Interannual-to-Decadal Variability of Wind Power Density over The Continental US: Sensitivity to Model Resolution and Teleconnections

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Introduction

What is the goal of this research?

- Explore the effect modeling at varying resolutions has upon wind power density
- See which resolutions are necessary to capture topographical features
- Increase predictive skill of wind power density variability over a variety of time scales (long and short)
- Determine if variability is correlated with teleconnections

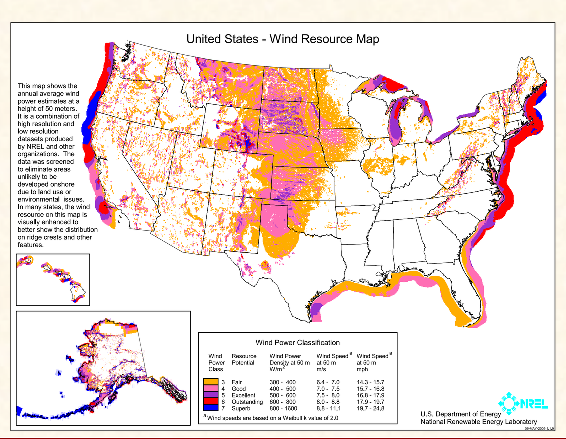
Why is this research necessary?

- Adoption of wind power is currently slower than originally expected, partially due to variability risk
- Interannual variability of power generation can be as high as 38% (Wan NREL 2012)
- Important for a wind farm to initiate on a good year to minimize early start-up costs
- Lack of predictability makes wind power more expensive
- Using numerical modeling for prediction allows forecasting at areas with no existing data record (airports, ASOS stations, etc.)

Methodology

The wind power density is organized by bin into a "class strength." NREL has bins based upon wind power density at 50 meters as follows. Using the same basic power laws as previously discussed, new classes for wind power density were extrapolated to 80 meters:

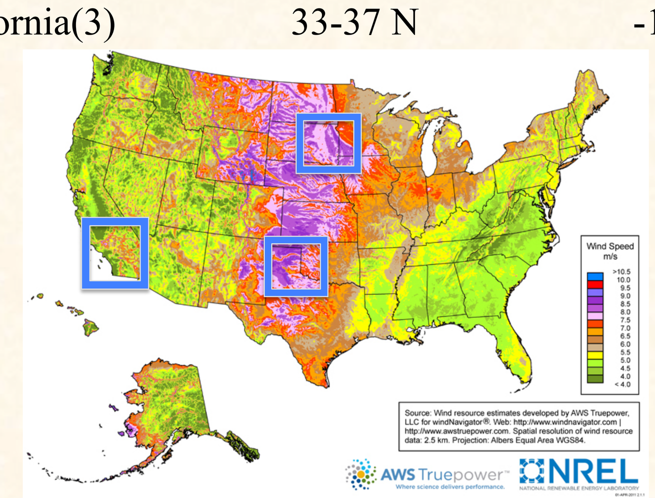
Class	Density (50 m)	Density (80 m)
1	0-200	0-244
2	200-300	244-366
3	300-400	366-488
4	400-500	488-610
5	500-600	610-732
6	600-800	732-976
7	>800	>976



Regions

This current study focuses on three main regions, each divided into 4° latitude by 6° longitude sections:

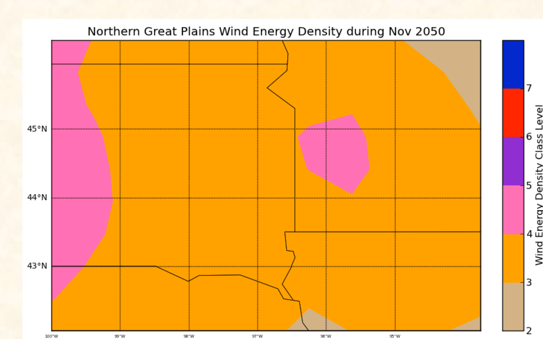
Region	Latitude	Longitude
N Great Plains(1)	42-46 N	-100 to -94
S Great Plains(2)	33-37 N	-104 to -98
S California(3)	33-37 N	-121 to -115



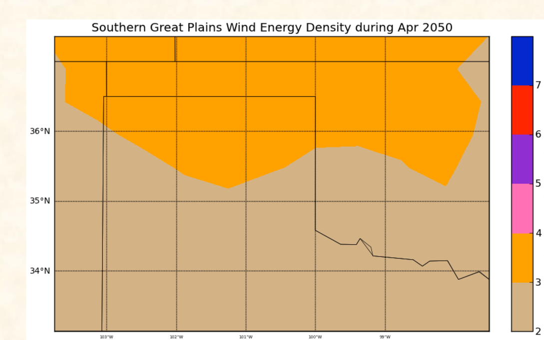
CCSM Results

Results from the CCSM (Community Climate System Model) (40.007b) for the years 2050-2051 for future climate assessment are shown here. With a model resolution of 62.75 km, topographical features are not evident, especially in California. This indicates the CCSM resolution is too small for accurate wind power density assessment.

NGP



SGP



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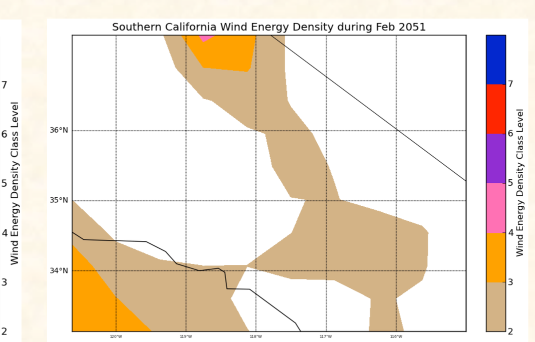
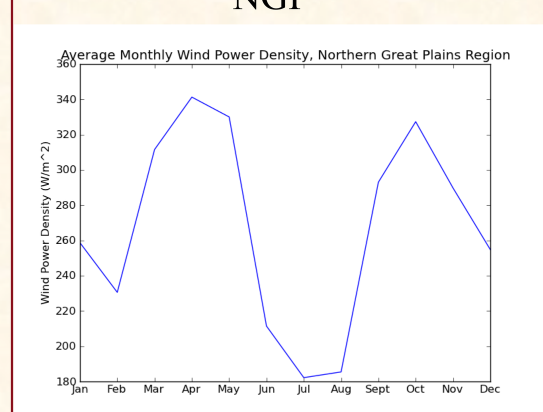


NARR Intra-Annual Averages

Based upon a regional average of all NARR (North American Regional Reanalysis) data points, all three regions have peak wind power density in April and a minimum in July/August. The Northern Great Plains had a secondary peak during October that wasn't as present in the other two regions.

NGP



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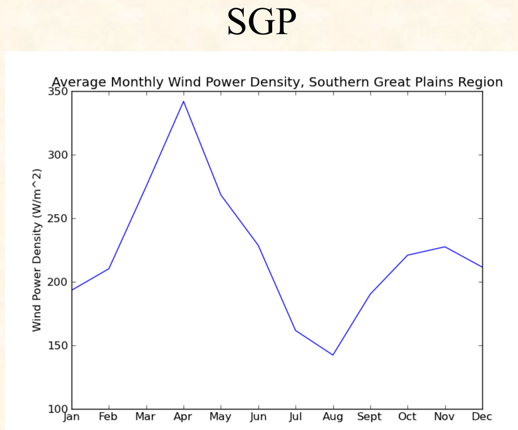

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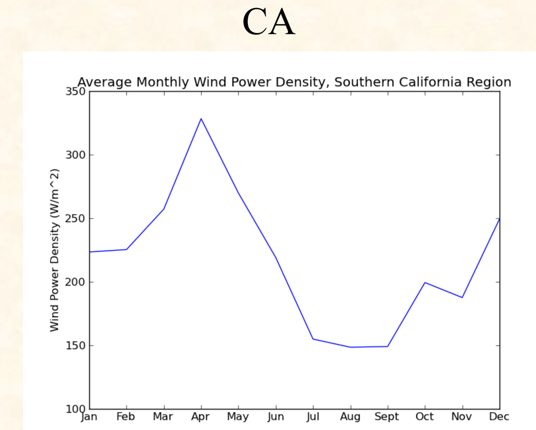
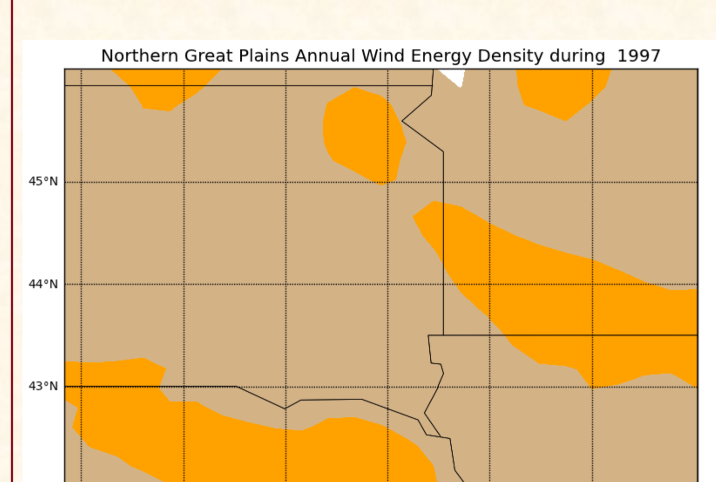


NARR/WRF Results

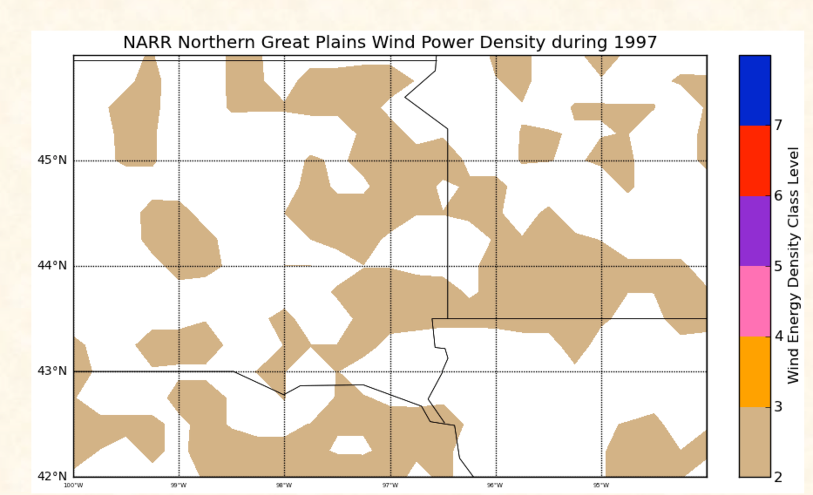
NARR data (at 32 km resolution) were used to compare modeling results of WRF regional climate modeling at 27 km resolution for the years 1980-2000.

Annual Comparison:

NGP WRF

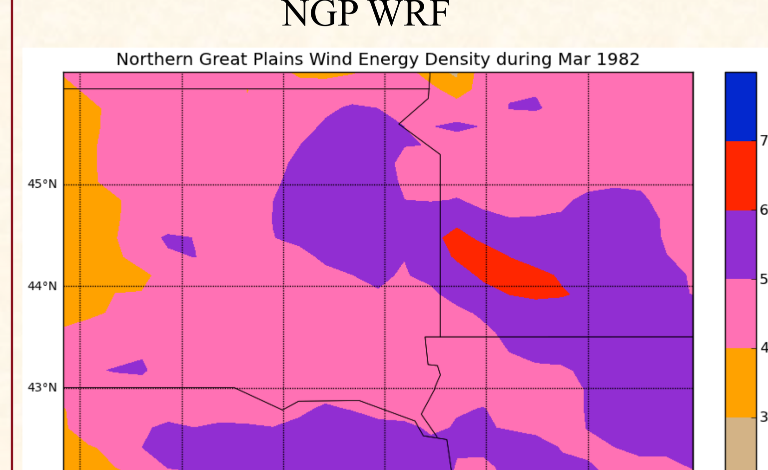


NGP NARR

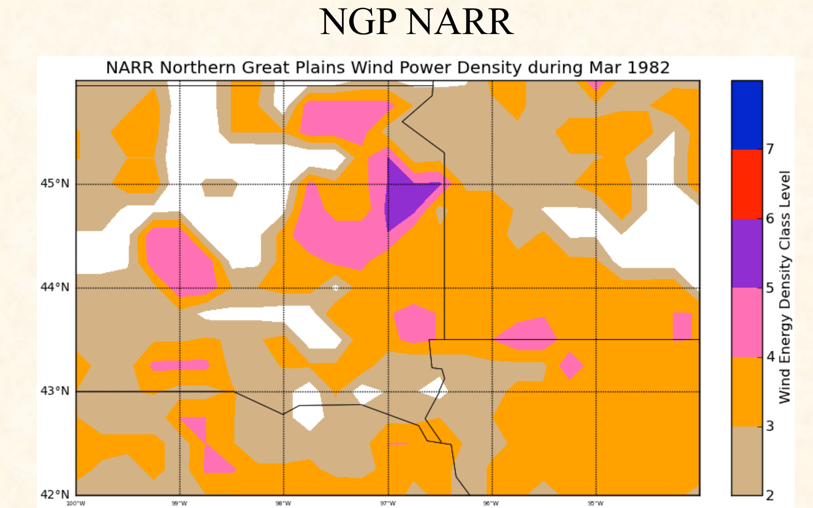


Monthly Comparison:

NGP WRF

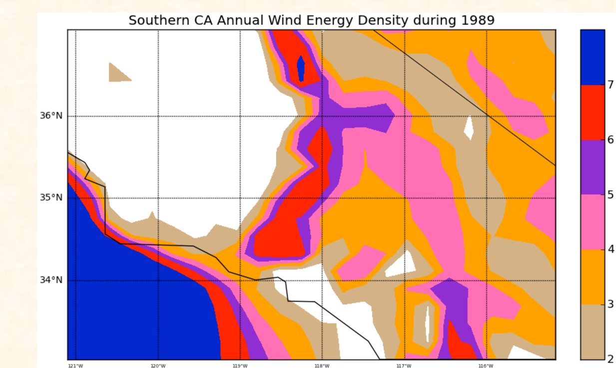


NGP NARR

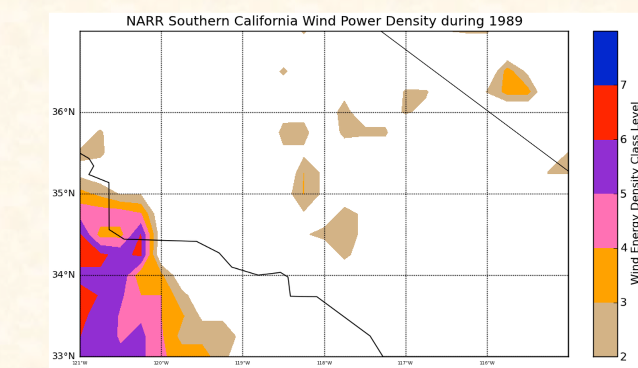


Monthly Comparison:

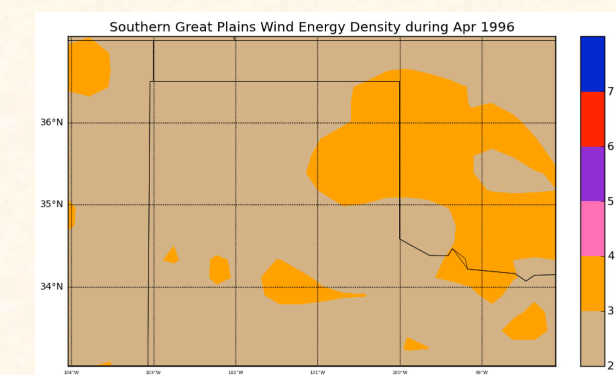
CA WRF



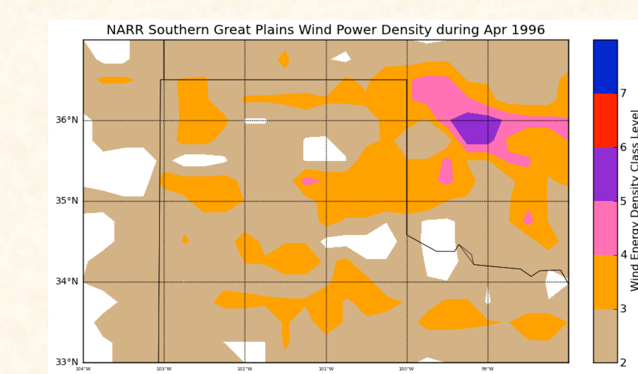
CA NARR



SGP WRF



SGP NARR



Teleconnection Results

The monthly NARR data were compared to Multivariate ENSO (El Niño/Southern Oscillation) and PNA (Pacific/North American) indices for any possible correlation. A slight negative correlation exists for both ENSO and PNA. Pearson r values are shown below.

	ENSO	PNA
Region 1	-0.1605*	-0.05297
Region 2	-0.1850*	-0.1662*
Region 3	-0.0800	-0.06647

*Statistically significant as defined by $p<0.05$

Conclusions

- Higher resolution modeling is necessary to properly discern topographical features
- Compared to NREL's results, WRF modeling tended to underestimate wind resource in the Great Plains while overestimating it in California. The NARR underestimated the wind resource in all three regions, even with a high time resolution of every 3 hours
- Multivariate ENSO index may have a slightly negative correlation with wind power density, but further work is necessary to confirm with a more robust set of data. PNA index correlation remains uncertain, although it does seem to have less of a negative impact on the wind resource in California
- April is the best month of the year in all three regions for wind power production, with October a secondary peak in the Northern Great Plains

References

Berg, N., A. Hall, S.B. Capps, and M. Hughes, 2012: El Niño-Southern Oscillation impacts on winter winds over Southern California. *Climate Dynamics.*, 1-13.

Chen, W. Y., and H. van den Dool, 2003: Sensitivity of Teleconnection Patterns to the Sign of Their Primary Action Center, *Mon. Wea. Rev.*, **131**, 2885-2899.

Pryor, S. C., G. Nikulin, and C. Jones (2012), Influence of spatial resolution on regional climate model derived wind climates, *J. Geophys. Res.*, **117**, D03117

Wan, Y.H., 2012: Long-Term Wind Power Variability. NREL Tech. Rep. TP-5500-53637, 32 pp.

Wolter, K., and M. S. Timlin, 2011: El Niño/Southern Oscillation behaviour since 1871 as diagnosed in an extended multivariate ENSO index (MEI.ext). *Intl. J. Climatology*, **31**, 14pp., in press.