EXAMINATION OF REGIONAL WIND TRENDS DUE TO GLOBAL CLIMATE CHANGE TO IMPROVE WIND RESOURCE ASSESSMENTS

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1. INTRODUCTION

In order to properly site arrays of wind turbines to achieve optimal wind power generation, estimation of the future mean wind speed for a given location is essential. This need is currently being met within the wind power energy community by high-resolution spatial maps of the wind climatology that have been created using climatological data and high-resolution numerical models. However, there is evidence that solely using climatological information as the basis of siting future wind turbines may not be a sound one because of the regional impacts of a changing global climate.

It is now a well-accepted conclusion that the earth has become warmer over the last century. The Intergovernmental Panel on Climate Change (IPCC), (established by World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to monitor climate), estimated the average surface temperature of the earth has increased during the last hundred years by about 0.6° ± 0.2°C. It is also generally accepted that at least part of this warming is due to the increase in greenhouse gasses emissions, primarily CO^2. The scientific disagreements that do still exist primarily concern detailed aspects of the processes that make up these largely accepted general themes. The impacts of these warming trends are currently not being taken into account when examining wind power potential for a region.

The evidence for changing wind patterns because of global warming is consistent with theory. The generally accepted scenario for global warming is that the greatest impact will be the warming of the Polar Regions. The primary energy source for generating winds in the midlatitudes is the difference in temperatures between the polar and tropical airmasses. In theory, the reduction of the thermal difference between the Polar Regions and Tropics should reduce the mean midlatitude wind speeds. There have been anecdotal wind trend studies done at a few locations that indicate that this may indeed be happening.

Even though the anecdotal wind studies tend to support the idea that wind speeds are decreasing in accordance with the theory of global warming, the impact of urbanization of an area could mimic this same trend. Wind speed is greatly reduced in urban areas versus open areas. The reduction in speed is typically on the order of 60% from a fully rural to fully urban land use. Also, the amount of reduction depends on the season. For

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example, deciduous trees in summer would tend to have more of a reduction effect than in the winter. It is possible that apparent changes in wind patterns are not actually due to global climate change, but rather due to regional changes in land use from rural forests and open fields to highly urbanized areas.

This current study uses the Global NCAR-NCEP Reanalysis 50+ year data set to identify (1) any global trends in the wind speed patterns; and (2) identify any regional trends that significantly differ from the global wind patterns.

2. ANALYSIS OF THE DATA

2.1 Mean Temperature Changes

The first step in the analysis of the data was to examine the changes in the overall thermal patterns of the troposphere to see if there is evidence in the data that there has been a shift in the thermal patterns over the last 50 years. The 1000-500 hPa thickness is used to represent the vertically averaged tropospheric temperature changes after methods used by Atallah et al. (2002).

The mean thickness changes over the period Jan 1, 1951 to Dec 31, 2001 shows there has been a general trend of increasing thickness value in most of the Northern Hemisphere. There are pockets of trends of decreasing values over Greenland, the Pacific, Siberia and Africa. The strongest thickness trend values are observed in the winter to spring months with much weaker trends in the summer and fall. Overall, there is a weakening and a shift to the north of the region of strongest thickness gradient associated with the mean position of the polar front.

2.2 Mean Low Level Wind Changes

The changes in the Northern Hemispheric mean thickness pattern appear highly correlated with changes in the mean surface wind changes. There is a band of decreasing mean u wind component (Fig. 1) that is nearly continuous around the globe between 30 and 40 degrees N latitude. In Figure 1, the shades of blue on the left side represent decreasing wind speed trends; green through orange on the right side represent increasing wind speed trends. This band corresponds to many regions around the globe that are very significant to the production of wind generated electricity.

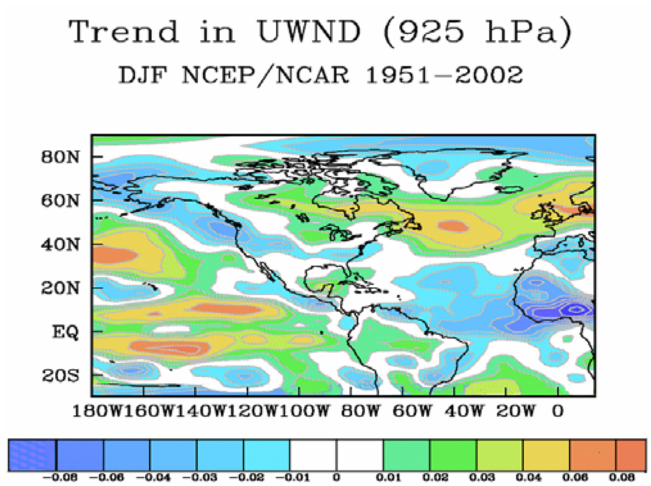

Fig. 1. Trend in U wind for 925 hPa.

3. REGIONAL ANALYSIS

Most regions seem to be uniformly impacted by the global trends. This is important because it fits into a global pattern more easily understood, and therefore predictable, regarding future trends. However, there are specific regions, such as the upper Mississippi

Valley and the southern California areas, that have trends that are significantly different from those of the larger scale trends that surround them. It is interesting to note that the locations of these trends seem to occur in regions where the low-level thermal trends significantly differ from the upper level trends. The initial hypotheses for the reason for these trends differ for each region. Southern California seems to have an increase due to an increase in the strength of local wind systems. The upper Mississippi Valley increase seems to be associated with an increase in synoptic forcing. Future research needs to be done to identify if either of these hypotheses is correct.

4. SUMMARY AND CONCLUSIONS

This research has shown that there has been a significant global trend for a shift in the mean wind speed values and patterns. These early results tend to indicate that the most significant trend that could impact the wind power industry is the trend of the mean wind speeds to lower in a general band between about 30-40 degrees North latitude. Within this band, there are regions that exhibit trends that are different from the larger scale pattern that are important when considering the economic impact of the winds speed trends. There are several areas that need to be researched further in order to understand the causes of both the large scale and regional differences in wind speed trends. If the trends are the result of a general warming of the entire globe, this would lead to very different mean wind speed patterns than if they are the result of long term oscillations or land use changes. If the wind trends are the result of global warming, this will change the general wind patters for entire regions of the globe for very long periods. If the trends are the result of long-term oscillation, the trends will tend to reverse at some point. However, if the cause of the wind trends is primarily due to land use changes, the effect will be more localized. Future siting of wind farms and the estimated power generated could be improved by identifying the trends and the causes of the trends.

Future research will include completing high resolution simulations using the MASS mesoscale model over the past 50-year period for regions that show substantial changes in wind patterns. The information generated from the simulations, along with comparisons of point observation wind climatologies, will then be compared with the MASS generated and Reanalysis generated climatologies. In addition, comparison of the changes of the upper levels versus low levels and seasonal influences will be examined.

5. REFERENCES

Atallah, E., Aiyyer, A., and Bosart, L. F., 2002: "Northern Hemisphere Cold Pool: A Thickness Climatology". 27th Annual Northeastern Storm Conference, 8-10 March 2002, Saratoga Springs, NY.