Analysis of wind shear in Sulafjorden

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Introduction

The E39 is a 1100 km highway route that connects Kristiansand to Trondheim (Figure 1). The E39 connects some of the largest Norwegian cities such as Kristiansand, Stavanger, Bergen, Ålesund, Molde and Trondheim.

The purpose of Ferjefri E39 project is to design a ferry-free highway route. Analysis of wind conditions and wind flow characteristics are essential for bridge design. The present study investigates monthly variability of the wind shear in Sulafjorden (Figure 1), which is one of the Norwegian fjord that E39 crosses. The analysis is based on one year of wind measurements, but the results are illustrated for one month chosen per season.

Figure 1. E39 highway route
(Source: vegvesen.no)

Theory and Results

The wind profile power law equations is :

$$\frac{u}{u_r} = \left(\frac{z}{z_r}\right)^{\alpha}$$

where U and U_r are the wind speeds (m/s) at height z and z_r (m) respectively. The wind shear or power law exponent (α) is a dimensionless coefficient that describes the wind shear and is widely used for wind energy applications [2]. The α exponent is depending on atmospheric stability [3], [4]. For neutral conditions, α is approximately 0.14 onshore. For offshore conditions, it is suggested that α equals to 0.11 is a good approximation [5].

For this study, wind measurements at heights 44.5 m and 92.5 m (period: 01.2017-12.2017) from the met mast at Kvitneset (Figure 2) has been used. The met mast is located at the northwest fjord entrance. Southwest of the met mast, there are mountains with heights of 627 m and 570 m.

Figure 3 illustrates the wind shear exponent as a function of wind direction at 92.5 m for a reference height of 44.5 m for one month per season in 2017. The different color indicates the different wind speed levels.

Figure 4 shows the wind shear exponent as a function of wind speed at 92.5 m for a reference height of 44.5 m for one month per season in 2017. The black color indicates wind directions from 150 to 200 degrees and the blue color wind directions from 250 to 300 degrees.

Location of Measurements

Figure 2. Location of met mast (orange pointer) in Sulafjorden
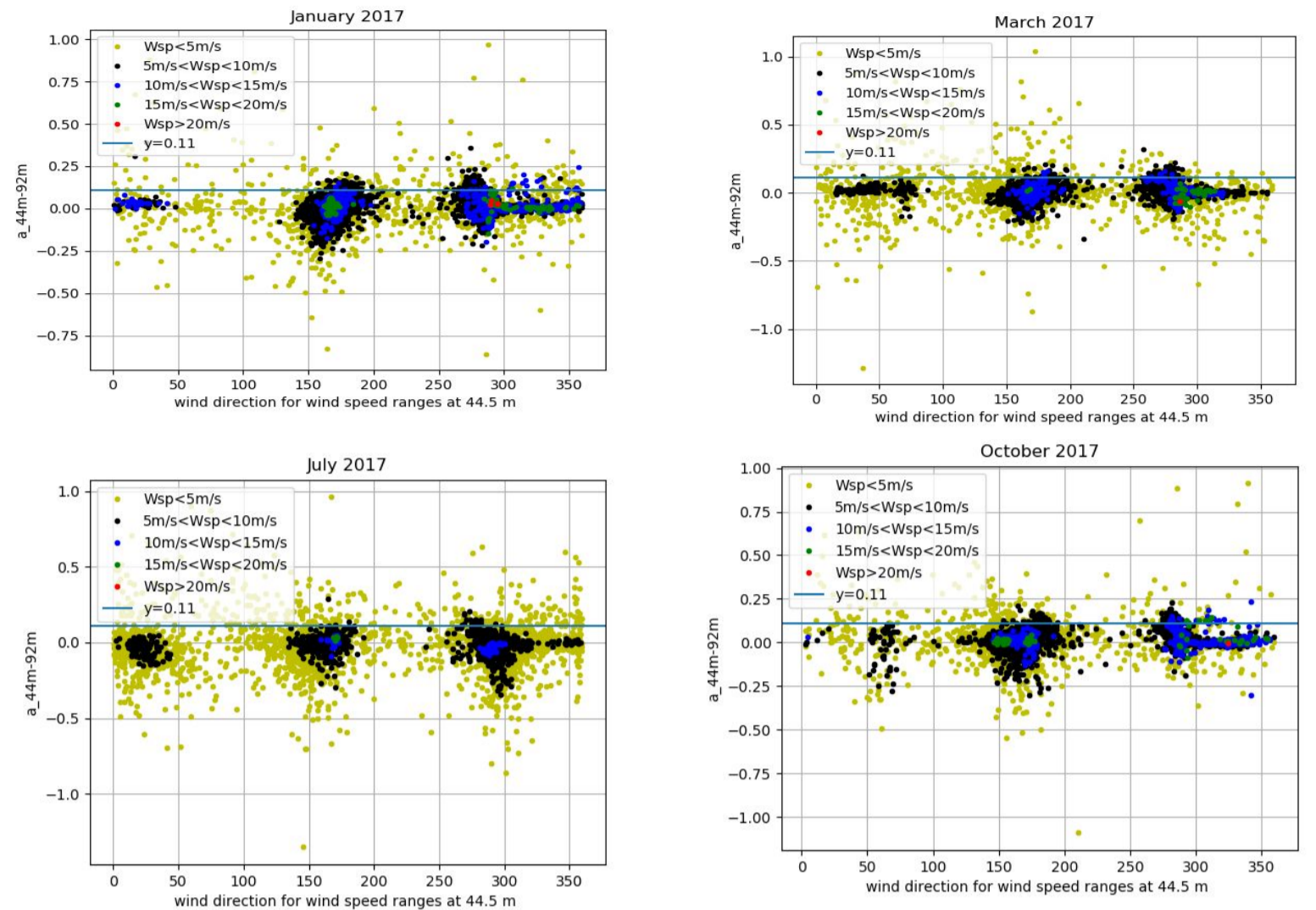(Source: Kartverket)

Figure 3. Wind shear exponent as function of wind direction for January 2017 (Top left), March 2017 (Top right), July 2017 (Bottom left) and October (Bottom right) in Sulafjorden
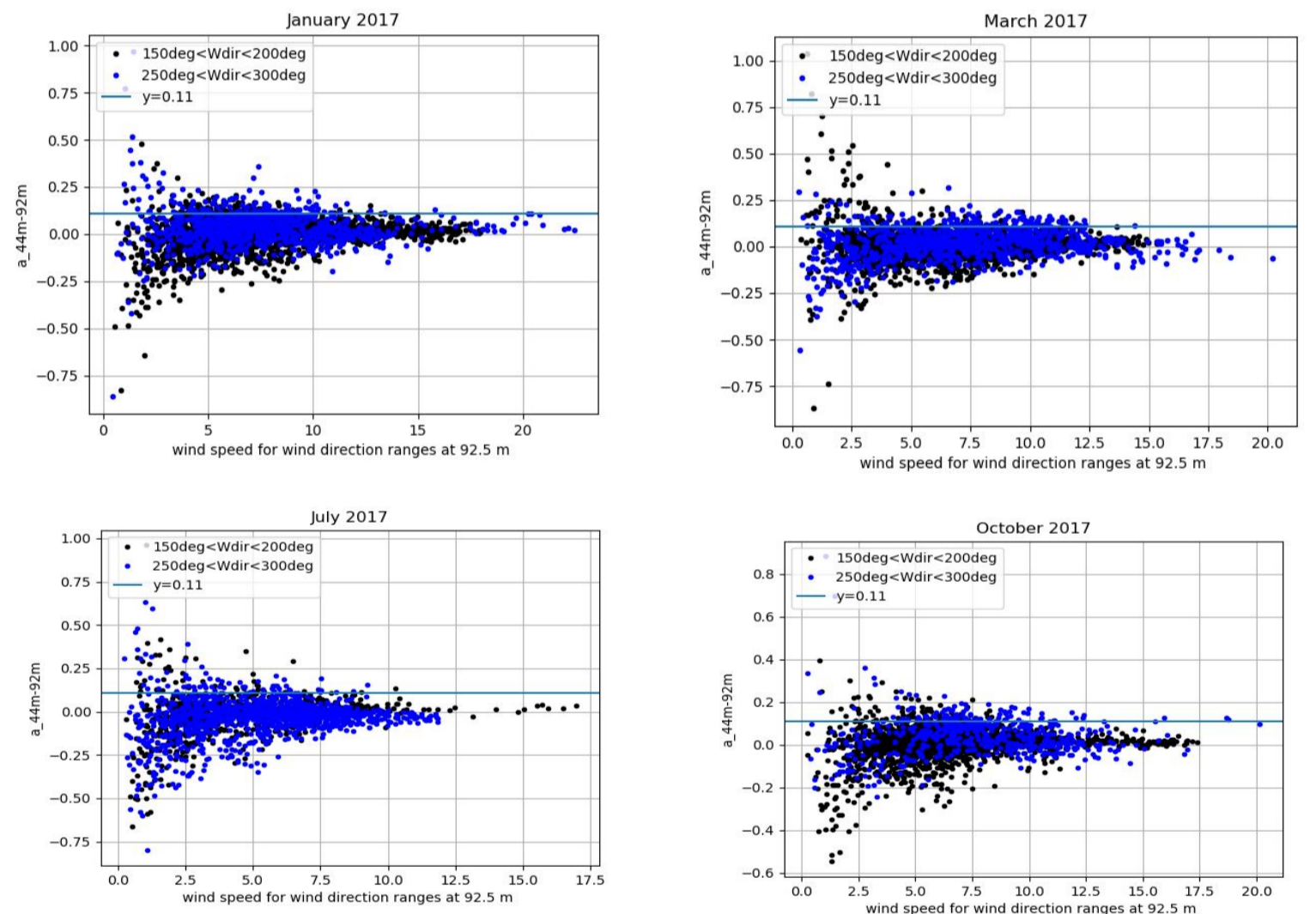

Figure 4. Wind shear exponent as function of wind speed for January 2017 (Top left), March 2017 (Top right), July 2017 (Bottom left) and October (Bottom right) in Sulafjorden for 150 to 200 and 250 to 300 degree in wind direction

Conclusions

The results for Sulafjorden show:

- The strongest winds were mainly observed from southeast and northwest.
- For moderate to high wind speed, the wind shear coefficient tends to decrease to values lower than 0.11 (suggested for offshore conditions).
- For low wind conditions, high absolute values of wind shear coefficient are observed.
- The month of June shows the highest value of wind shear coefficient. The maximum value is 2.51 while the minimum value 0.09 in November.
- The monthly rms value of wind shear fluctuates between 0.09 in November to 0.29 in June, which shows the limitation of using the value of 0.14 onshore and 0.11 ofshore for design purposes.

Acknowledgments

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