Frequency of winds in various terrain

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Introduction

The frequency of wind speeds in complex terrain is related to the orography. The terrain can both enhance and reduce wind speed, depending on its size and shape, wind speed, static stability etc. It is common to approximate wind speed frequency with the Weibull distribution. Although the distribution may not be appropriate in complex terrain it may be of value to see how complex wind field is characterized by the distribution. Here we calculate the Weibull parameters for observations from 70 stations in Iceland. The stations are divided into seven categories depending on the location and complexity of orography (Figure 1).
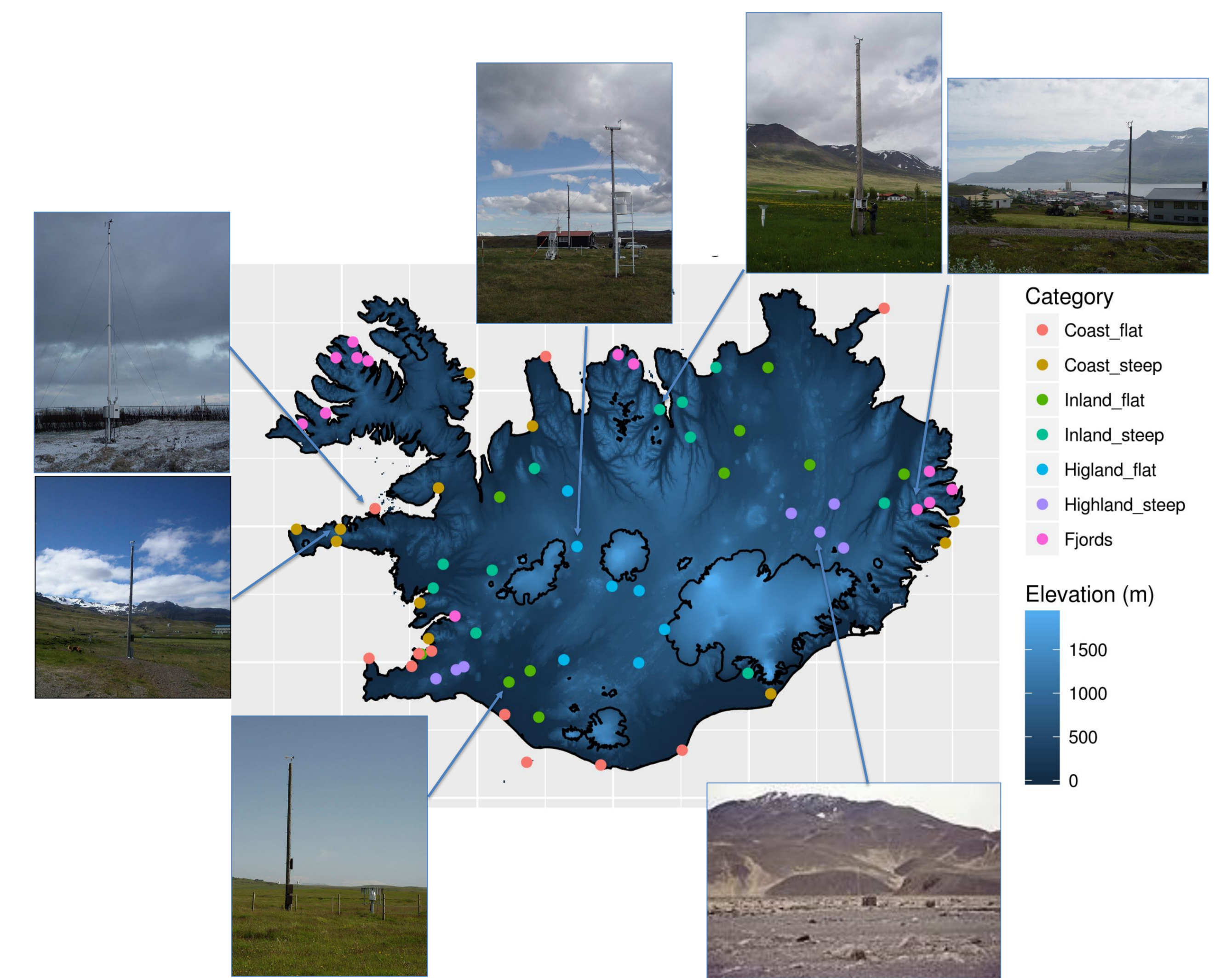

Figure 1. The selected weather stations divided into categories, depending on location and nearby orography. The map shows the orography of Iceland, 1 km resolution. One station in each category is represented in the photos.

Weibull distribution of wind speed

The two-parameter Weibull distribution is expressed as

$$f(v) = \frac{k}{A}\left(\frac{v}{A}\right)^{k-1} e^{-\left(\frac{v}{A}\right)^k}$$

where f(v) is the frequency of occurence of wind speed v, A is the scale parameter and k is the shape parameter. If the wind regime at a site can be described with a Weibull distribution, the potential wind energy production can be estimated given a power curve.

Results

Figure 2 shows maps of the Weibull parameters while Figure 3 boxplots for each category. The scale parameter, A, has the highest values in regions of high wind speed, in the highland as well as on coastal points, and lower values in fjords and inland. The boxplot shows that for coastal regions the spread of values is the largest. The shape parameter, k, has the largest values again at coastal points but the lowest values, and least spread, for the fjord-category. Some stations in complex orography have shape parameters of similar values, e.g. on each site of the Snæfellsnes Peninsula, where downslope windstorms are common.
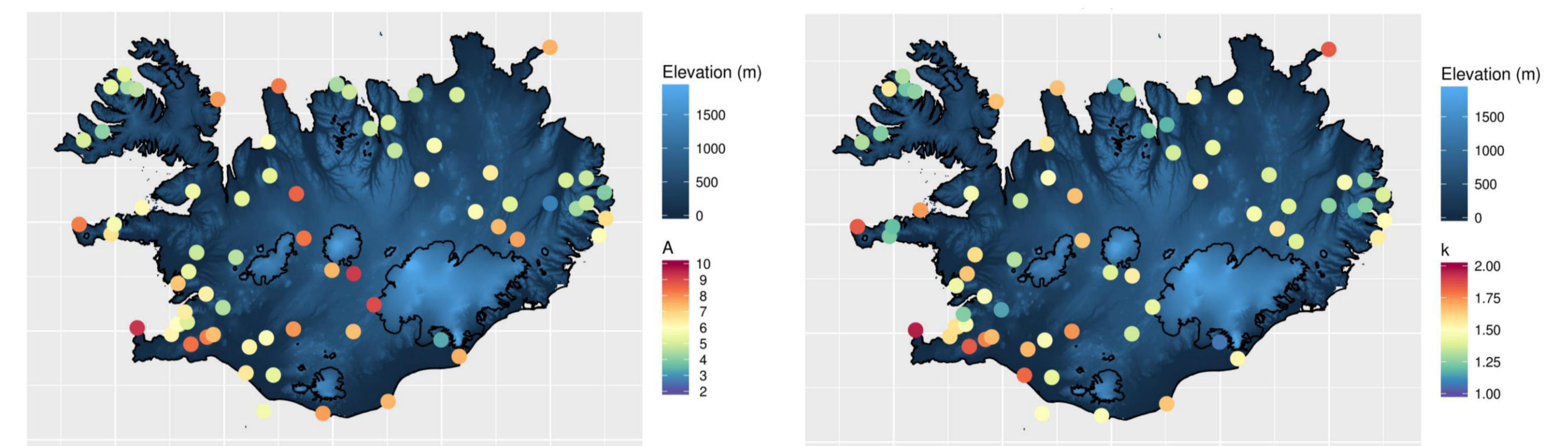

Figure 2. For each station the Weibull parameters (a) the scale parameter A (m/s) and (b) the shape parameter k.
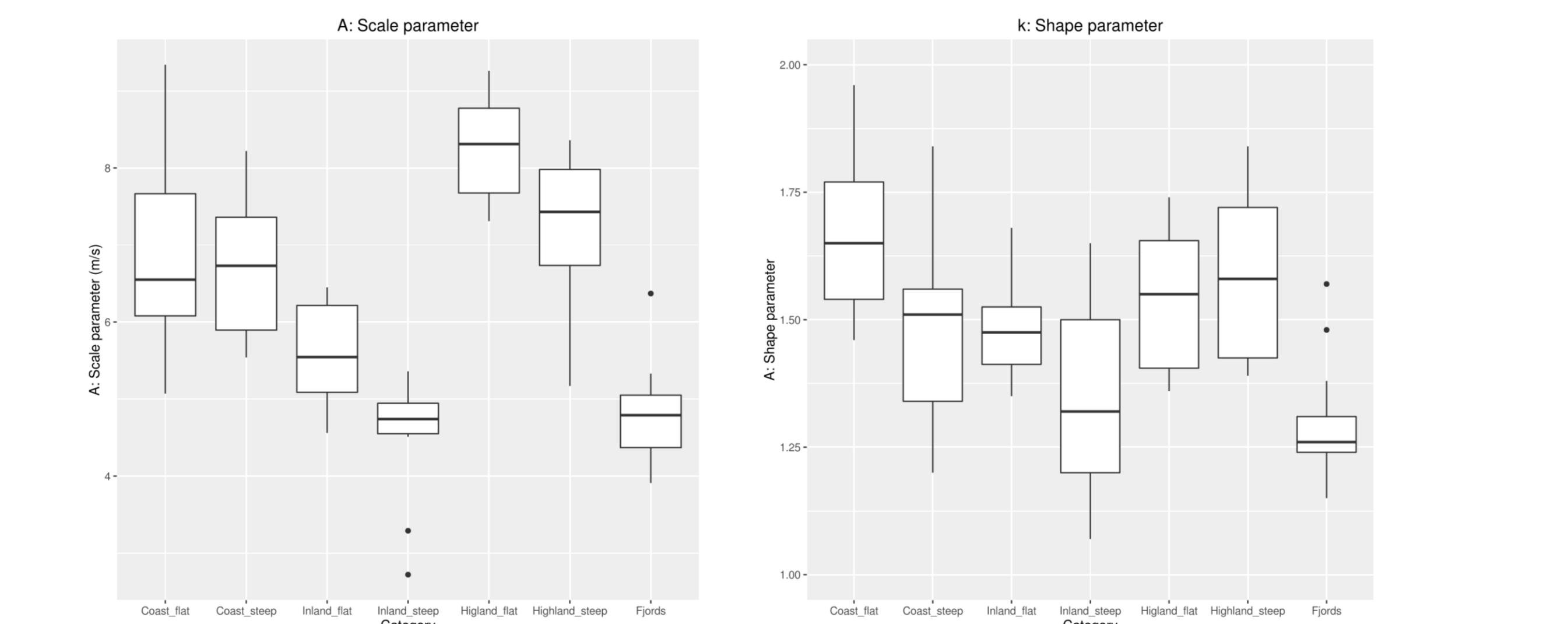

Figure 3. Boxplots of the a) scale parameter A (m/s) and (b) shape parameter k for each category.

Wind speed frequency

Figure 5 shows the annual wind speed frequencies at the stations shown in photos in Figure 1. The figure shows that the stations in complex orography have a higher frequency of very low wind speeds and an indication of longer righthand tails, indicating how complex orography may shelter the stations in certain situations while enhancing the wind speed in other.
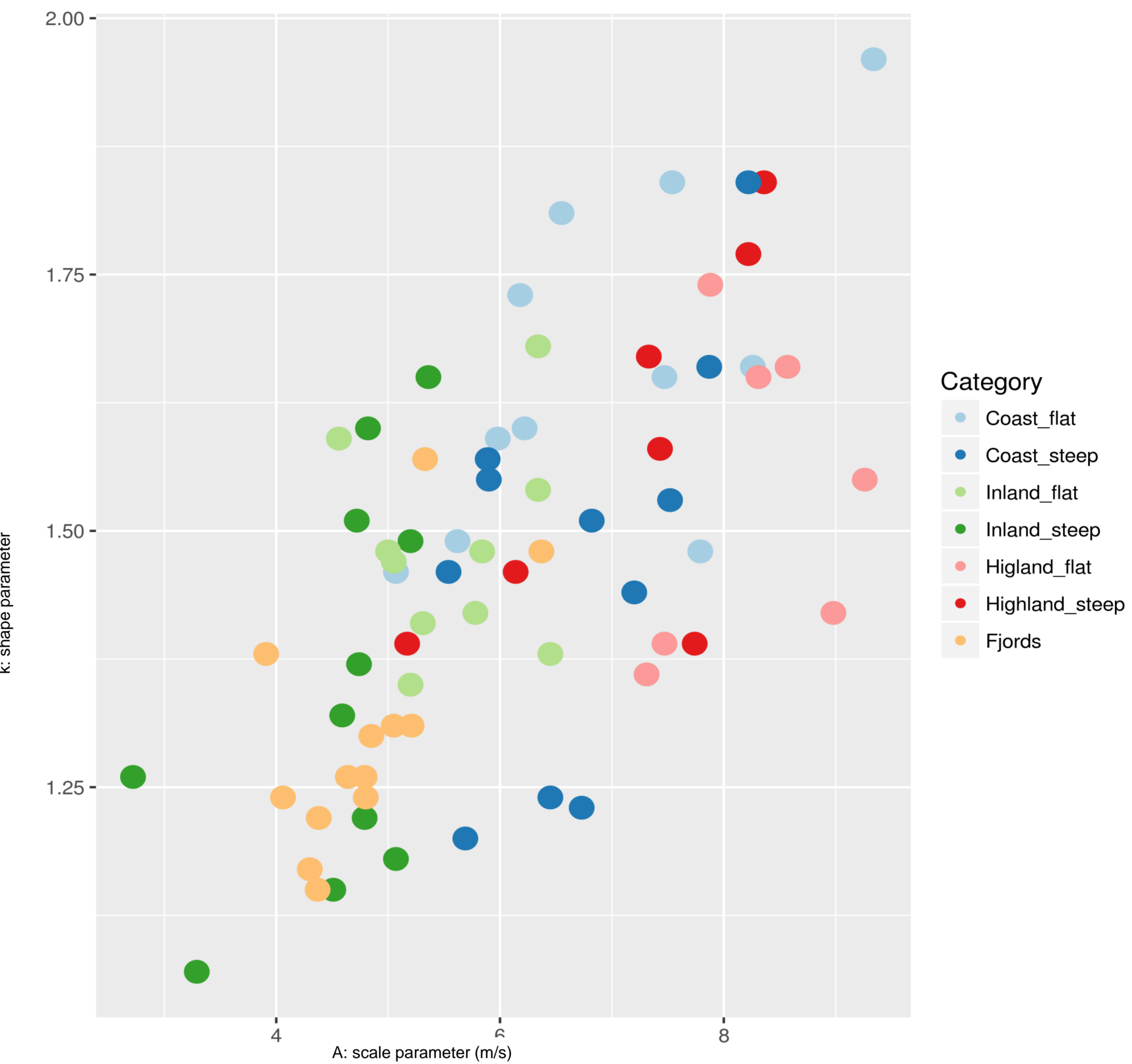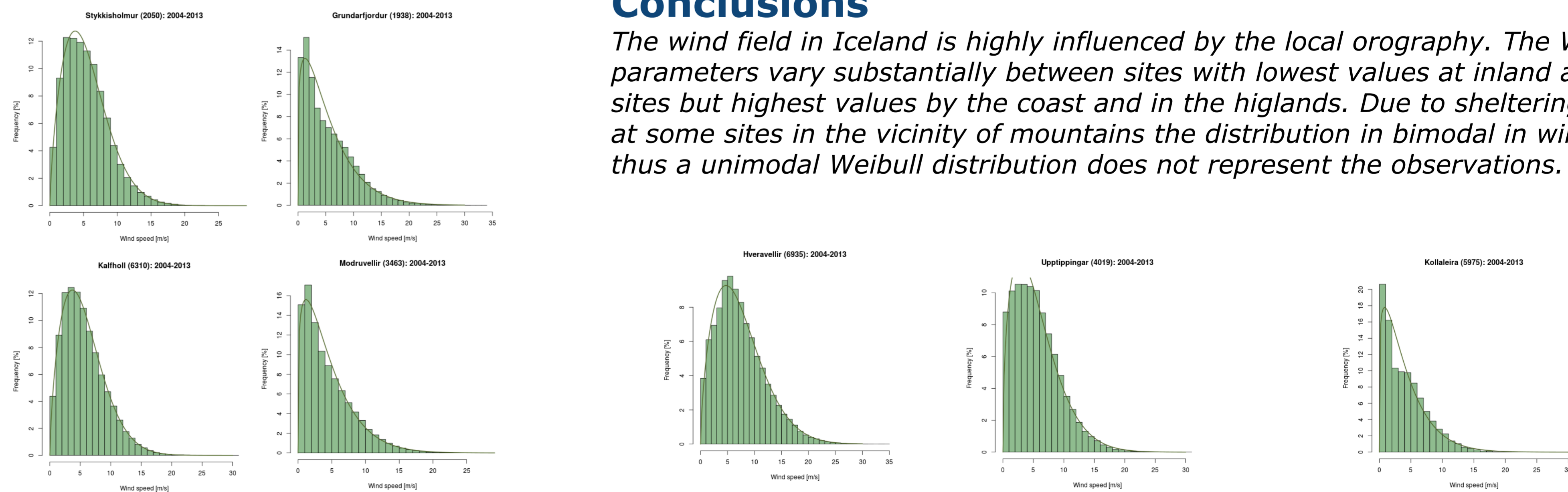

Figure 4. A scatter plot of A and k.

Results

A scatter plot of A and k, coloured by the category, shows that inland stations and fjord stations tend to have the lowest values of both parameters, with very similar values for fjord stations and inland stations in complex orography (Figure 4).

There is little difference in the scatter of highland stations with and without complex orography nearby. This difference between the impact of orography in the highland and the lowland is most likely due to the terrain in the higland being more open than in the lowlands, where the complex orography is dominated by relatively valleys and fjords.

Conclusions

The wind field in Iceland is highly influenced by the local orography. The Weibull parameters vary substantially between sites with lowest values at inland and fjord sites but highest values by the coast and in the higlands. Due to sheltering effects at some sites in the vicinity of mountains the distribution in bimodal in winter and thus a unimodal Weibull distribution does not represent the observations.