Wind Resource Assessment Utilizing Time-Averaged Community Earth System Model Data

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What is the goal of this research?

- Utilize high resolution climate model data as an alternative method of wind resource assessment

- Discover utility of different wind resource assessment techniques that maximize effectiveness of climate model data

It was the light, it was the angle/Flickr

Why is this research useful?

- Climate model data is saved at varying temporal and spatial resolutions
- Model vertical levels can also vary and are usually not at 80 meters
- Can these data be utilized to give approximate initial estimates of the future wind resource?

Datasets utilized in this study

Datasets

CESM (Community Earth System Model)
20 year period

NARR (North American Regional Reanalysis)
2003-2012

Metadata

¼ degree horizontal resolution (27km), monthly and daily temporal resolution

32 km horizontal resolution, 3 hour temporal resolution

Techniques used to improve accuracy

Techniques

Extrapolation to 80 meters using interpolated alpha value

EPF (Energy Pattern Factor) from best-fit Weibull distribution

Methodology

$$\frac{V_{high}}{V_{low}} = \left(\frac{Z_{high}}{Z_{low}}\right)^{\alpha}$$

Alpha parameter (typically 1/7)

$$k = \left(\frac{\sigma_U}{\overline{U}}\right)^{-1.086}$$

Weibull k shape factor

Utilize between two vertical layers of wind data

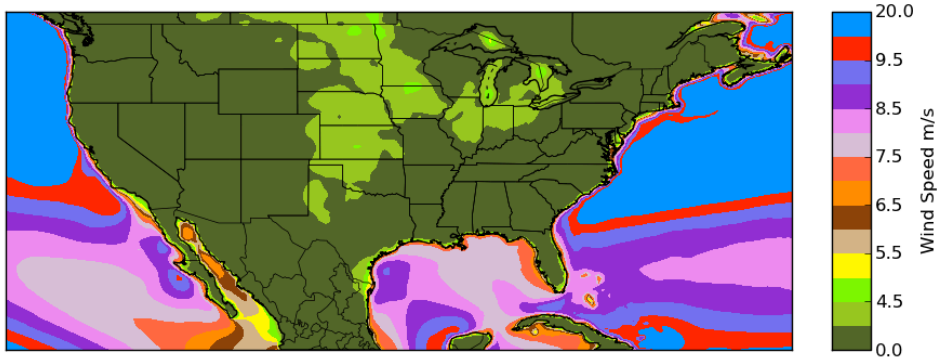
$$K_e = \frac{\overline{U^3}}{(\overline{U})^3} = \frac{\Gamma\left(1+\frac{3}{k}\right)}{\Gamma^3\left(1+\frac{1}{k}\right)}$$

Energy Pattern Factor

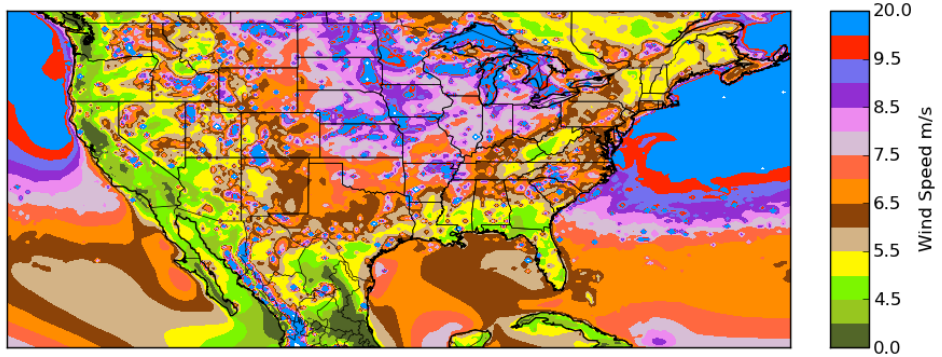
Holt and Wang 2012, Justus et al. 1978, Manwell et al. 2009

Comparison of constant alpha to alpha extrapolation for *monthly* CESM

Constant alpha of 1/7

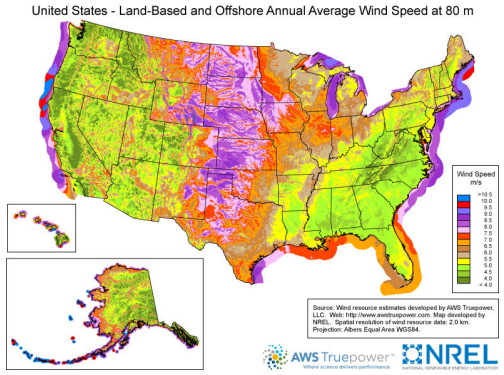


Alpha interpolation scheme

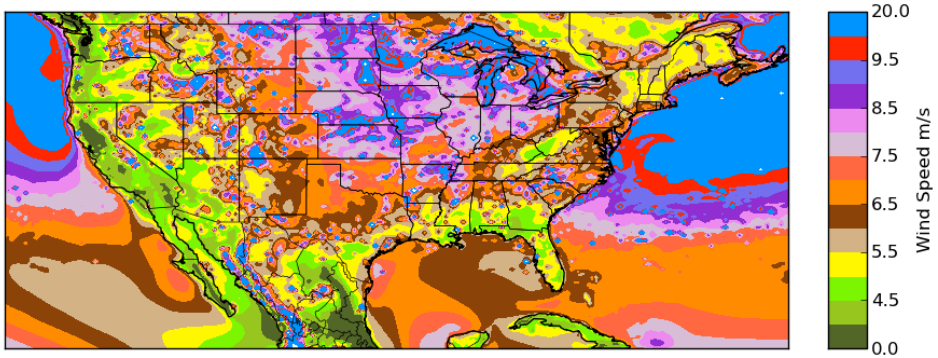


Comparison of constant alpha to alpha extrapolation for monthly CESM

NREL average winds at 80 meters



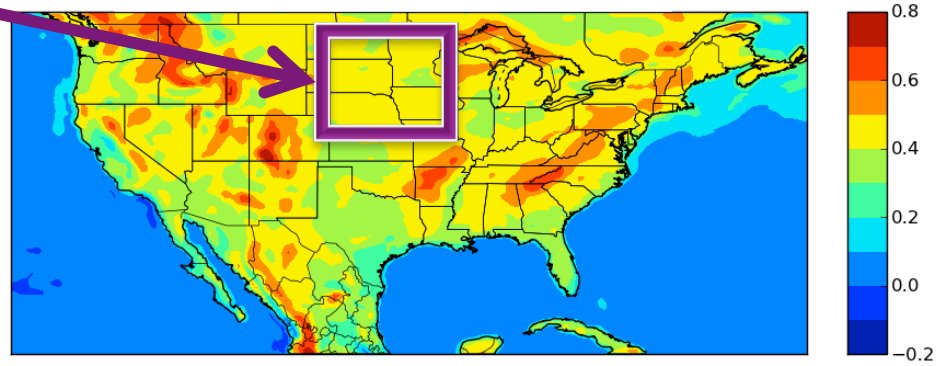
Alpha interpolation scheme
(no alpha maximum)



Comparison of alpha values found in CESM and NARR

Average of 0.4-0.5 in Northern Great Plains

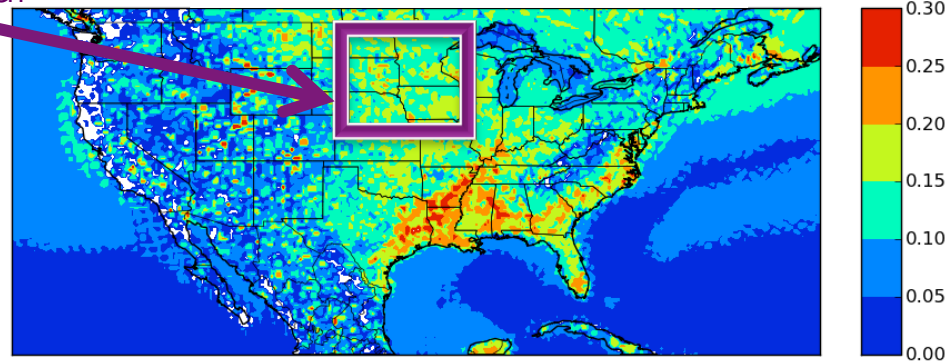
Average alpha values, monthly CESM



Alpha values much larger in CESM

Average of 0.1-0.2 in Northern Great Plains

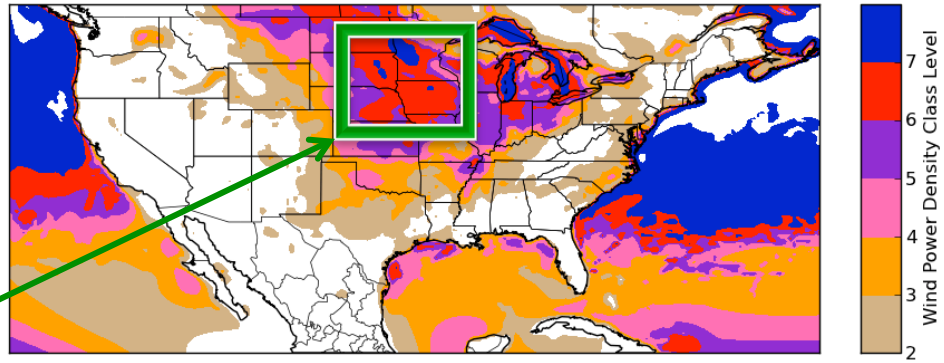
Average alpha values, 3 hourly NARR



Allowed greater wind speeds

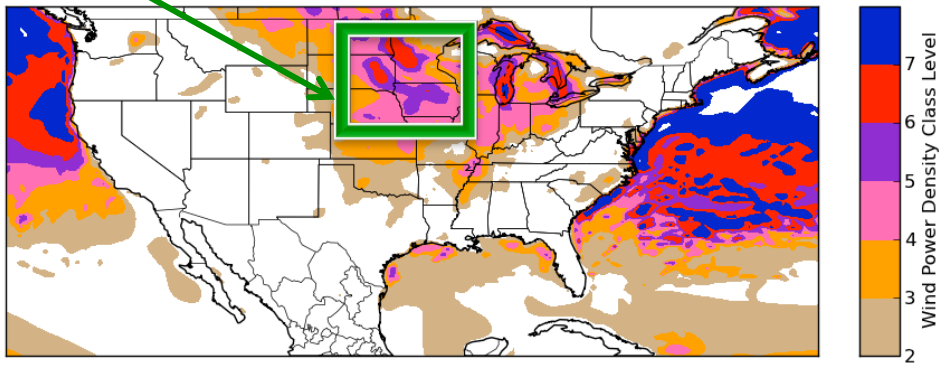
EPF reduces overestimation of Rayleigh distribution

0.75 max alpha, Rayleigh assumption, monthly CESM



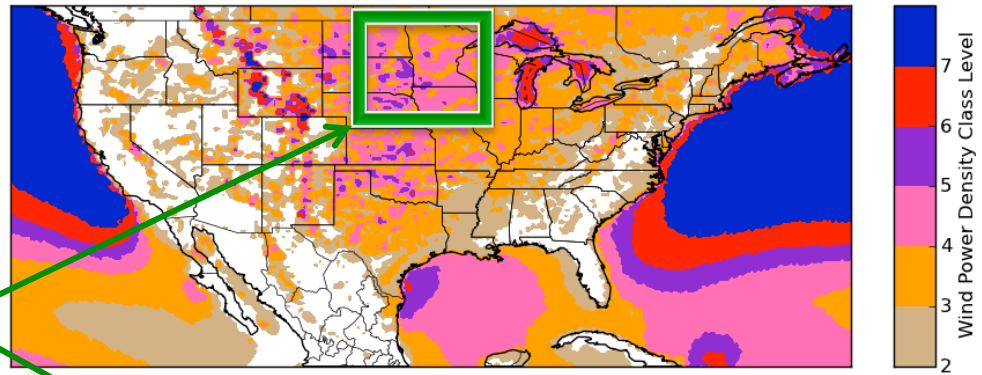
Wind power density overestimated

0.75 max alpha, EPF included



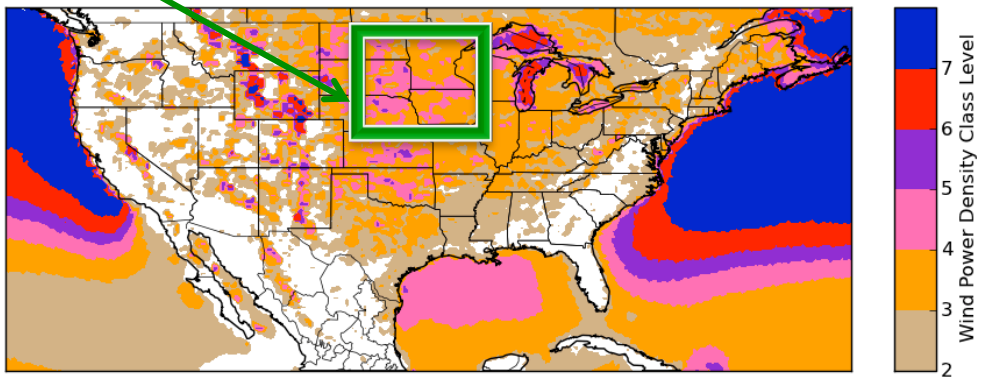
EPF reduces overestimation of Rayleigh distribution

Rayleigh assumption, 3 hourly NARR



Wind power density overestimated

EPF included

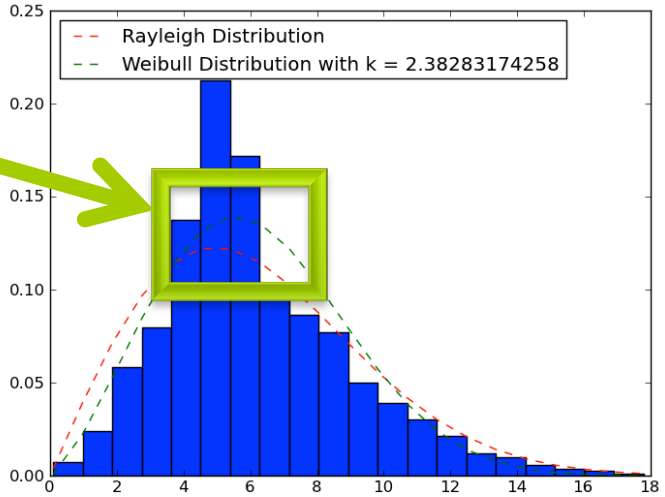


More pronounced in CESM than NARR, possibly due to lower temporal resolution

Larger k values lead to smaller EPF

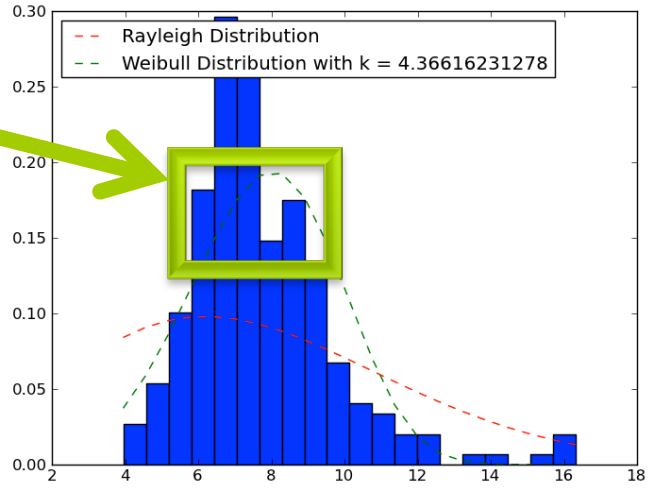
k = 2.38

Weibull best-fit vs. Rayleigh, 3 hourly NARR, at 42,-100



k = 4.37

Weibull best-fit vs. Rayleigh, monthly CESM (with max alpha 0.75), at 42,-100



Larger k values lead to smaller EPF

- K values were larger for the CESM data based on the distribution having more of a peak

- K value and EPF are inversely related, causing an overestimation of the wind power density

Using a greater temporal resolution

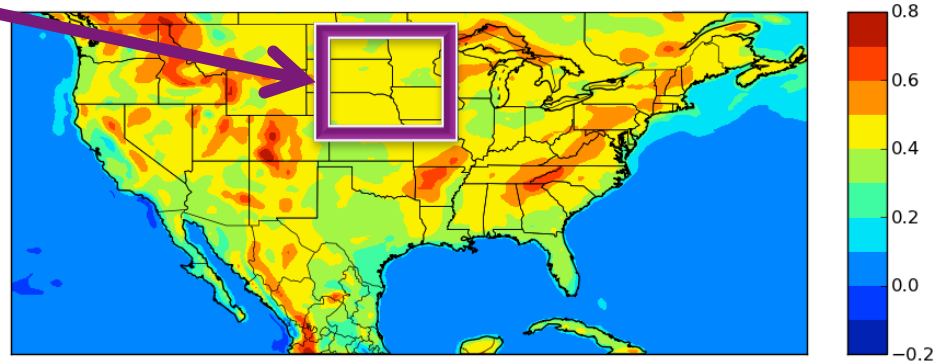
- Apply same techniques to ~5 years of CESM at daily temporal resolution instead of monthly

- Only vertical levels available for data are at lowest level (~ 60 meters) and at 850 hPa level

Greater temporal resolution seems to reduce alpha values

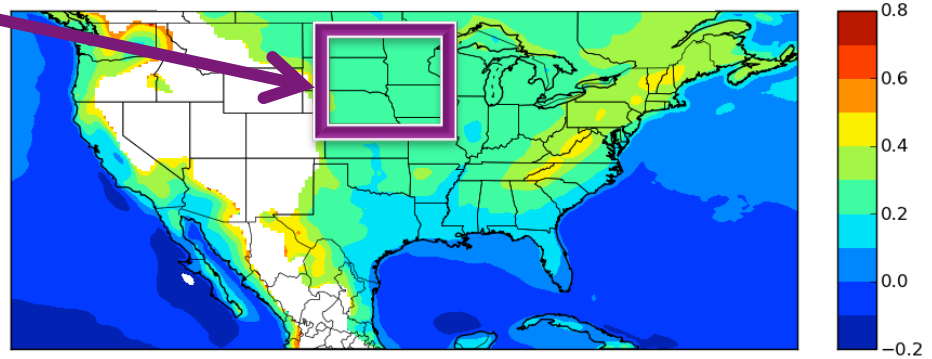
Average of 0.4-0.5 in Northern Great Plains

Average alpha values, CESM monthly



Average of 0.2-0.3 in Northern Great Plains

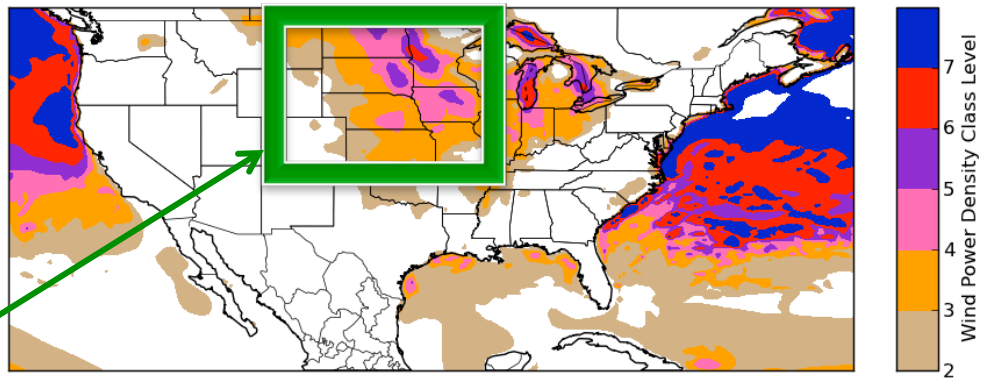
Average alpha values, CESM daily



Alpha values still larger in monthly data but not by as much

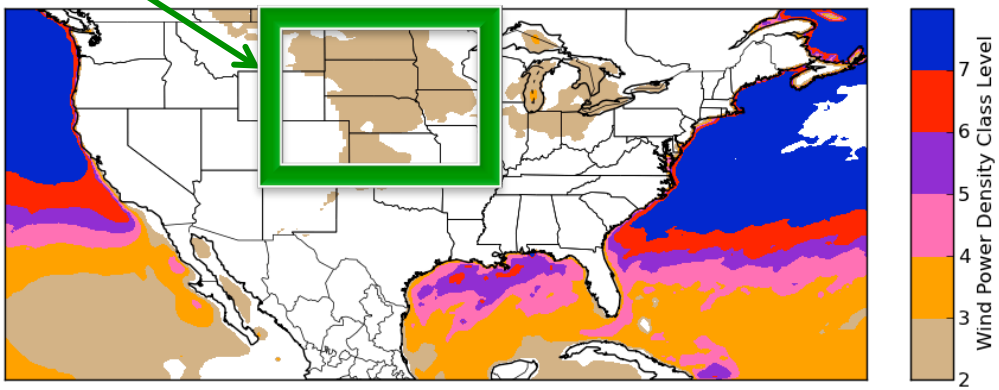
Lower alpha values result in lower wind power densities

0.7 max alpha, monthly CESM



Significantly decreased wind power density

0.7 max alpha, daily CESM



Time-averaged data can be used but is not ideal

- Both techniques (best-fit EPF and power law interpolation) can improve accuracy of climate data evaluation

- If utilizing climate model data, try to have a layer as close to 80 meters as possible with high temporal resolution

How to improve

- Greater horizontal resolution modeling using a regional climate model instead of global

- Improvement to planetary boundary layer parameterization schemes

- Have a vertical level in the model at 80 meters

- Statistical downscaling (such as Pryor et. al. 2005, Haas and Pinto 2012)

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