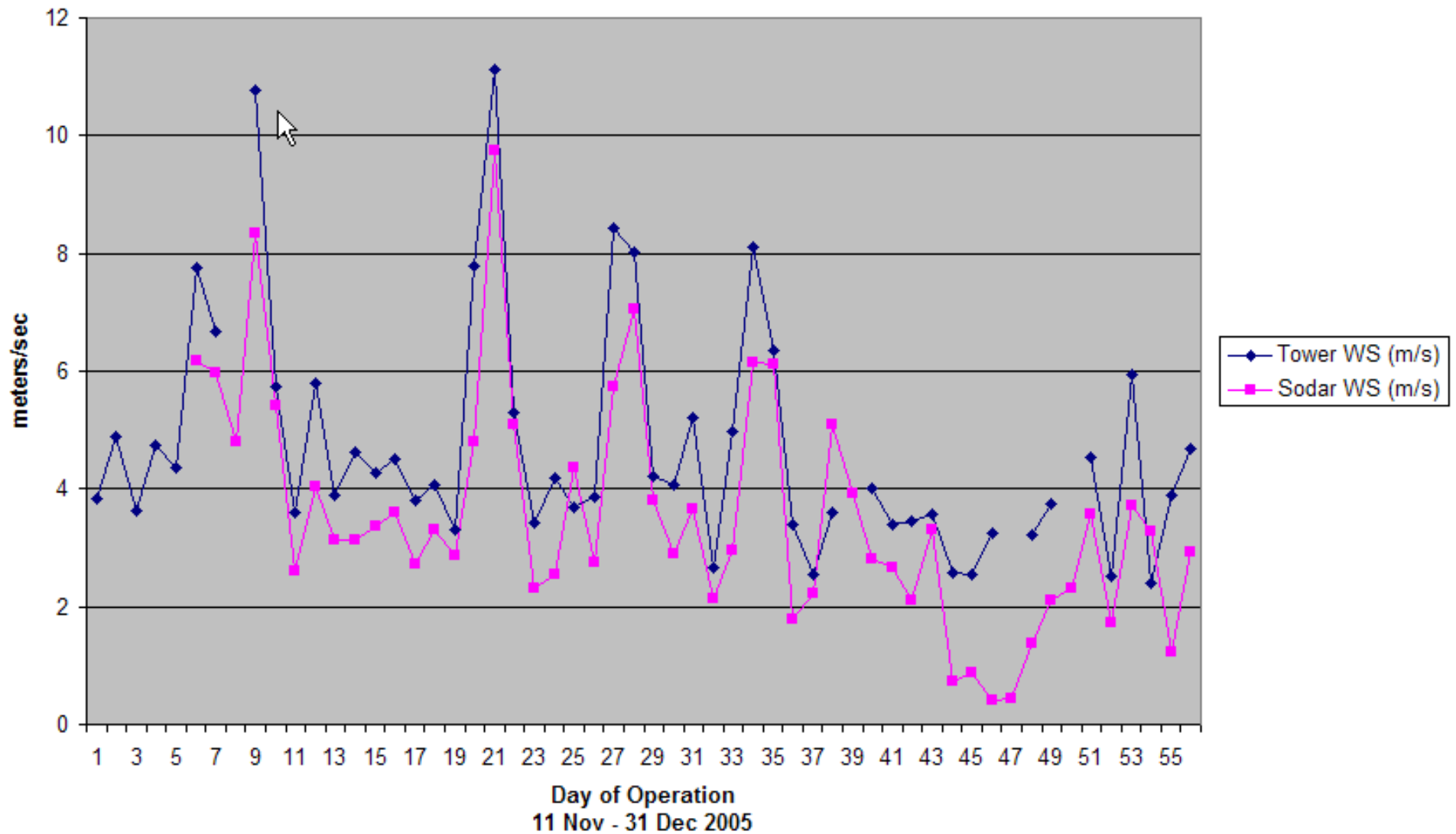
(4b) Adaptive-grid OMEGA modeling

Proposal approved, but funding is not available yet.

- DRI, UNLV, and Meso Inc.
 - High-resolution modeling with variable resolution; highest resolution in the areas of interest.
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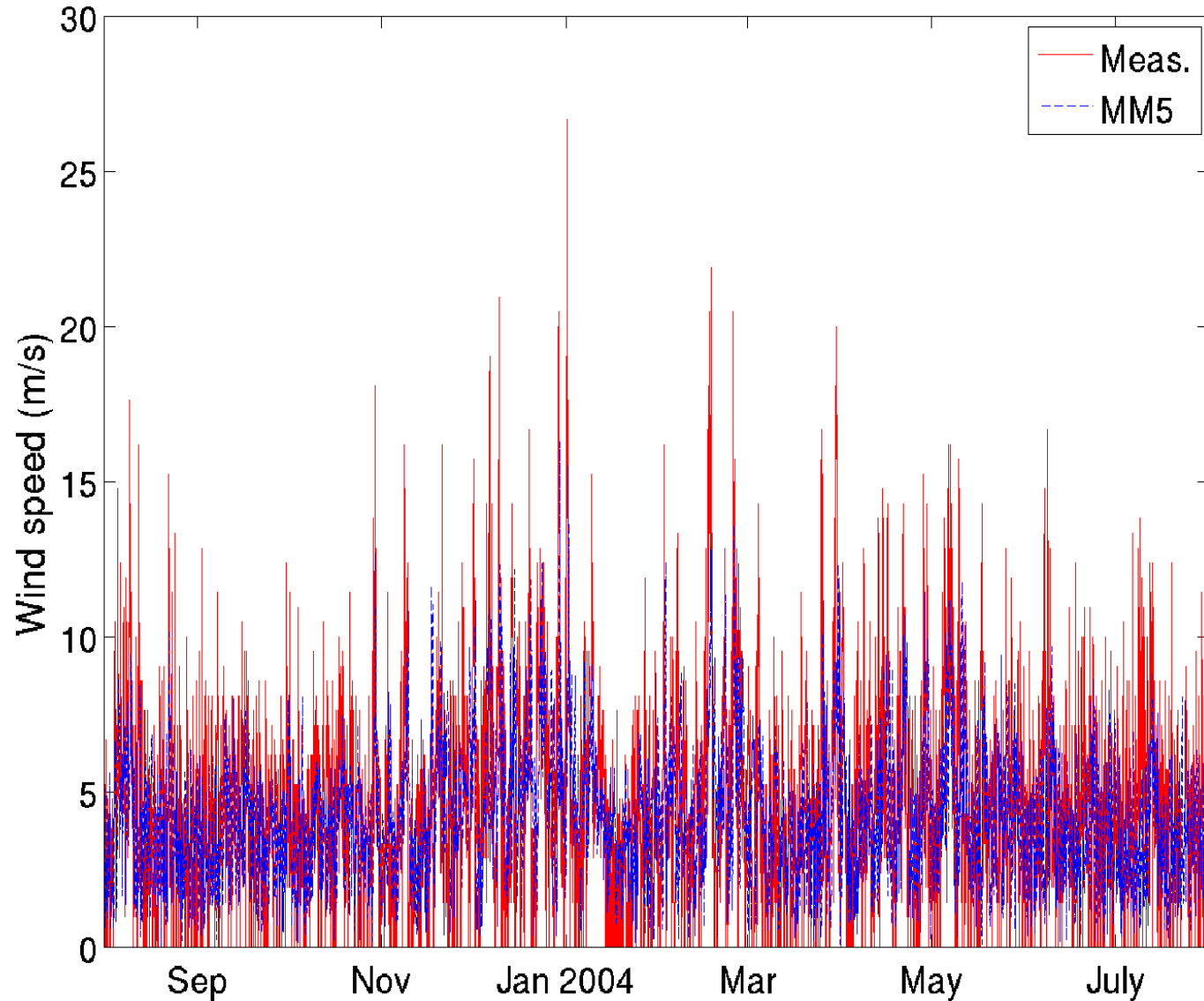
Comparison: SODAR vs. tower data at 50 m tower - Tonopah

Wind Speeds at 50 meters
Tonopah 24NW



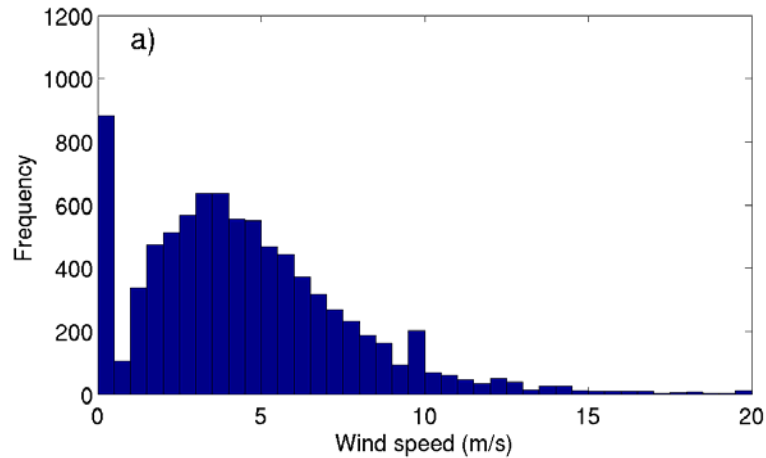
Model evaluation – surface stations

Comparison between MM5-simulated and RAWS-measured wind speed for the Brawley Peaks station.

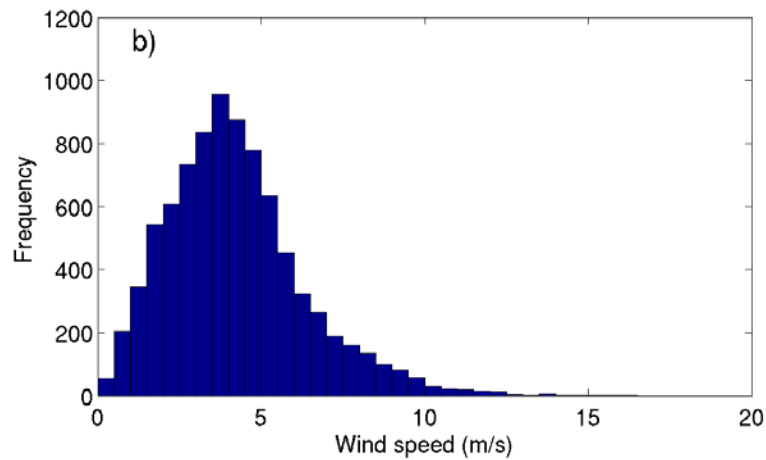


Model evaluation – surface stations

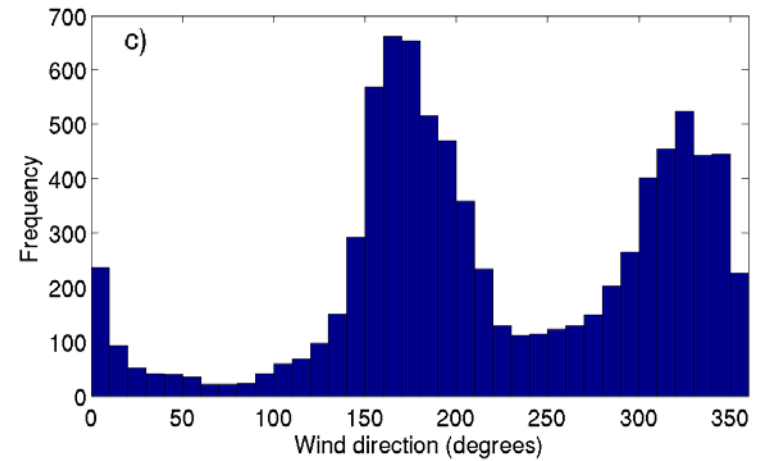
RAWS



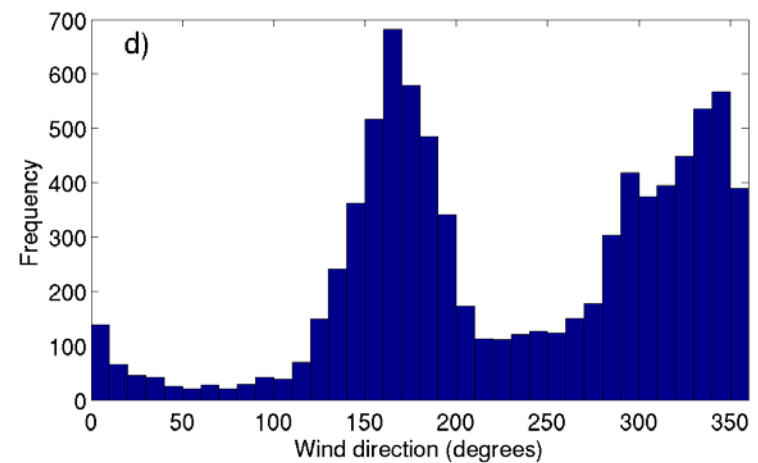
MM5



RAWS



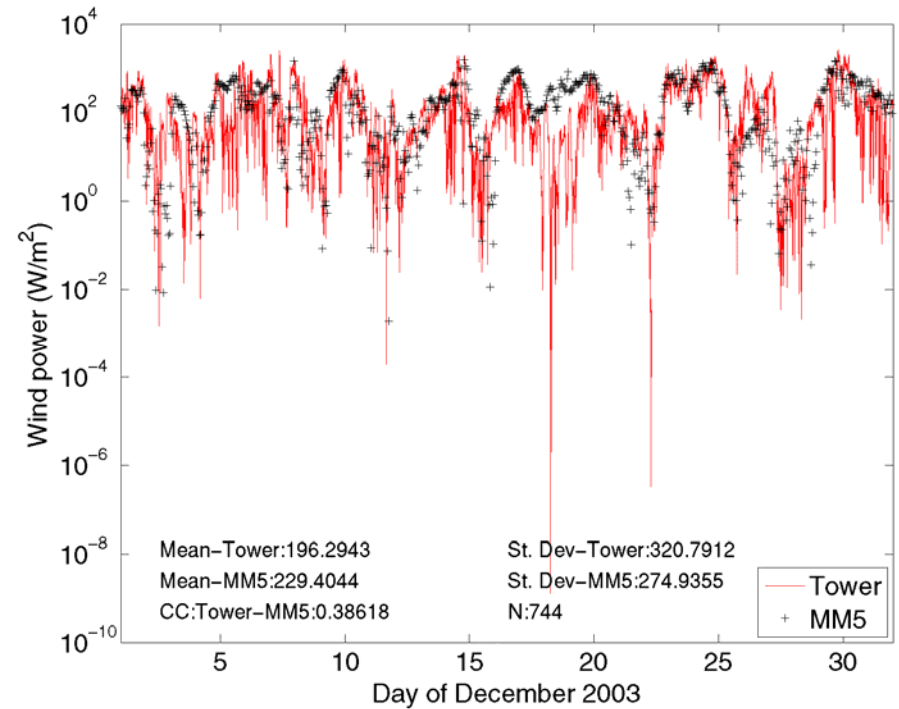
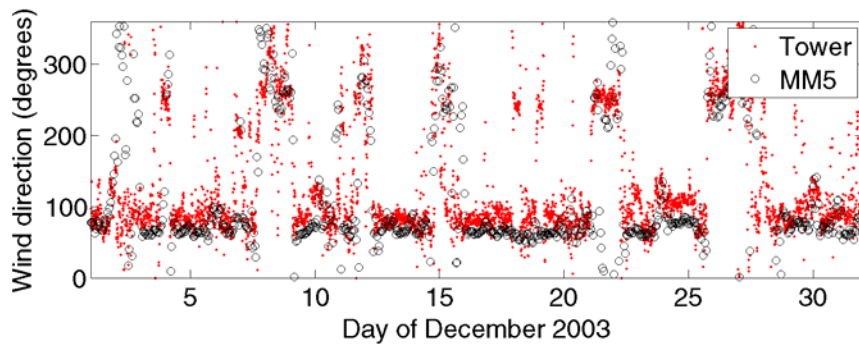
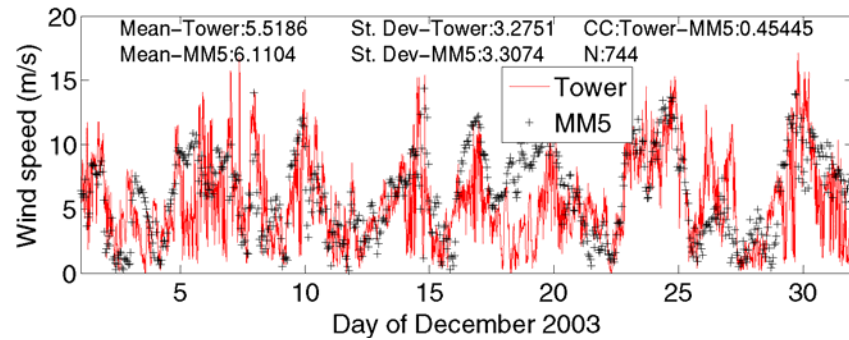
MM5



Histograms of wind speed (left) and wind direction (right) at the Brawley Peaks station for the annual period (1 August 2003 – 31 July 2004).

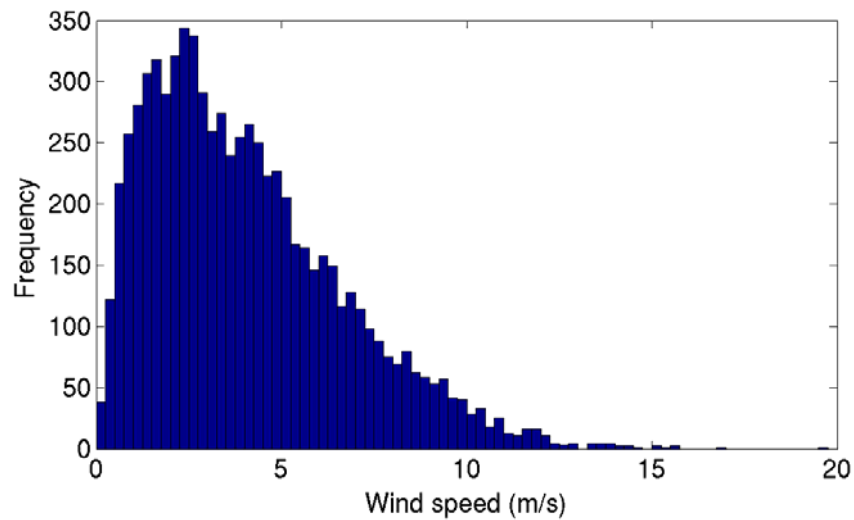
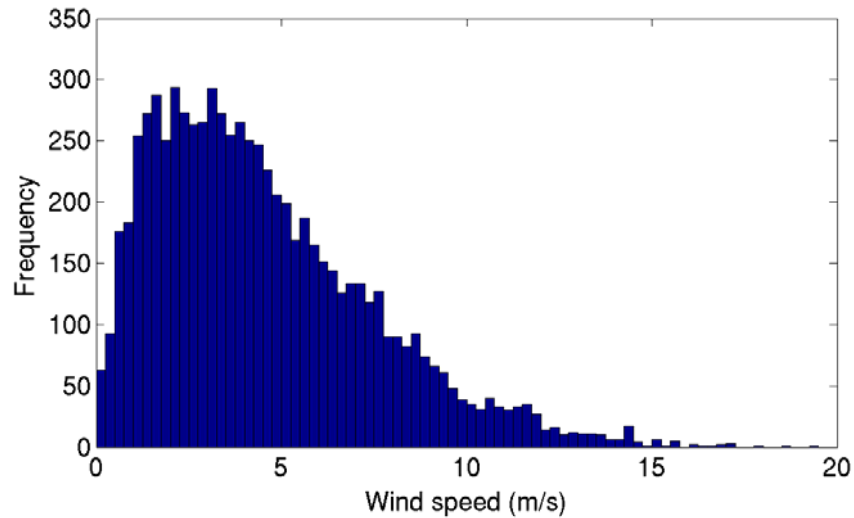
Model evaluation – 50 m tower

Model evaluation – wind power density at 50 m (tower)



Comparison between MM5-simulated and tower wind speed and direction at 50 m (left panels) and corresponding wind power density (W/m^2) (right panel) for the Luning-7W tower for December 2003.

Model evaluation – 50 m tower

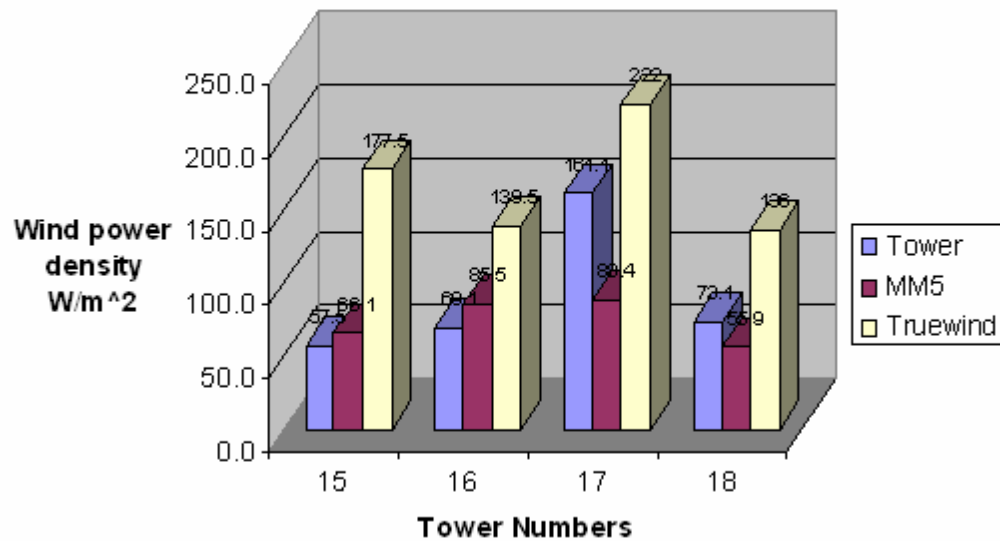


Measured

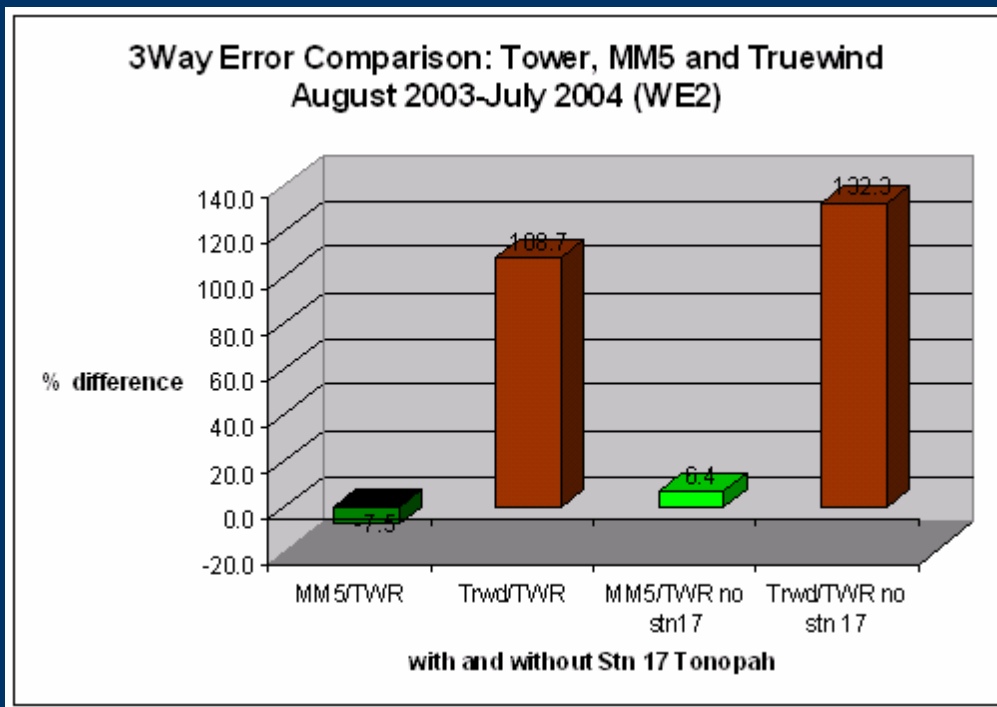
Comparison between the measured and MM5-simulated wind speed histograms for the Luning 7W tower at 50 m for the period from August 2003 to July 2004.

MM5

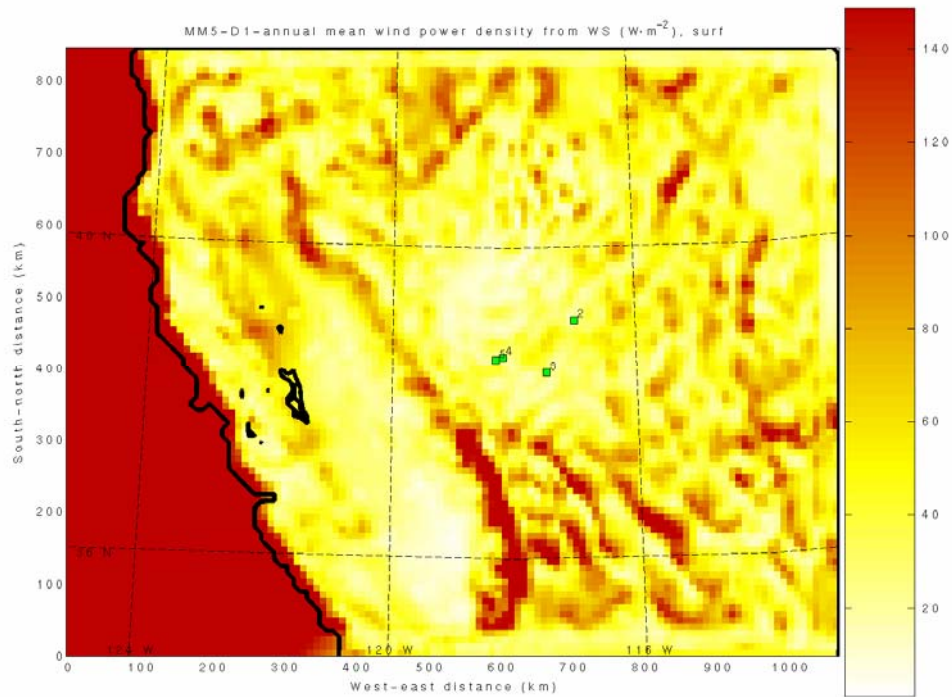
3 way Wpd Comparison of MM5, Truewind and Tower Data, Aug 2003--Jul 2004 (WE2)



Three-way comparison of the wind power density at the four tower locations computed from the tower data, atmospheric model results for the period from August 2003 to July 2004, and the TrueWind estimates.



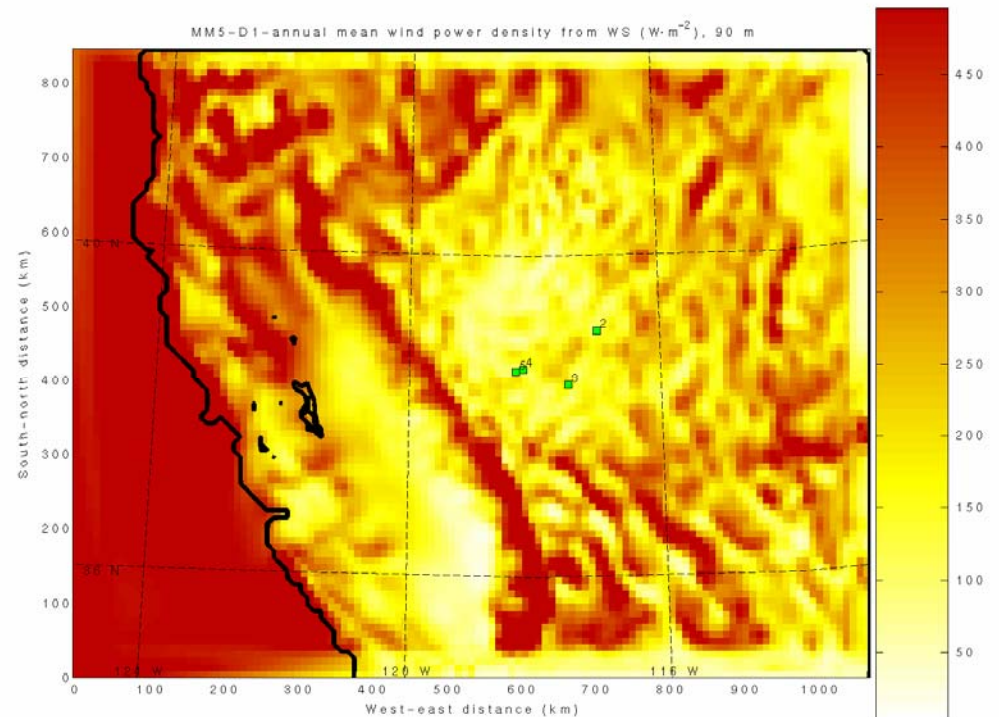
Percentage differences of the wind power density from MM5 (green) and TrueWind (brown) versus the towers with (left-hand side) and without (right-hand side) the Tonopah tower location.



MM5 - Wind Power Density (W/m^2) – Annual mesoscale simulations

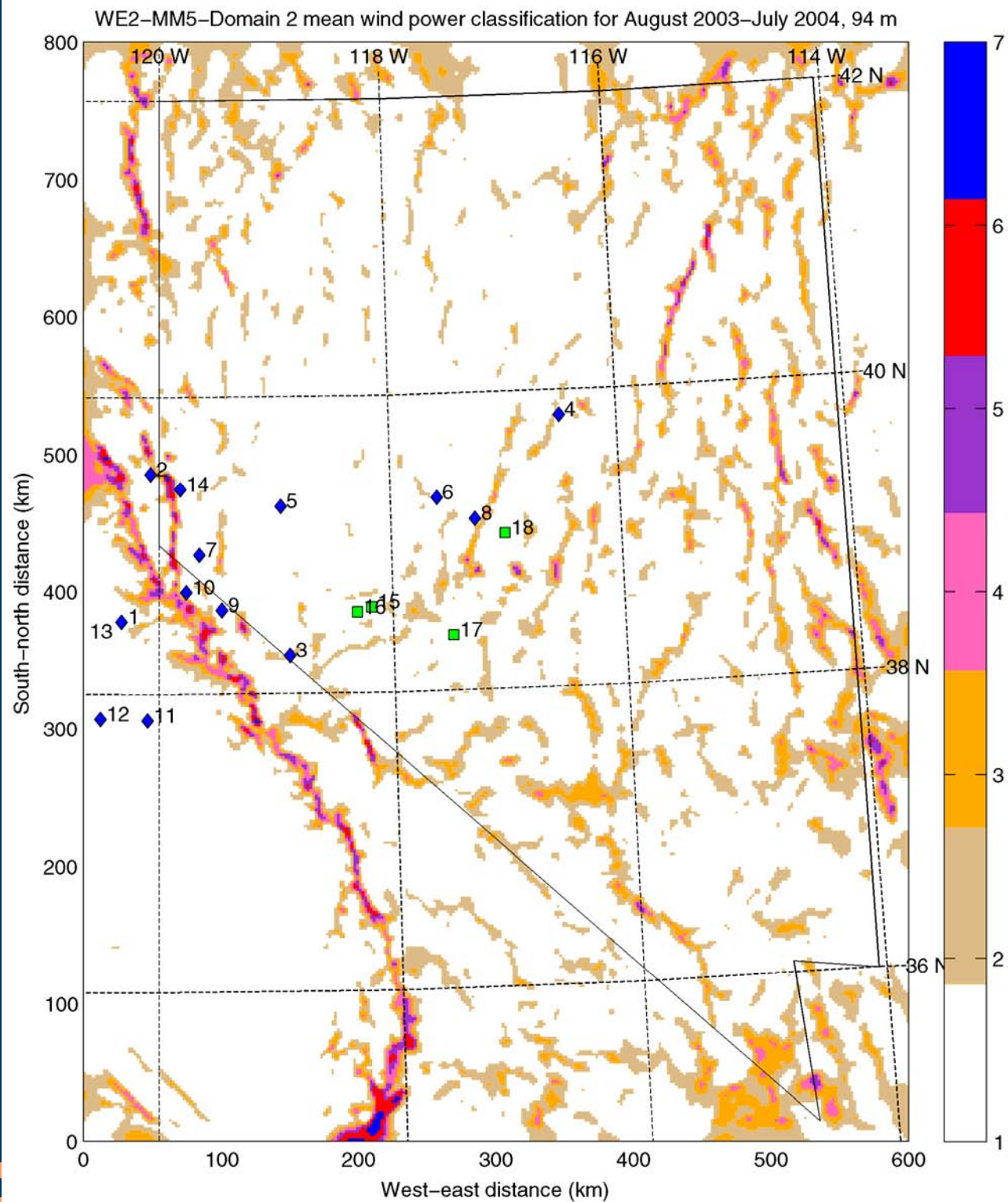
90m

10m

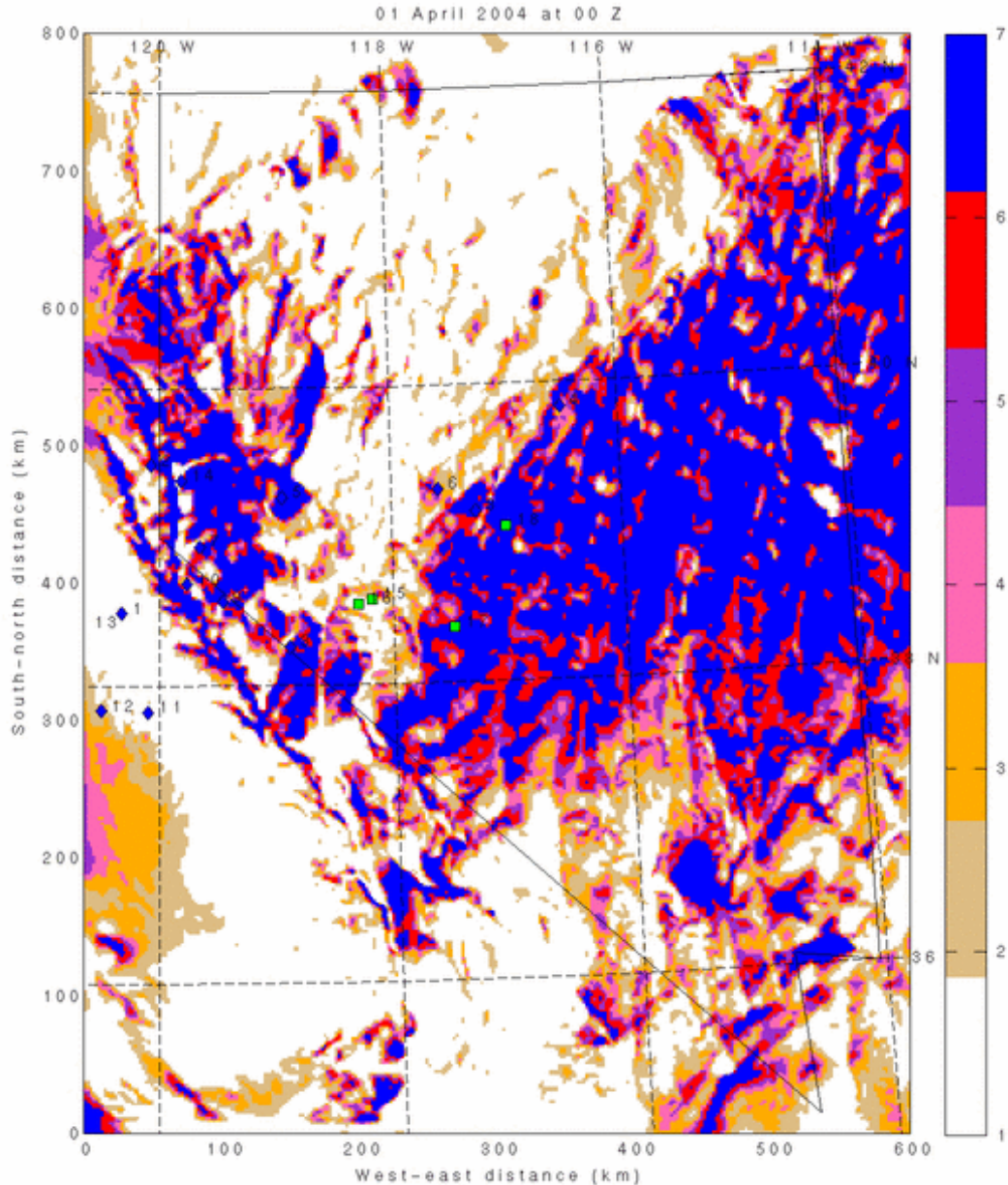


Annual mean wind power density map (classes) for Nevada for 2003/2004 cycle at 90m computed from the numerical mesoscale model results

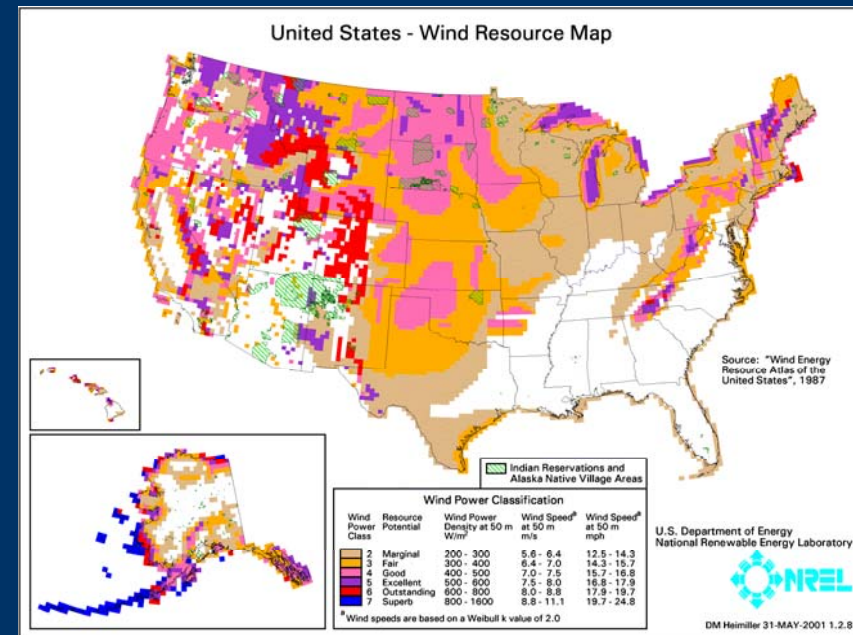
- 2 - Marginal
- 3 - Fair
- 4 - Good
- 5 - Excellent
- 6 - Outstanding
- 7 - Superb



Current and planned modeling – wind variability, winds aloft, short-term and long-term forecasting

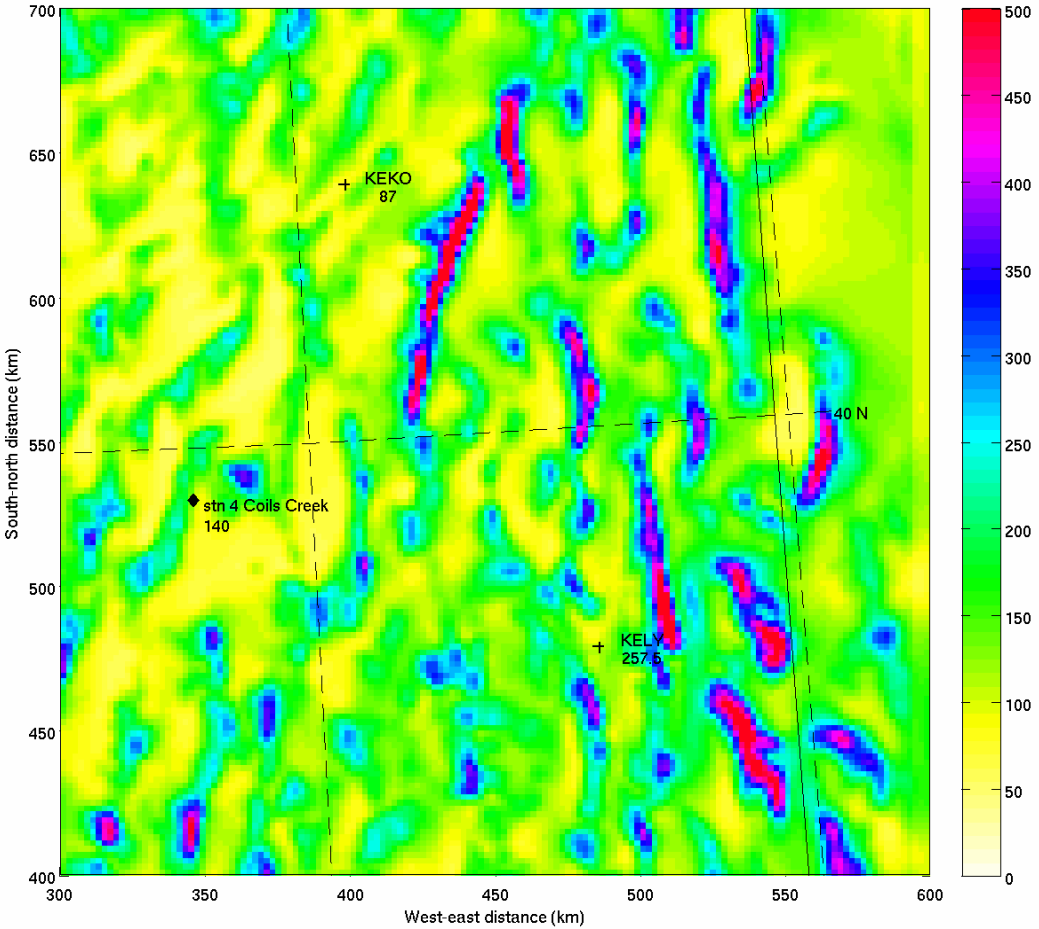


Animation – wind power density class for every day in April 2004 at 4am and 4pm local time

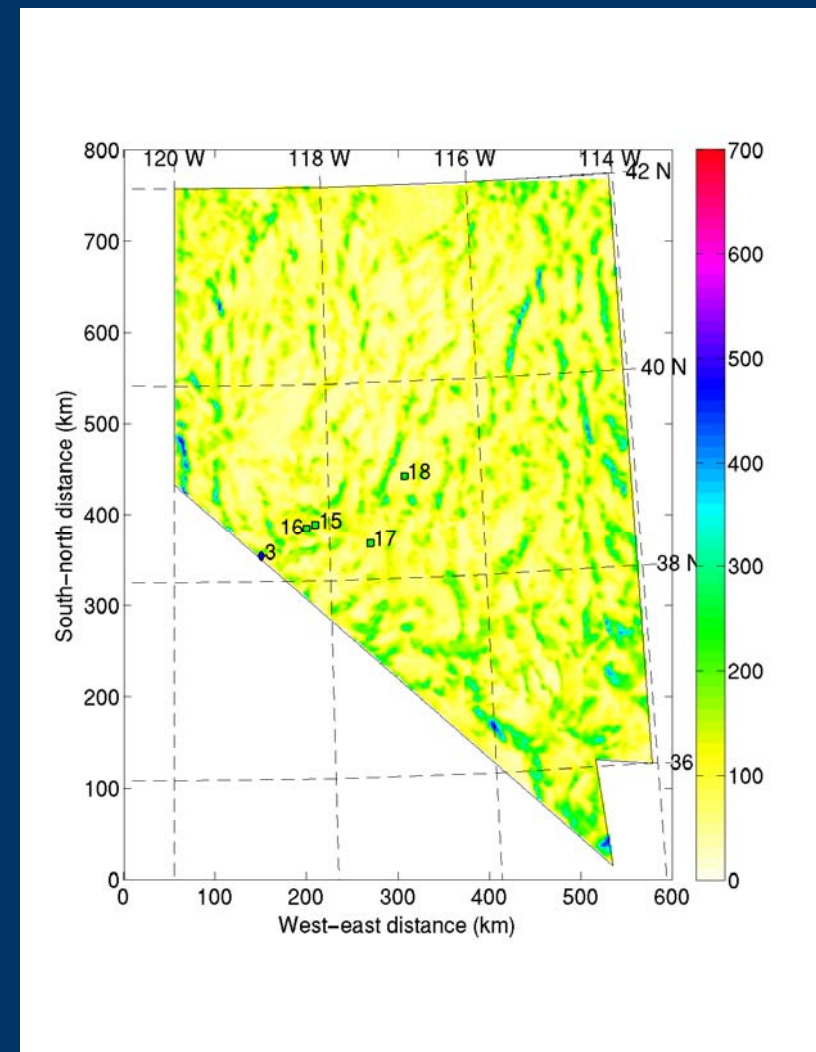
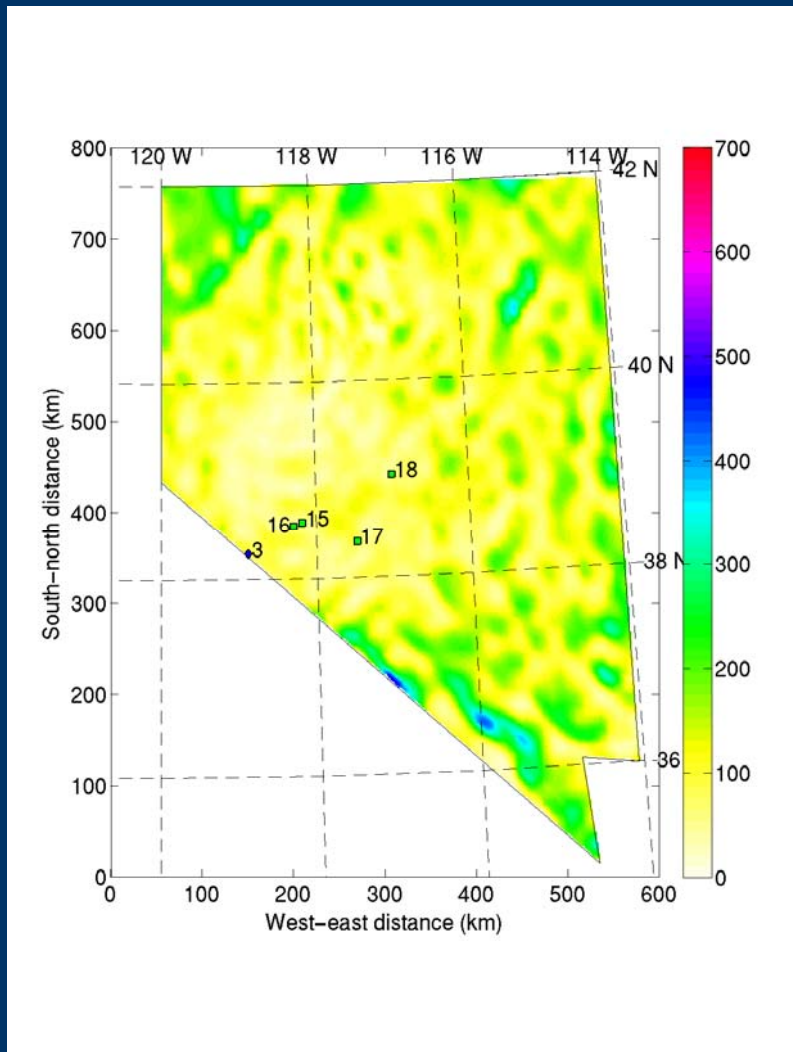


Reference – existing Wind Resource Map

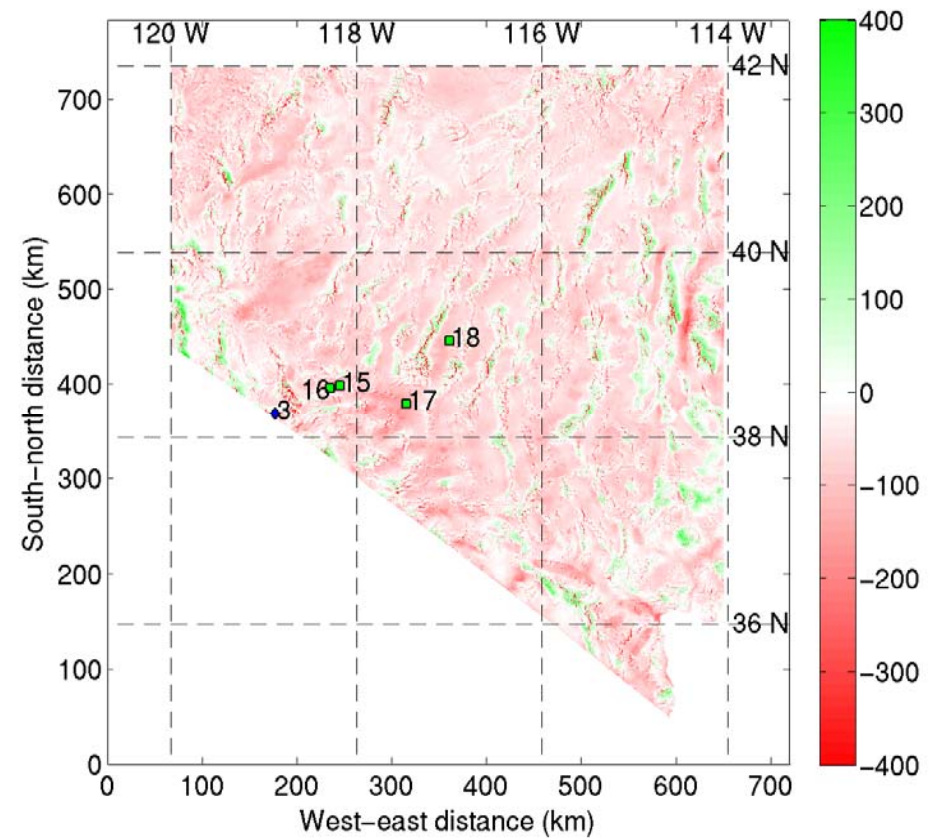
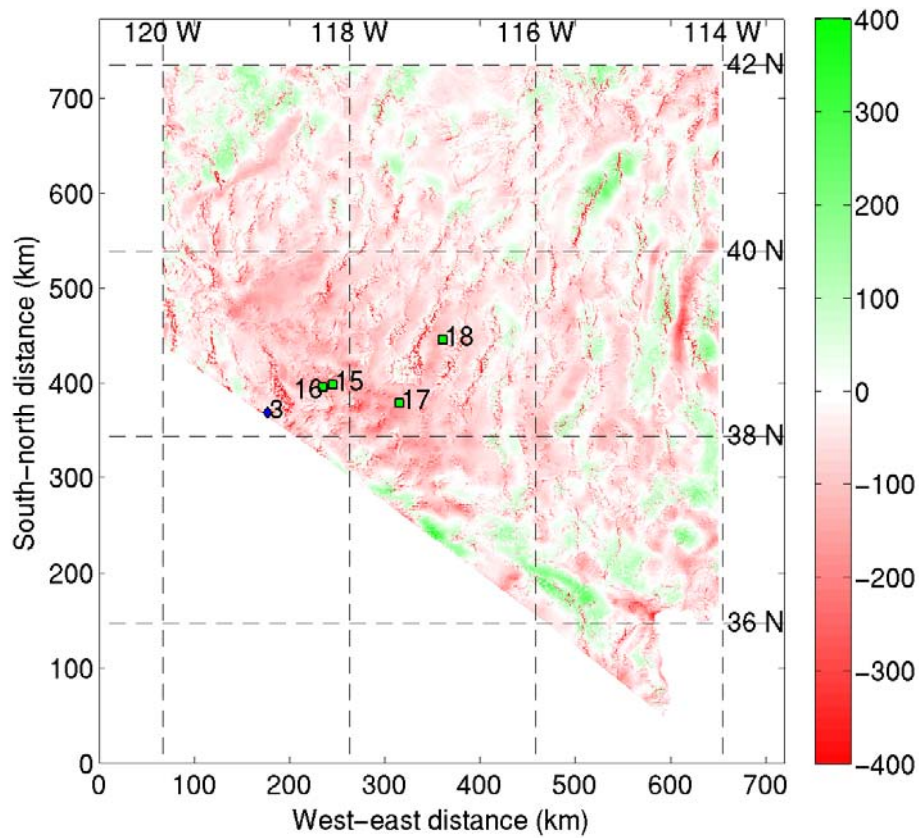
Average wind power (in W/m^2) for level 5 (94 m), August 2003-July 2004
Values near stations are averaged values from Truewind data



Annual wind power density (W/m^2) estimated from the numerical mesoscale model results for eastern Nevada and single point True Wind map estimates.



Wind power density (W/m^2) over Nevada at 50 m as estimated from the MM5 simulations from 1 September 2001 through 31 August 2002 (WE1_01_02) (left panel) and from 1 August 2003 through 31 July 2004 (WE2_03_04) (right panel).



Differences in the wind power density (W/m^2) between the annual cycle of MM5 simulations for 2001/2002 (left panel) and 2003/2004 (right panel) with the TrueWind results over Nevada at 50 m.

CONCLUSIONS

- The MM5 results compared well with the tower data
- The model results for both annual cycles show similar results
- Greatest wind power density simulated over the Sierra Nevadas and mountainous regions
- Central Nevada characterized by lower wind power density
- TrueWind generally shows higher values for wind power density than MM5
 - TrueWind is lower than MM5 over the mountains

The results of this study suggest that the synthesis of the data from the network of tower observations and high-resolution mesoscale modeling is a crucial tool for assessing the wind power density in Nevada and more generally other topographically developed areas. Future efforts should also be directed at obtaining data from additional tower networks and at higher elevations as well as evaluating models to predict winds and turbulence at blade heights for mid-size and large wind turbines.

Questions?

