Local Contribution of Windmill Turbulence to Muon Fluctuations

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Abstract

In a recent study Meisel et al. (2019), a strong Gaussian signature was found at the highest detectable frequencies in the Fourier spectra of muon flux received at Geneseo. Due to atmospheric attenuation, if these frequencies are purely acoustical they must be locally derived. One possible explanation for this local implication are two nearby windmill farms, in Dunkirk and Perry-Warsaw, New York. That these windmills radiate acoustical or turbulent energy is suggested by the “steady-state plumes” constantly seen on the Buffalo weather radar. A simple model of turbulence generation from the tips of the windmill rotors will be applied to the muon situation to evaluate the size of a local contribution to the observed muon fluctuation. This research was supported with a NY NASA Space Grant during 2018.

Muon Turbulence

When cosmic rays collide with the upper atmosphere, collisions and decays occur, in which muons are an important byproduct. We can detect these muons at the surface of the Earth because of relativity. Based on the data obtained from the SUNY Geneseo TeachSpin Muon detector, a clear correlation could be seen between muons and turbulence using Fourier analysis.

Windmill Turbulence

In order to further and solidify our findings, the windmill data was obtained for the surrounding areas of Geneseo. It was observed in the muon detected atmospheric inertial wave regions that there was a possible indication of the nearby wind farms causing a turbulent flow in the muons among other factors. The evidence that windmills exhibit turbulent flow is well known. Using a general model of a windmill turbine, analysis of the turbulent flow was examined. In order to do this, a general model was constructed from the Horns Rev offshore windmill farm.

The Fermi Problem

In order to use this data as a model, we have to use what is known as a fermi problem. A fermi problem is a “back of the envelope” calculation of a given problem. The some software had to be used in order to scale the measurements. Using ImageJ and Mathematica, the images were imported into the software. Then, the pixel measurement was done and compared to the actual measurement of the turbine. This yielded a pixel to meter ratio which could be used for that image to obtain the actual values. As a result, the size of the eddies could be measured which in turn allowed for a calculation of a Reynold’s number.

Reynold’s Number

The Reynold’s number is a dimensionless value that measures the ratio of the inertial forces to viscous forces and is an indicator of turbulent flow. From the scaled model, the size and flow velocity of the eddies could be measured. The International Standard Atmosphere was referenced to obtain an accurate measurement of the kinematic viscosity at ~500 m. Using the equation:

\[ R_e = \frac{v \cdot L}{\nu} \]

An average Reynold’s number was calculated via the size of the eddies and flow velocity. An average Reynold’s number of (1.09 ± 0.01) x 10^9 was calculated indicating a clear turbulent flow.

Results

In order to compare this model of windmill turbulence to the observed turbulence in the muon signature, the size of the eddy is interpreted as a wavelength in the flow, and thus an estimation of the frequency can be determined from the ratio of the flow speeds. This can then be matched to the frequency of turbulence seen by the muons. Using the Reynold’s number calculated, a crude estimate is determined. To compare to the muon spectrum, the log10 of the frequency was taken and plotted on the muon spectrum.

Summary

The usage of external data and scaling methods in this project provides a crude estimation for what is seen on the muon signature via the nearby windmill farms in Dunkirk NY and Perry-Warsaw NY. The use of the scaling properties yields results that give a plausible result as seen by the overlaid graph above. To further investigate, a more accurate scale model should be created through the dimensions of the nearby windmill farms.

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Image of Jupiter's Red Spot

A wall bounded flow where the turbulence begins shortly after the fluid hits the wall. Periodic disturbances to the laminar flow begin to grow, and after just a few wavelengths the fluid suddenly becomes turbulent. Source: Xjd4

A wind tunnel flow where the turbulence begins shortly after the fluid hits the wall. Periodic disturbances to the laminar flow begin to grow, and after just a few wavelengths the flow suddenly becomes turbulent. Source: Xjd4

Turbulent flow is exhibited throughout the universe. The surface of Jupiter is an excellent example. The picture (left) shows the eddies throughout Jupiter’s turbulent atmosphere as well as the famous Red Spot. Source: Xjd4

Flow analysis of a turbine wing. Notice the similarities between NASA's wall bounded flow image. Notice the eddy size is small where the stream speed is increased going around the side of the foil, and then periodically gets large. Source: Xjd4

Windmill Turbulence

Horns Rev Windmill Farm. The farm itself consists of over 80 turbines. The above shows the farm, and the eddies produced by the air moving around the windmill. These eddies exhibit turbulent flow.

Turbulent flow of the vane as seen in the above picture. The red arrows indicate turbulence. Eddies can be seen directly following the tip of the vane, which then follow into more chaotic flow. These can be measured and are necessary to calculate the Reynold’s number.

Above shows an estimation for the location of the windmill turbulent signature (yflow) overlaid with the muon spectrum. This makes sense as the Gaussian noise is unresolved, and this could explain the turbulent signature in this region.

The picture (left) shows the eddies throughout Jupiter’s turbulent atmosphere as well as the famous Red Spot. Source: Xjd4

A wall bounded flow where the turbulence begins shortly after the fluid hits the wall. Periodic disturbances to the laminar flow begin to grow, and after just a few wavelengths the flow suddenly becomes turbulent. Source: Xjd4

The Reynolds number is a dimensionless value that measures the ratio of the inertial forces to viscous forces and is an indicator of turbulent flow. From the scaled model, the size and flow velocity of the eddies could be measured.