Effects of wind direction and speed on turbulence and wind shear

By

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A senior thesis submitted to the faculty of
Brigham Young University - Idaho
in partial fulfillment of the requirements for the degree of

Bachelor of Science

Department of Physics
Brigham Young University - Idaho
March 2010
ABSTRACT

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Turbulence and wind shear are important effects of wind in general and can provide clues to the behavior of wind itself. By studying how terrain, direction and speed affect turbulence and wind shear it is possible to install wind turbines in particular areas to harness wind energy. Comparison of different locations with different terrain and elevation can help us to understand what types of areas are ideal for wind turbine siting. The data gathered from each location will show what ranges of turbulence and wind shear can be expected from similar locations in the future. Comparisons are made between elevation and direction to understand the variability of the Hellmann coefficient in the wind shear equation and what affects it. The issue of turbulence is discussed as well by focusing on the wind speeds from various directions to see a trend in wind behavior vs. direction.
Acknowledgements

I would like to thank my husband Carsten for his support and enthusiasm in helping me understand the different principles of wind behavior in this project. Advice and discussion provided by the faculty of BYU-I including Stephen Turcotte and Ryan Nielson was essential in helping me interpret the data and understand the material. I would also like to thank my family for their advice and support as well.
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Introduction

In the past few years Earth has experienced a higher demand for energy. Thus, many different research studies are underway to find alternative sources of fuel to offset the depletion of fossil fuels such as natural gas and crude oil. One of these possibilities is wind. Fernando D. Bianchi stated in his book *Wind Turbine Control Systems and Principles*, “The progress of wind power around the world in recent years has exceeded all the expectations. In numbers, the wind turbine capacity installed in Europe increased during the last years at an average annual growth rate superior to 30%.” \[1\]

AWEA (the American Wind Energy Association) is currently performing thousands of studies around the country simultaneously. The state that has most of these projects is Texas which is home to almost 1,000 sites. Idaho has just about 150 sites under construction at this time. \[2\] There is progress throughout the world as well. In the past decade, “the Danish wind industry has seen average yearly growth rates of 20 percent over the last ten years. The intense growth rates in particular are because Danish suppliers have increased their export to foreign manufacturers on the global market.” \[3\] These statistics led Denmark to being the leader of offshore wind energy production in the European nations.

As of 2008, the USA is the world’s leader in total wind energy with an astounding 25,000 Mega Watts of energy produced each year. \[3\] Germany is the 2\textsuperscript{nd} largest with about 20,000 MW and China producing 12,000 MW. \[3\] A recent study found that the total production of wind energy worldwide is over 120,000 MW of power. \[3\] The best news is that these numbers are continuing to grow. This large growth in production is due to the fact that the benefit of using wind as an energy source is the lack of damage or, in other words, the low impact to the environment, the inhabitants in the area, and most importantly, the low cost.

Like other alternative energy sources wind energy does have some drawbacks and opposition. The process of choosing eligible sites for wind turbines can be a risky and complex. The area chosen must have the right properties to support the wind turbines. These sites must possess, “high quality wind, meaning that it blows fast, and often, and with minimal turbulence created by the surrounding landscape. Turbines are also more effective the higher they are above the ground.” \[4\] The problems associated with these factors are some of the issues facing wind energy today.

Companies involved in wind energy have found that the higher up the wind turbines are in the atmosphere, the higher amount of energy generated. This is a logical observation but also a big issue for the neighboring communities in the area which claim that the presence of the wind turbines disrupt their
Many residents make the “not in my backyard” argument. But these oppositions are in no way comparable to those facing other energy sources such as nuclear energy.

There is some concern dealing with wind turbines constructed offshore. Countries such as Denmark, as previously stated, build many turbines off shore. There has been some understandable opposition from the fishing industries who would not be able to drag their nets in the area. But there has also been worry of how wind turbines will affect the ocean wildlife. Fortunately, it has been found that the presence of wind turbines does not introduce any danger to the environment. “The Danish story, by far the most complete, shows that fish exist in the same manner they did previous to the turbine installations. [This] way of thinking shows the turbine installations as creating reefs, which add to the diversity and health of ocean life.” [4]

One obstacle to many is the inconsistency of wind itself. The best way of harvesting wind power is using large windmills. But placing these windmills correctly is essential. If one were to place them in an area where there is either a low average wind speed or no wind at all, there is no benefit that comes with the cost of building the windmill. For this reason scientists must visit potential sites to study the properties of the area and understand the wind behavior. They also measure the wind speeds and find if the wind is consistent enough to justify building a windmill.

Sometimes companies need to build windmills around buildings. This set up causes problems for the scientists who need to go into that area and gather data. The turbulence that results from the surrounding buildings causes inaccurate wind data and threatens the wind blades of the turbines. The damages on the wind turbines due to turbulence is a cost that companies want to avoid whenever possible. On the other hand, turbulence shows different patterns of behavior and provides information on different factors that contribute to it. Scientists calculate the amount and direction of turbulence due to the surrounding buildings, terrain and other circumstances not yet known by employing mathematical equations, and principles to the data collected.

Even though I’m not working to find a potential site for windmills, the aspect of understanding wind behavior is just as important in the industry. I expect that our work can be useful in accomplishing this. My goal is to better understand the wind behavior in the Rexburg area through the comparisons of average wind speeds, turbulence and wind shear between different locations. I will be working with the turbine and anemometers located at 3 different sites to calculate how much wind turbulence affects the data and then compare the results. Along with this I plan to figure out the trends in wind.
Background Information

Wind Turbine History and description:

In order to better understand this paper we must first describe the basic principles and instruments used in this experiment. We will be working with wind turbines and anemometers. It is because of their accuracy and simple but effective design that these instruments are commonly used when taking wind speed measurements.

The wind turbine is the structure that many have seen on hillsides. The wind turbines are what are responsible for actually gathering the wind energy and converting it into mechanical energy that spins the inner shaft of the turbine which then spins the generator. These actions result in the electricity which is used to power towns, factories, and other facilities. The picture to the left is an example of what is called a horizontal axis wind turbine or HAWT. These are much more common than the vertical axis wind turbine which is of course VAWT. Another name for the VAWTs is egg-beater designs. There are many advantages that the HAWTs have. One of their biggest advantages is their height of the towers that support the turbines. This height provides access to higher wind speeds which will increase the rate of electricity produced.

The heights of the turbines also provide access to areas where there is a healthy amount of wind shear. Wind shear occurs when there is a change in the wind directions within a small area. Wind shear can also be called wind gradient. According to Gail S. Langevin, a NASA official, wind shear can be “defined as any rapid change in wind direction or velocity.” Langevin went on to mention the effects of severe wind shear. “Severe wind shear is a rapid change in wind direction or velocity and causes horizontal velocity changes of at least 15 m/s over distances of 1 to 4 km, or vertical speed changes greater than 500 ft/min” [7].
**Anemometers history and description:**

Anemometers are capable of recording wind pressure or wind velocity. Since speed and pressure are so closely related, many anemometers are able to tell us both values. There are many different types of anemometers in use today. The anemometer was first invented in around 1450 A.D. by Italian architect Leon Battista Alberti. But it was not until 1846 that John Thomas Romney Robinson came up with the simple cup anemometer. This consisted of four hemispherical cups attached at right angles to each other and then placed on a tower in the wind. The moving air would then push the cups until they were moving in circles. The rotating cups in turn rotate the inner shaft along a vertical axis of rotation. Today, this inner shaft transports the information to computers which record the number of times the cups rotate and then calculates the average wind speed.

The windmill anemometer, shown in Figure 2, gives the pressures and velocity of the wind and the direction of the wind as well. This is made possible by having the axis of rotation be horizontal instead of vertical. Along this axis there is a propeller on the front which gives us the velocity and pressure. On the back there is a tail which is changes direction as the wind does. Thus we can have the direction of the wind. By knowing the direction and speed of the wind, we can better calculate the wind shear and turbulence at different elevations. The windmill anemometer is what will be used in this study.

**Previous Studies:**

Many studies on wind energy have already been performed. The results of these studies have helped to provide valuable information. The Idaho National Laboratory (INL) is currently studying different sites that have the potential to have wind turbines. In order to find out if these places have sufficient wind speed for wind energy production, anemometers must be installed for at least one year in order to collect enough wind data to have a thorough understanding of the wind trends in that area. INL confirmed this by stating in their mission statement, “the anemometers remain in place for at least a year, and the wind data is collected and analyzed for each site to help determine if it is feasible and cost effective to install a wind turbine or turbines at that site” [10].

Other studies are headed by the AWEA organization. AWEA (American Wind Energy Association) is currently performing thousands of studies around the country simultaneously. The state
that has most of these projects is Texas which is home to almost 1,000 sites. Idaho has just about 150 sites under construction at this time. [2] These numbers are rising as the nation is gradually becoming more accustomed to the concept and benefits of wind energy.

Studies have also been performed to simply understand the behavior of winds patterns and what affects them. One study in particular performed by Adam Kochanski, Mary Ann Jenkins, and Steven Krueger [11] focused on how wind behaved around hills to predict how fire would spread. This study helped to increase the safety of fire fighters while in the field. In conclusion they found the turbulent kinetic energy of the wind to be higher at the top of the windward side of the hill, even though wind vectors illustrated high turbulent character at the top of the leeward side of the hill. They observed, “In the case of the model turbulent kinetic energy, the spatial distribution is different. The data shows a maximum of turbulent kinetic energy (TKE) on the windward slope of the hill, slightly ahead of its slope with much smaller TKE values on the leeward side. In this case the observed spatial pattern may be attributed to the stronger wind shear TKE production on the windward than on the leeward slope.” [11]

Otto Zeman and Niels Otto Jensen of Denmark performed studies that found through a certain amount of math different layers of turbulence in the air flowing over a two dimensional hill. The inner layer which was closest to the ground surface obeyed the surface layer laws. The middle layer, which is called the equilibrium layer, exhibits a wind profile that follows a logarithmic pattern that is constant with height. The outer layer is more susceptible to the rapid distortion effect that predicts, “The longitudinal turbulence component is expected to decrease and the vertical one to increase with respect to the upstream level.” [12] In conclusion Zeman and Jensen found, “It was found that apart from rapid distortion the curvature of streamlines has an important dynamical effect on turbulence. The curvature effect is shown to be particularly pronounced in the vicinity of the inner layer height on the hill top, where it attenuates turbulence.” [12]

Raupach, Weng, Hunt and Carruthers of Austrailia and Cambridge studied the effects of temperature and humidity over low hills. They also found evidence of different layers in the air flow over a hill. The inner layer lies within a predicted distance from the surface of the hill and within the planetary boundary layer. The inner layer experiences large amounts of turbulence and is easily affected by the terrain and buildings within it. The outer layer they postulated to be inviscid, or having almost no viscosity, but found that there were potentially large amounts of turbulence here as well. They concluded by stating, “Matching these layers, hill-induced perturbations in the concentrations and fluxes of an arbitrary scalar can be determined in terms of upwind and surface conditions and the calculated mean and
turbulent wind fields over the hill.” [13] In other words, the different properties of these layers can give information on the turbulence in the air.

Teolan Tomson and Hannu Lamp studied the effects of wind shear in different types of terrain. It had been previously assumed that the wind shear coefficient was constant depending on the type of terrain and had been evaluated to be about 0.2. [14] The data provided show a strong correlation between the height and the terrain of the wind shear coefficient. These values also changed similarly. They ranged anywhere from zero to one throughout the year by exhibiting a periodic nature. In other words the wind shear coefficients were a certain value in the Mays of different years and then a different value in the Junes of each year. [14]

Studies done on wind patterns in Hawaii by scientists Chock and Cochran assumed differently and calculated the wind shear constant for oceans to be about 0.16. They continued to work under the assumption that the wind shear coefficient was constant in similar terrains. Their assumption was consistent with the Engineering Sciences Data Unit. [15]
Method

**Description of the locations:**

The three sites which will be subjects of comparison are locations that possess different characteristics. These differences in locations present an interesting comparison. The Livestock center is located in the bottom of the Upper Snake River Valley stationed at a close distance to several buildings that will cause some turbulence and inaccurate wind readings. The water tower is at the crest of the one of the hills surrounding the valley. And the Webster farm is on top of the hill but located some distance away from the crest. Logically it is expected that wind readings from the Webster Farm will be higher and more accurate than wind data from the Livestock Center and the water tower. While some previous studies have been performed concerning the pressure, this study is concerned with turbulence and wind shear.

In order to study the effects of wind shear there will be anemometers installed at different altitudes on the water tower. The data acquired from these anemometers will be listed as speed 1 and speed 2 to for the elevations of 95 feet and 60 feet respectively. The difference in speed between readings from each of the anemometers will provide the information needed to calculate the severity of wind shear and the overall wind speed, turbulence intensity and overall direction. The comparisons will be divided into the northern (0° -45° and 325° -360°) and southern (135° -225°) directions.

The Livestock center will make a fair representation of the wind behavior in the valley bottom. But the data only includes information from one elevation. This is due to the close vicinity of buildings which would increase the amount of turbulence at lower elevations to the point of not being useful. The anemometer height is 33 feet above the ground. This is about 10 feet above the buildings in this area.

The water tower will probably be a source of the most interesting data. This data as stated before contains the two anemometers at different elevations allowing us to calculate the wind shear between them. Another reason why the data will be important is because the water tower is located at the crest of a hill. Because of this it will be subject to updrafts and extra turbulence due to the sloping terrain. Along with this interesting location is the presence of a 10 foot structure at the base of the tower on the windward side. This can also cause the some turbulence and possibly inaccurate readings.

The Webster Farm shouldn’t have much turbulence due to structures since there is only a house across the street from it. But there might be some turbulence due to hillcrests some distance away from it. This location will probably be the best place with the high wind readings gathered here. The height of this anemometer is currently 95 feet above the ground. In the future there will be another anemometer installed to study the effects of wind shear at this site but for this study we will simply be analyzing data from one elevation.
Data and Observations

Data Description:

The raw data was first gathered using the software downloaded from the NRG Systems website. Measurements were taken every 10 minutes every day for different time periods at each site. The reason for the different time periods is damaged instruments that were not able to be repaired for some time due to the difficulty of their location and elevation. For this reason we have data that covers different years at each site.

The Livestock center data ranges from May 11 to the beginning of November in 2009. Data from the water tower is from the time period of January 26 to October 22 of 2005 with the exception of March 1 to March 10 of that year. This gap in data is probably because of instrument failure. The Webster Farm data contains those dates in 2007. The data from all 3 sites needs to be imported from the NRG Systems to Microsoft Excel format. Brother Turcotte used the batch method of importing to do this. The next step will be to analyze the data from each site and elevation. This will be performed using the Microsoft Excel program. Highlights of the data can be found in the Data Analysis section of this paper.

Data Organization:

After all the data was in the correct format there needed to be quite a bit of organization to more thoroughly manage the data. I categorized the data into its respective locations: Livestock center, Webster Farm and the water tower. Then I chronologically ordered the data into each month. For some months I analyzed specific days.
Data Analysis:

Correlations between turbulence and direction:

The first logical step in understanding the trends in wind patterns is to compare the average speeds of each month between the different locations. By knowing the average speed we can then take the standard deviation of different portions of the data and then find the turbulence of the wind at location and time. Turbulence is the unstable flow of a fluid. By understanding the amounts of turbulence in ranges of speeds and directions we can know how different buildings and terrain of the area affects the wind flow over it. The calculating of turbulence and average wind speeds utilized the following formulas:

\[
\text{average wind speed} = \frac{\text{sum of all the wind speeds}}{\text{number of total amount of wind speeds}}
\]  

(1)

\[
\text{turbulence} = \frac{\text{standard deviation(σ)}}{\text{average wind speed}}
\]

(2)

Since there are 3 different locations to consider, I compared the data available for the time period of May 11 to May 31. I did this to try to find the most similar conditions in which to compare the data from the different locations even though the data from each location was collected in different years. Once the data was organized, I calculated the average wind speeds over different time intervals to see if any periodic trends were present. The resulting graphs were very different and didn’t appear to show any obvious or useful patterns between years.

The wind properties that are the subject of this study deal with the turbulence intensity and the wind shear between these different locations. One of the questions of this project was whether the turbulence intensity was correlated to directions and speed. The graphs shown below illustrate these property relationships for the water tower.

Figure 12: TI vs. Northern speed water tower
We can see from these graphs there is more turbulence coming from the northern direction. This set of graphs was the first location that I began to analyze. The graphs presented an interesting observation. The layout of this site is the water tower with a ten foot structure at its base to the north followed by a sloping hill. To the south is a subdivision. This geography leads to the reasonable prediction that the southern direction would experience more turbulence based on the large amount of buildings in the section. But in this case, the opposite was occurring. The water tower was experiencing more turbulence from the direction of a sloping hill and the small structure next to it. Where was the turbulence coming from?

This question caused some more thorough research into the behavior of wind over a sloping hill. The conclusions and principles I gathered are contained in the previous studies mentioned earlier in this paper. The study performed by Kochanski, Jenkins, and Krueger stated a profound and very useful idea. They noticed that, “the data shows a maximum of turbulent kinetic energy (TKE) on the windward slope of the hill, slightly ahead of its slope with much smaller TKE values on the leeward side.” This behavior was very similar to what I was seeing in the water tower data. This could explain why there was higher turbulent intensity come from the north as the wind flowed up the hill.

This observation supported evidence of high turbulence from the north; it was also able to support the evidence coming from the Southern directions as well. This was confirmed by their statement, “The highest parts of the hill evidently speed the flow [of the wind] up and induce strong eddies on the leeward side of the hill.” This explains the amount of turbulence coming from the south.

Other studies done by Danish scientists Zeman and Jensen found that air flowing up a hill divides itself into three layers. There is the possibility that the recombining of these layers at the hilltop would
induce turbulence as well. Another factor that could account for the turbulence from the north would be the 10 foot structure at the base of the water tower. The flow of the inner layer is interrupted by the structure as the air attempts to flow around it to recombine with the other layers.

These different discussions were my attempts to explain the northern turbulence issue. But the data and graphs collected from the Webster Farm, shown below, illustrated some interesting behaviors as well. These graphs showed some striking similarities to the water tower data through the amount of turbulence. This demonstrates that the differences in turbulences between the crest of a hill and a relatively flat area are small and do not vary by a large amount. My primary assumption that there was always low turbulence in a flat area as opposed to a hill was disproved.

![Figure 14: TI vs. Northern speed Webster farm](image1.png)

![Figure 15: TI vs. Southern speed Webster farm](image2.png)

According to the above graphs the water tower is actually experiencing higher turbulence from the south by a small amount. But even though the southern turbulence is higher, the southern speeds are still higher as well. This observation gives an interesting pattern of the wind. I was finding that the
southern wind speeds were usually higher than the north. I decided to look in different areas throughout the Snake River Valley to see if there was a trend.

After some research I was able to find from the INL website some data collected from sites around Pocatello, Shelley and Rexburg. The Rexburg site happens to be the same water tower that has been previously mentioned throughout the paper. The comparison of the average wind speeds in these areas is shown in the graphs below. The heights of the anemometers are 66 feet at Pocatello and Shelley, and 95 feet in Rexburg. The measurements from Pocatello come from 2005 and the data from Rexburg and Shelley comes from 2001.

The speed differences between each graph especially the Rexburg water tower site, is obvious. The wind speeds in the lower Snake River Valley are much higher than in Rexburg. The fact that the anemometer in Rexburg was over 30 feet higher but still recorded speeds about 10 mph slower than in Shelley and Pocatello shows that the wind does in fact slow down as it progresses towards the upper valley.
The Livestock center was in a very different area than the water tower and the Webster Farm. It was located in the valley bottom and in close proximity to other buildings. The anemometer was also placed at a low elevation of just 33 feet. According to the previous requirements and the below graphs we can see that this area is shows the lowest wind speeds out of all three sites.

The results seen in these graphs are logical. The speeds were slower and the turbulence still comparable to that of the water tower and the Webster farm. These comparisons make sense because it was primarily assumed that the turbulence would still be high due to the close proximity of the buildings. If we were to compare the ratios between the turbulence and speed in each of the locations, we would probably see that the turbulence from the livestock center is very high for its relative speeds.

The similarities between the water tower and Webster Farm data show many similarities. These similarities probably result from the idea that turbulence over a region is not greatly changed by relatively small changes in terrain. Even though the sloping hill did cause some differences in the respective data, the overall change in speed and directional turbulence between these locations was minimal. But if one does look at the slight differences between the water tower and farm, we will be able to see the effects of
the terrain, however slight, on the turbulence and speed. The Livestock center’s data was much different from the other locations probably because of the difference in height at which its measurements were taken and the small distance to the structures around it.

**Correlation between Wind Shear with direction and speed:**

The effects of wind shear are also of certain importance in better understanding wind behavior. The idea of wind shear is the change in wind directions at different elevations. In order to study this natural phenomenon one must have two anemometers installed at different elevations but in the same area. The only site available to me that had these characteristics was the water tower. As a result, the water tower data will be the subject of our study. The equation for calculating wind shear is shown below.

\[ U = U_{ref} \cdot \left( \frac{z}{z_{ref}} \right)^{\alpha} \]  

(3)

Solving for \( \alpha \) we get:

\[ \alpha = \frac{\log \left( \frac{U}{U_{ref}} \right)}{\log \left( \frac{z}{z_{ref}} \right)} \]  

(4)

Here \( U \) is the average wind speed at 95 feet and \( U_{ref} \) is the average wind speed at the reference height which in this case is 60 feet. \( z \) and \( z_{ref} \) are the elevations 95 feet and 60 feet respectively.

Convention has usually assumed the wind shear coefficient, or Hellmann coefficient, for this type of terrain to be equal to 0.2. But as I applied this equation to data I found very interesting observations. Tomson and Lamp also found these same observations in their studies as well. They observed that the Hellmann coefficient varied between directions, speeds and over time as well. [14] This paper will not be as detailed but will attempt to at least show that the values of the Hellmann coefficient do in fact vary.

I first compared the Hellmann coefficient values between months of March and May of 2005 using the northerly wind speeds:

**Table 1: Wind shear for May 2005**

<table>
<thead>
<tr>
<th>May-05</th>
<th>Column1</th>
<th>Column2</th>
<th>Column3</th>
<th>Column4 wind shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>z</td>
<td>Uref</td>
<td>zref</td>
<td></td>
</tr>
<tr>
<td>14.432</td>
<td>95 feet</td>
<td>12.112</td>
<td>60 feet</td>
<td>0.381</td>
</tr>
</tbody>
</table>
Table 2: Wind shear for March 2005

<table>
<thead>
<tr>
<th>Column1</th>
<th>Column2</th>
<th>Column3</th>
<th>Column4</th>
</tr>
</thead>
<tbody>
<tr>
<td>March-2005</td>
<td>U</td>
<td>z</td>
<td>Uref</td>
</tr>
<tr>
<td>16.413</td>
<td>95 feet</td>
<td>12.359</td>
<td>60 feet</td>
</tr>
</tbody>
</table>

We can see that the Hellmann coefficients shown in column 4 are clearly different. More importantly, neither value is equal to 0.2. These numbers were very surprising to me. Why are these numbers different and not the conventionally accepted value? Both sets of measurements were collected from the same site and during the same year. The only differences that could have affected the coefficient values could be the different average wind speeds from month to month. It appears from the data that with a combination of higher average speeds the values increase. What else could affect the Hellmann coefficient? In order to test this I decided to focus on one month and compare the values between the northern and southern wind directions. The data from May is shown below:

Table 3: Southern wind shear from May 2005

<table>
<thead>
<tr>
<th>Column1</th>
<th>Column2</th>
<th>Column3</th>
<th>Column4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern</td>
<td>U</td>
<td>z</td>
<td>Uref</td>
</tr>
<tr>
<td>14.432</td>
<td>95 feet</td>
<td>12.112</td>
<td>60 feet</td>
</tr>
</tbody>
</table>

Table 4: Northern wind shear from May 2005

<table>
<thead>
<tr>
<th>Column1</th>
<th>Column2</th>
<th>Column3</th>
<th>Column4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>U</td>
<td>z</td>
<td>Uref</td>
</tr>
<tr>
<td>11.099</td>
<td>95 feet</td>
<td>9.908</td>
<td>60 feet</td>
</tr>
</tbody>
</table>

Here we see different values between the northern and southern directions. There is also agreement with previous observations made in this paper. The average speeds from the south are higher than from the north. And along with these higher wind speeds we see a higher Hellmann coefficient. Even though there is a difference between the northern and southern measurements. It can be safely assumed that the wind shear coefficients are ultimately affected by the wind speeds.

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1 The values shown in this paper were the most reasonable. Other values of the Hellmann coefficient, such as over all directions, were too large. There has also been no error analysis performed on the data in this study.
**Conclusions**

The purpose of this paper was to better understand the wind behavior in the Rexburg area through the comparisons of average wind speeds, turbulence and wind shear between different locations. In order to understand Rexburg wind we also needed to compare its data to other sites throughout Southeastern Idaho to get a better idea of the general wind flow in the region. By knowing this we can understand why the wind in Rexburg behaves the way it does.

The question of turbulence was answered by observing that the northern direction possessed more turbulence intensity and lower speeds than its southern counterpart. This was confirmed in similar findings at all three sites under consideration. The reasons for this behavior can be explained by comparing the wind speeds in not only the different sites around Rexburg but in other sites in the lower valley. The numbers showed a trend of higher wind speeds around Pocatello and Shelley but slowed by almost 10 mph in Rexburg. Since Pocatello and Shelley are south of Rexburg it is logical that the wind speeds from that direction have higher wind speeds and thus lower turbulence. Even though there was higher turbulence from the southern direction at the Webster Farm, the difference was only by a small amount; too small to be a point of concern.

Wind shear was found to be not always equal to 0.2. The different wind speeds changed the Hellmann coefficient to different values. The higher the wind speeds, the higher the coefficient. This coefficient also changed between the different directions but probably because the difference in the speeds. The wind speeds illustrated the fact that the wind possessed higher speeds in the lower Snake River Valley but as it flowed up into Rexburg, the wind decreased in average speed by about 10 mph.

The data analyzed for this research project was collected in different years. This made it harder to compare the data. In the future it would be better to collect all the data in the same time period so that we have a better presentation of the overall wind behavior throughout the region. The only location that provided the information for wind shear was the water tower because of the presence of two anemometers. It would have been interesting to see the effect of wind shear in different areas such as the Livestock center and the Webster Farm. This would have provided a more thorough picture of wind shear over the region as well.
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