Clouds 2

Stratocumulus Cloud/Wind Turbine Interaction

Ernesto Grossmann

Mechanical Engineering

Boulder, April 29th 2012

Context

Wind energy is perhaps the most stylist form of producing electricity. Looking at the blades of a wind turbine spinning is somewhat fascinating. My passion for renewable energy, and specifically wind energy, was the main inspiration of this second cloud assignment, which is part of the flow visualization course at the University of Colorado at Boulder. The main purpose of this assignment is to analyze the nature of clouds and weather. For this assignment, I decided to take a picture of a cloud formation together with a wind turbine because of the interaction both have with the wind, which simulates a synergic

In order to find the right spot for the picture, NREL's National Wind Technology Center (NWTC) on highway 93 between the towns of Boulder and Golden in Colorado was chosen. The NWTC has several wind turbines installed for research purposes. For security reasons, the entrance to the facility is limited to staff and special pass carriers. Therefore, the image was taken from behind one of the turbines with the cloud formation at the background. The camera was facing south, forty five degrees (45°) from the horizontal (Fig. 1). The picture was taken on April 8th, 2012 around 2:00 p.m. mountain time.

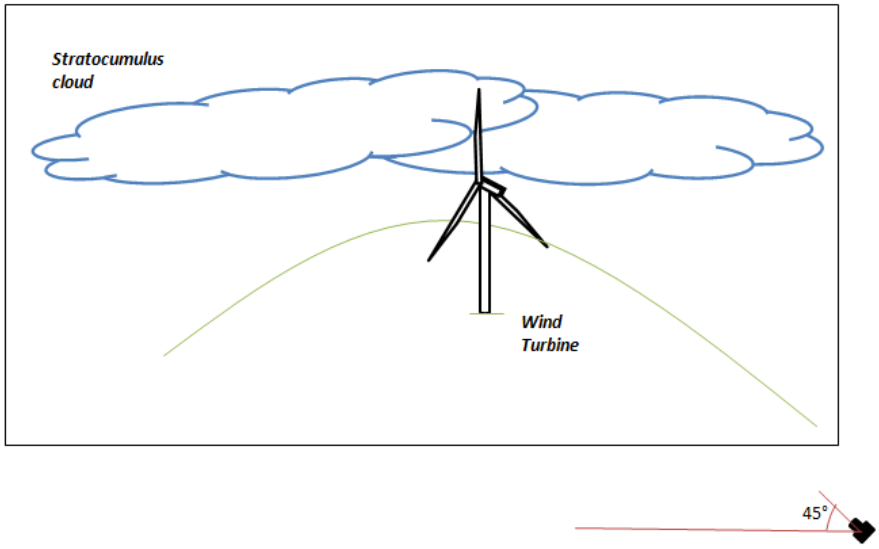

Figure 1. Picture frame sketch

Weather phenomena

The cloud that was captured can be classified as a stratocumulus cloud, which in many parts of the world is considered to be the most common cloud type. The stratocumulus cloud it's a low layer, formed by individual or a joined-up series of clumps, better known as cloudlets [1]. Stratocumulus clouds tend to be the sign of bad weather approaching, or for the contrary, they formed after a bad weather cell has dissipated [2]. Furthermore, an interesting fact is that these cloud formations tend to

block the sunlight, letting that light sometimes pass through its structure forming a scattered ray pattern, better known as crepuscular rays [3].

As mentioned previously, the picture was taken on April 8th, 2012 around 2:00 p.m. mountain time, which corresponds to 21Z in Zulu time. However, Skew-T plots are only available twice a day for each day; at 00Z and 12Z. For this reason, the Skew-T that better matched our case was the one issued on April 9th at 00Z, which is basically three hours apart. Moreover, another limitation of the Skew-T plot is the location in which the weather data is taken. Therefore, the closest Skew-T plot for our case was the city of Denver, Colorado (Fig. 2).

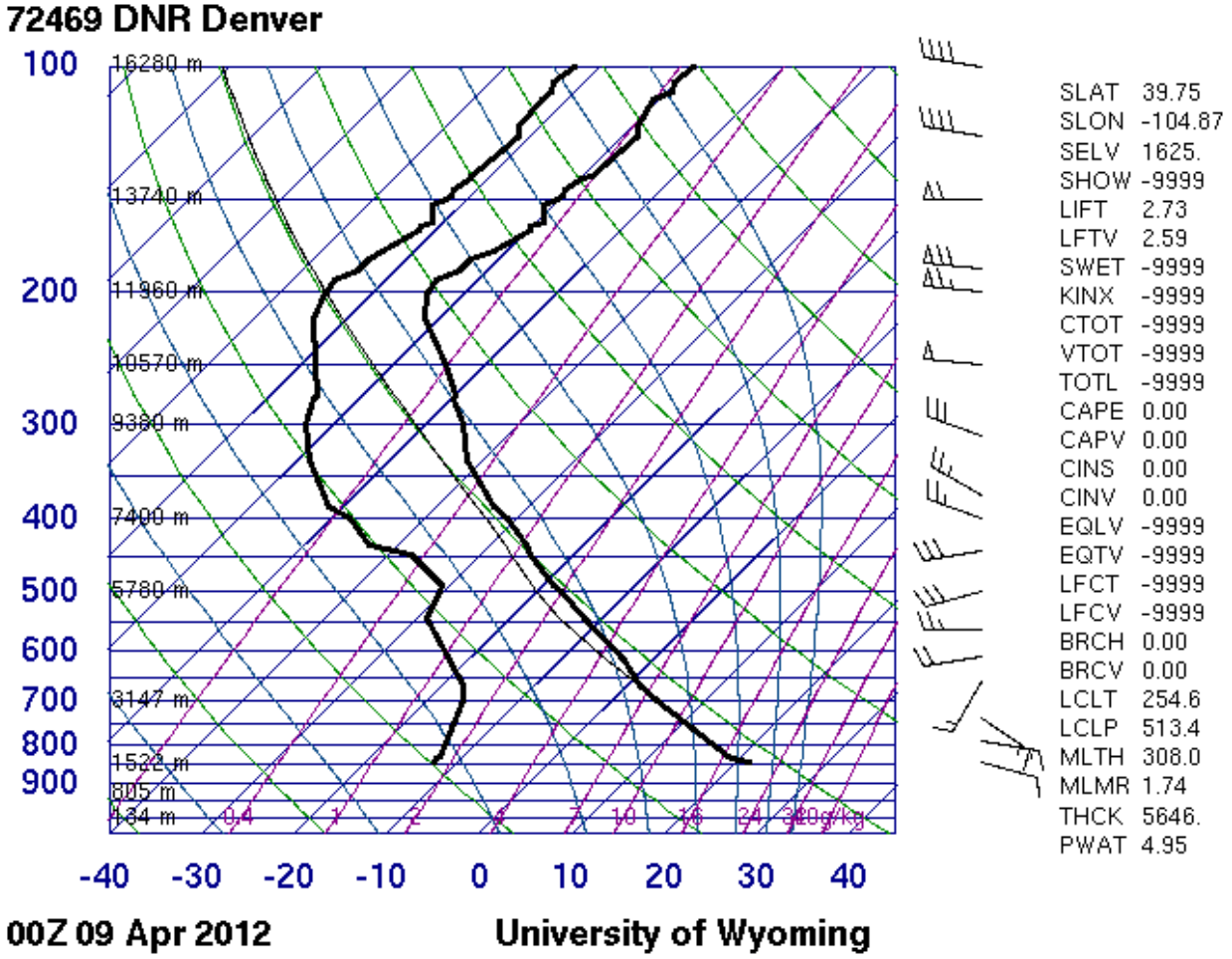

Figure 2. Skew-T plot for Denver (April 9th, 00Z)

Source: http://weather.uwyo.edu/upperair/sounding.html

Besides the Skew-T plot, weather forecast data was collected from weather spark to better understand the conditions in which the cloud was formed. Figure 3 shows the cloud coverage, wind speed and direction, and temperature profile for April 8. It is appreciable from the Skew-T plot that the atmosphere was stable by the time the picture was taken. This can easily be stated by looking at the Convective Available Potential Area (CAPE) value on the right side of the Skew-T plot. In our particular

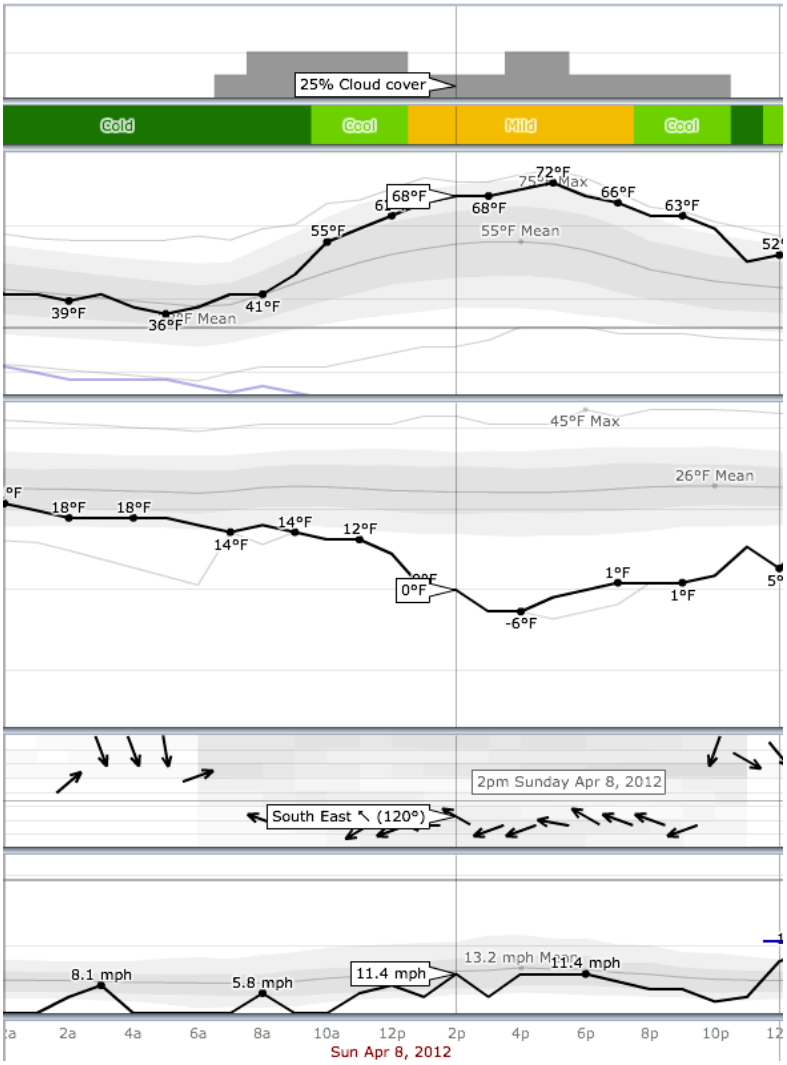

Figure 3. Golden's weather data for April 8, 2012

Source: http://weatherspark.com/

case the CAPE value is zero, corroborating the statement of a stable atmosphere made previously. In addition, if the CAPE value is not found, it is possible to predict an unstable atmosphere by looking at the adiabat and the environment temperature line. If neither crosses each other, it can be said that the atmosphere is somewhat stable, otherwise, is unstable. Furthermore, looking at the weather data corroborates the behavior of the cloud seen that day, which was moving towards the mountain and the sky was pretty much clear with few cloud formations.

In some cases where the Skew-T plot is not available, it is possible to find the cloud base height by knowing the dry bulb and the dew point temperature. The following expression can by used to calculate the cloud base height [4].

$$H_b = \frac{T_{db} - T_{dew}}{0.008021} \qquad (1)$$

Where T_{db} is the dry bulb temperature, T_{dew} is the dew point temperature, and H_b is the cloud's base height. Based on the weather data, the dry bulb temperature was 68°F (20°C) and the dew point temperature was 0°F (-17°C). Therefore, the cloud base height using (1) was 4.613 Km (4613m).

Photographic Technique

To capture the image a Nikon D5100 DSLR camera was used in manual mode to have more control over the image exposure. The lens attached to camera was an 18-55mm focal length range lens with an aperture range of f/3.5-5.6. Since the shot was taken in the middle of the day where a lot of light was present, an f/11 aperture and a shutter speed of 1/500 sec were chosen. Likewise, an ISO 100 was chosen to decrease the light sensitivity of the sensor as much as possible. Also, a large depth of field

(f/11) was chosen to capture in focus the turbine at the foreground and the clouds at the background. The software Adobe Lightroom was used to crop, enhance the photo and to change it to black and white since the original version was not so interesting.

Table 1. Image Specs

Date and Time	April 8th, 2012 2:00 pm
Camera	Nikon D5100 DSLR Camera
Lens	Nikkor 18-55mm f/3.5-5.6
Aperture	f/11
Shutter Speed	1/500 sec
ISO	100
Focal Length	55mm
Direction	South
Location	National Wind Technology Center (NWTC), CO

Stratocumulus clouds are characterized for being dark and to be signed of bad weather. However, they are the most common cloud types seen all around the world and their nature let them interact with the landscape in an interesting way. For this reason, what I like most about my image is the fact that the cloud seems to be originated out off the horizon. The artistic setting of the turbine on the right side of the frame gives this image a its uniqueness.

Figure 4. Final version (top) and original version (bottom)

References

[1] The Cloud Collector's Reference. Retrieved February 25, 2012 from http://cloudappreciationsociety.org/collecting/mick-ohrberg/

[2] Wikipedia, “Stratocumulus clouds”. Retrieved from http://en.wikipedia.org/wiki/Stratocumulus_cloud

[3] The Great British Weather. “Cloud Spotting Guide”. Retrieved from http://downloads.bbc.co.uk/tv/greatbritishweather/cloudspottingguide.pdf

[4] WolframAlpha, Retrieved February 25, 2012 from, Web site: http://www.wolframalpha.com/input/?i=cloud+base+height&f1=97+°F&f=CloudBaseHeight.Tdb_97+°F&f2=37+°F&x=9&y=8&f=CloudBaseHeight.Tdew_37+°F

[5] Atmospheric Soundings: Wyoming Weather Web (2012). Retrieved February 25, 2012 from University of Wyoming, Department of Atmospheric Science Web site: http://weather.uwyo.edu/upperair/sounding.html

[6] SKEW-T, LOG-P DIAGRAM ANALYSIS PROCEDURES (2007). Retrieved February 24, 2012 from, Web site: http://www.met.tamu.edu/class/atmo251/Skew-T.pdf