Department of Physics and Society of Physics Students Seminar

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Atmospheric turbulence near the surface of the Earth

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Above: A linear array of 50 ultrasonic anemometers, spaced 5 meters apart and located 4 m above the ground, was used to measure turbulence structure over the flat, dry, and uniform ground near Tonopah, Nevada, during the summer of 2023. The measurements will be used to test a recent theoretical development.

ABSTRACT: Turbulence refers to the unpredictable variability of fluid velocity. It is a significant subject in physics, engineering, and Earth and environmental sciences because it efficiently transports fluid properties, such as pollutants, trace gases, temperature, and momentum, through mixing. Turbulence diffuses gradients and dissipates kinetic energy into thermal energy, homogenizing fluid properties. Turbulence usually occurs when the inertial forces of the flow are larger than the fluid's viscous forces. Turbulence can be generated via mechanical shearing or buoyancy forces (convection), but density stratification may suppress it. Kolmogorov's classical turbulence theory provides an easy conceptual model for idealized cases. Statistical methods are routinely used to describe and model turbulence, as it is computationally expensive to resolve it across the wide range of scales it spans. For example, weather prediction models based on the Navier-Stokes equations employ coarse grids and include additional terms that capture the turbulent momentum transport at small and unresolved scales. Modeling the effect of turbulence is an especially challenging problem near solid boundaries, such as the Earth's surface, because the boundary's presence limits the turbulent variations' size, and the Earth's surface is a source and sink of countless variables. This seminar aims to introduce these concepts and challenges and describe a recent research project to observe and improve the modeling of lower atmospheric turbulence.