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Wind Pattern Effects on the Southern Shetland Islands

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Abstract

The Shetland Islands, northeast of Scotland, experienced an unusually extreme storm that caused unique sand shifting patterns and sand dune formations that resulted in the destruction of the Village of Broo. There is little existing information about the weather and terrain of the Shetland Islands during the extreme storm that was estimated to have occurred between 1650 and 1670. WindNinja, a wind model originally developed for wildland fire application, was used to understand the wind patterns that may have caused the unique sand patterns and resulting destruction. It incorporates existing terrain elevations and vegetation as well as average wind speed and direction to produce spatially varying wind patterns. Because unique sand patterns were created by the storm in question, it was determined that the prevailing southwest wind was not the cause of the sand patterns, but the prevailing wind was used as the basis to analyze the reliability of the model. Analyzing the model output of several average wind directions and speeds aided in the determination of potential causes of the sand patterns and dune formations. The results of the model suggest that the output depends most significantly on the average wind direction input and the ground terrain as defined by the digital elevation model.

Introduction

Northern Scotland, including the Shetland Islands, is the windiest area in the United Kingdom.

Figure 1: 1906 Shetland Islands Map

The windiest season is winter and from December to February the Shetland Islands frequently experience storms with wind gusts between 100 and 150 miles per hour.

The southern tip of the Shetland Islands experienced a large storm in the mid-1600's that resulted a significant damage to the village of Broo and a series of unique sand formations. Wind modeling software was used to simulate different wind patterns (speed and direction) that may have caused the destruction and sand shifting patterns.

The wind model results can be used in conjunction with additional research to build a plausible hypothesis for the cause of the destruction and sand formations.

Data & Methodology

The wind modeling software, WindNinja, was developed by the Rocky Mountain Research Station's Fire Sciences Laboratory to compute spatially varying wind fields for wildland fire applications. The software has been repurposed in this project to simulate terrain effects on wind flow in the Shetland Islands.

WindNinja simulates the spatial variation of wind for one instant in time. The required inputs include:

- Digital Elevation Model
- Domain Average Wind Speed – 150 mph
- Domain Averaged Wind Direction - Varied
- Dominant Vegetation - Grassland
- Output Resolution – Fine (71m)

The WindNinja algorithms manipulate the input data to produce spatially varying wind fields with unique wind vector direction and wind speed, as seen in the image to the right.

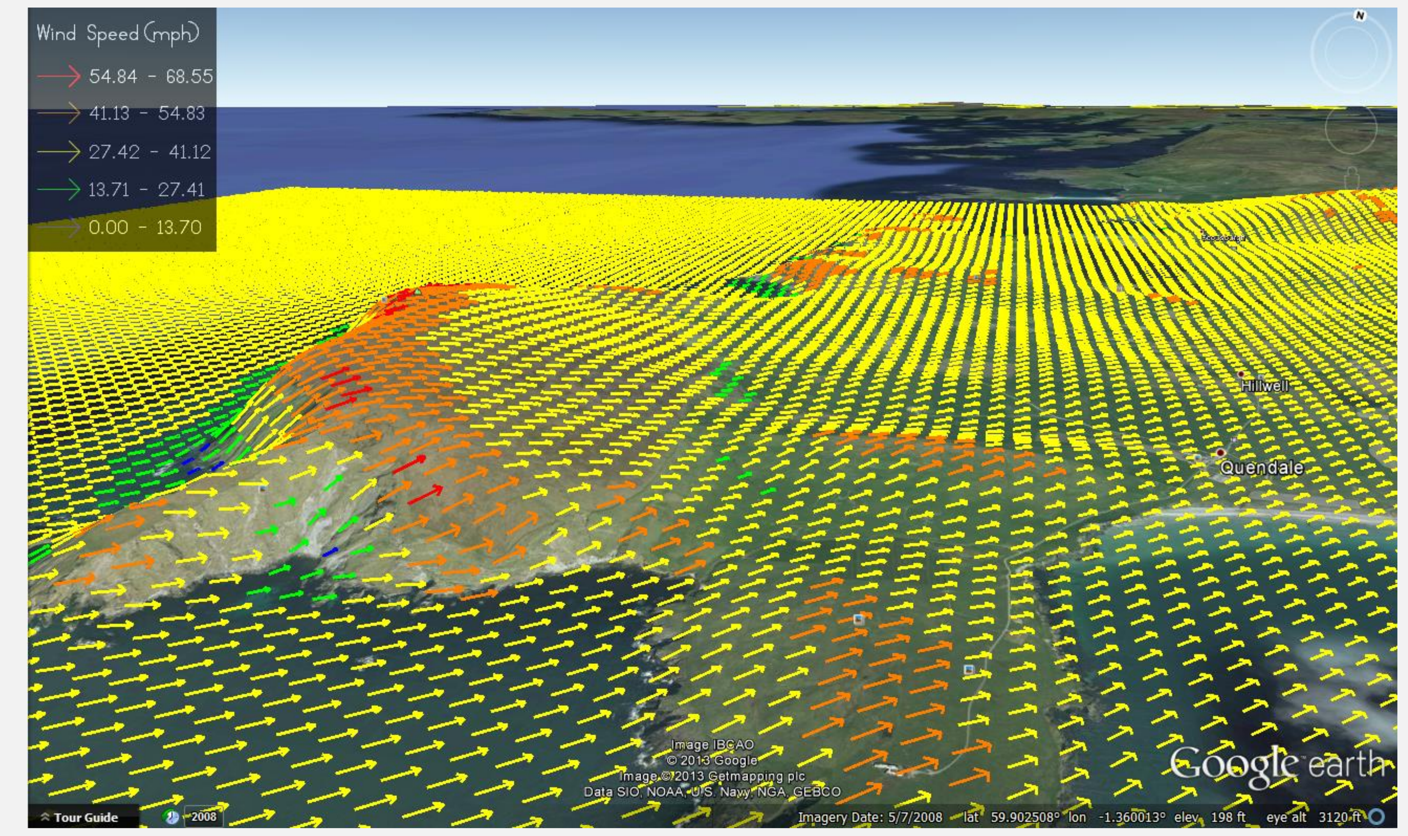

Figure 2: WindNinja Output Example Overlain on the Shetland Islands within Google Earth

WindNinja does have several limitations that include:

- Simplification of momentum equation
- Decreased accuracy near the boundary domain
- Inability to simulate buoyancy driven flows

Although the model limitations exist the results still provide a basis for creating a probable hypothesis.

The results are based on the inputs as previously outlined, with wind directions varying from north to south and east to west. Based on the prevailing southwest wind, several directions between south and west were further explored.

The WindNinja output creates a point file with each point having a resolution of 71 meters and a unique wind speed and direction. The point files were then converted to raster images, see Results, based on the wind speed. A review of the model results showed that the direction did not significantly vary based on the wind direction input, however the wind speed results produced a large range of values from the initial input. The wind speed input was 150 mph, while the results ranged from 26 – 265 mph.

Results

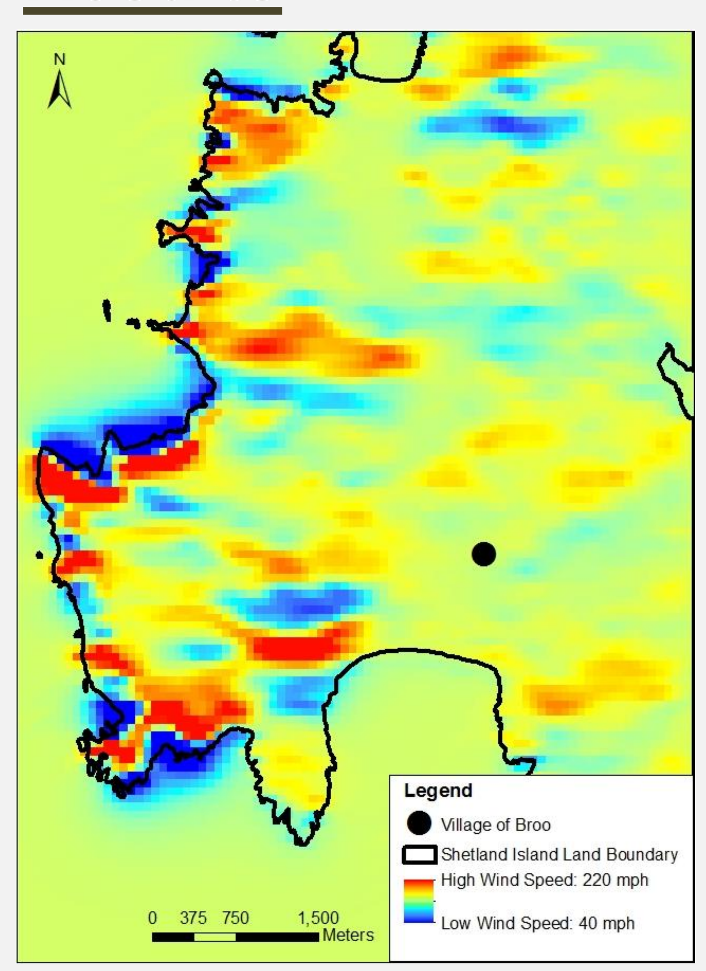

Figure 3: Prevailing North (360°) and South (180°) Wind

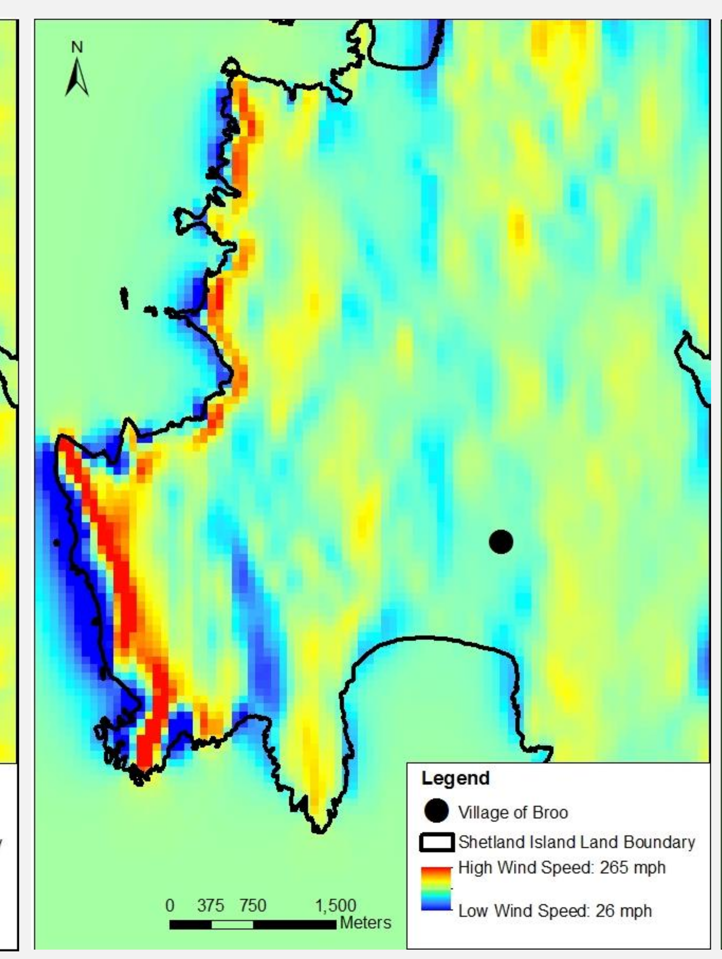

Figure 4: Prevailing East (90°) and West Wind (270°) - Degrees

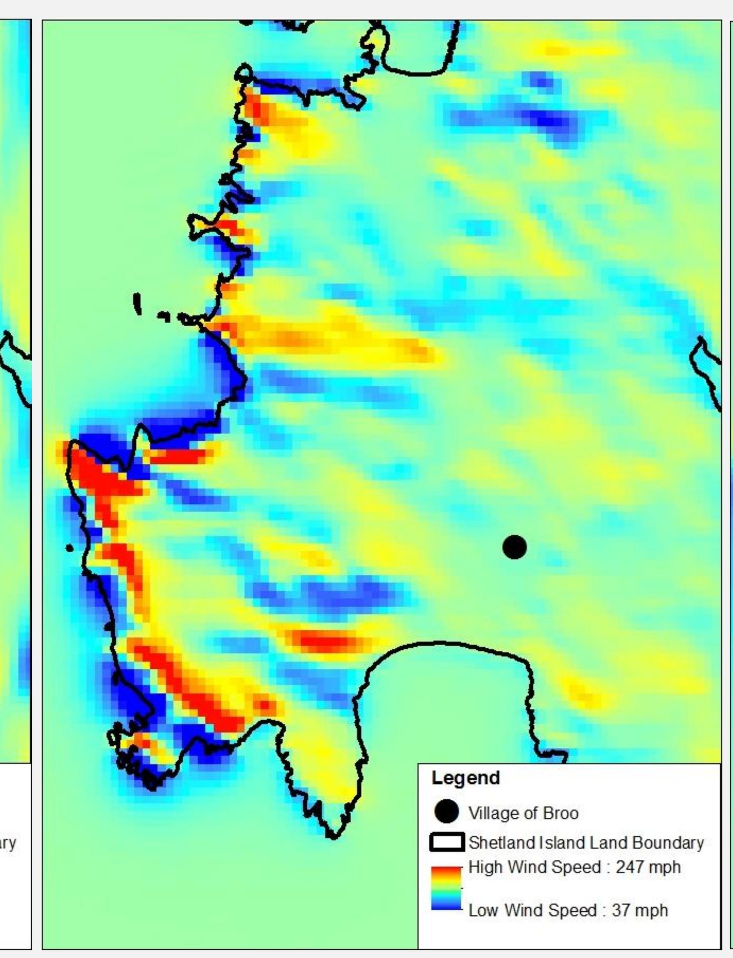

Figure 5: Prevailing South-Southwest (202°) Wind

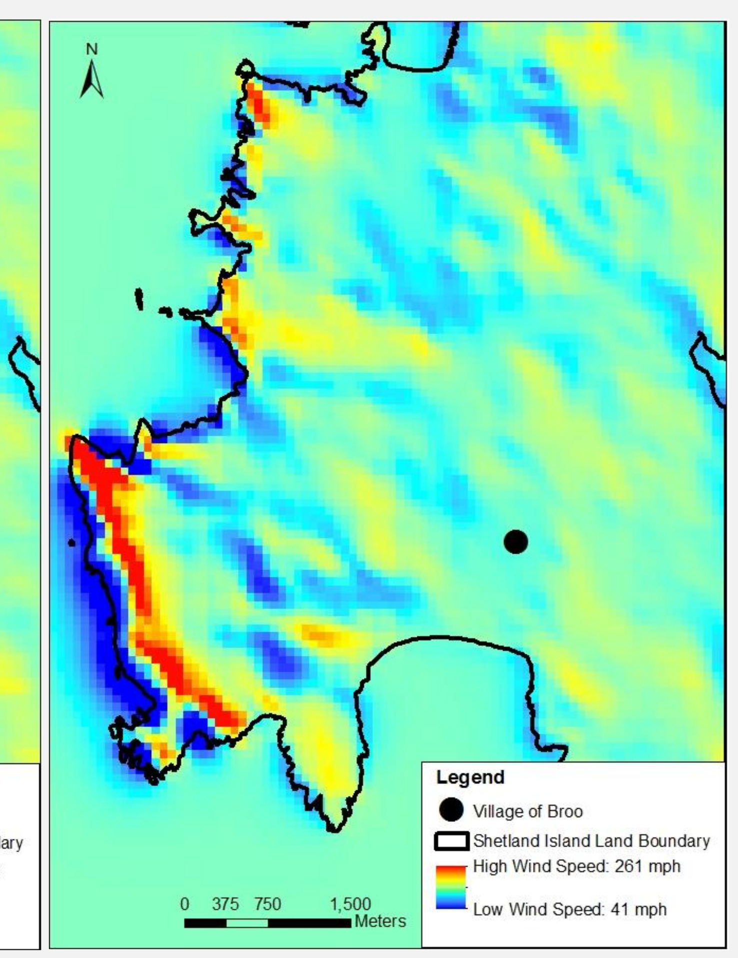

Figure 6: Prevailing Southwest (225°) Wind

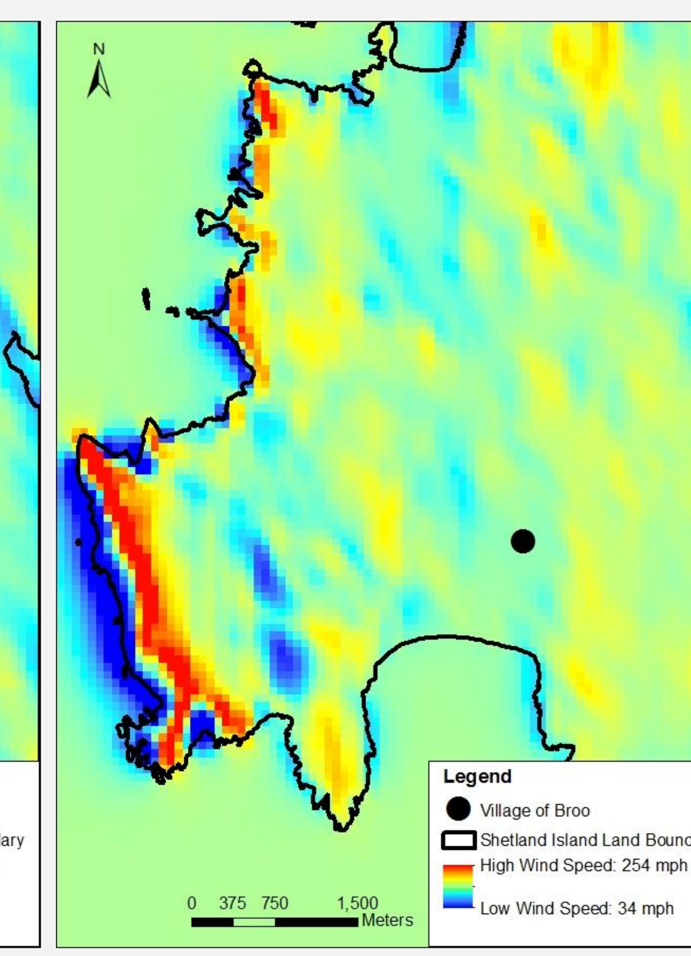

Figure 7: Prevailing West-Southwest (247°) Wind

Conclusions

The southern tip of the Shetland Islands, as seen in Figure 8, was the area investigated by this project.

Figure 9 shows the results of the model simulation for the area of interest under the prevailing southwest wind condition. This condition shows reduced wind speeds in the existing area sand inundation.

Sand dunes form under the following conditions:

1. Granules accumulate in an area devoid of vegetation (i.e. beach).
2. Significant wind speeds transport sand granules.
3. Granules settle into drifts and dunes as they accumulate against a stable barrier to the wind, such as vegetation or rocks.

Figure 8: Southern Tip of Shetland Islands

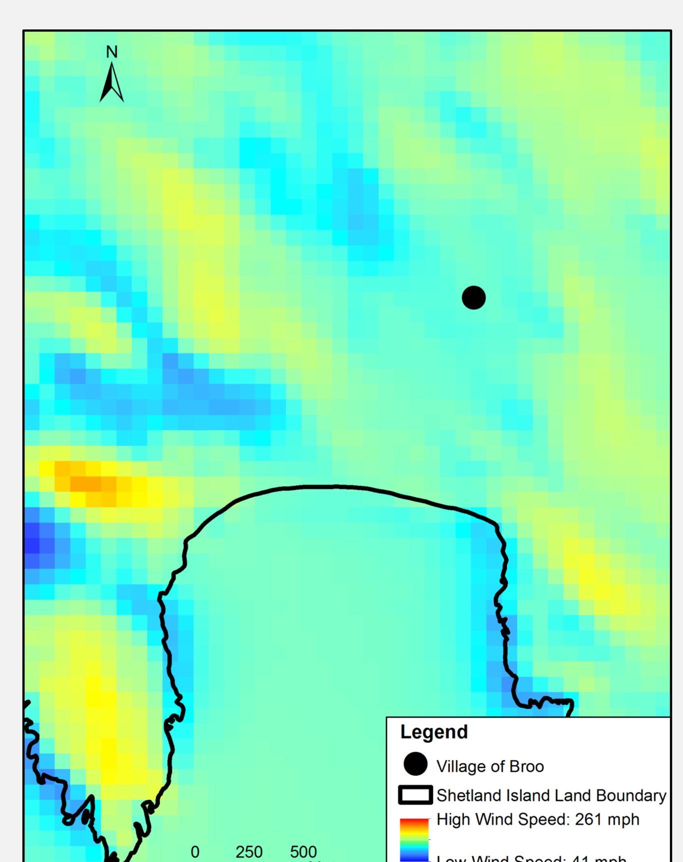

Figure 9: Prevailing Southwest Wind

Slower wind speeds deposit sand that is carried by the faster winds. The results of the model indicate several scenarios in which low wind speeds occur in the areas of interest.

According to the WindNinja output southwest (Figures 6 and 9) and west (Figure 4) winds appear to be the most plausible wind directions for the formation of the existing sand dunes.

The model output provides a basis for developing a testable hypothesis for the cause of the existing conditions.

References

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