Understanding the Effects of Turbulence on Falling Snowflakes

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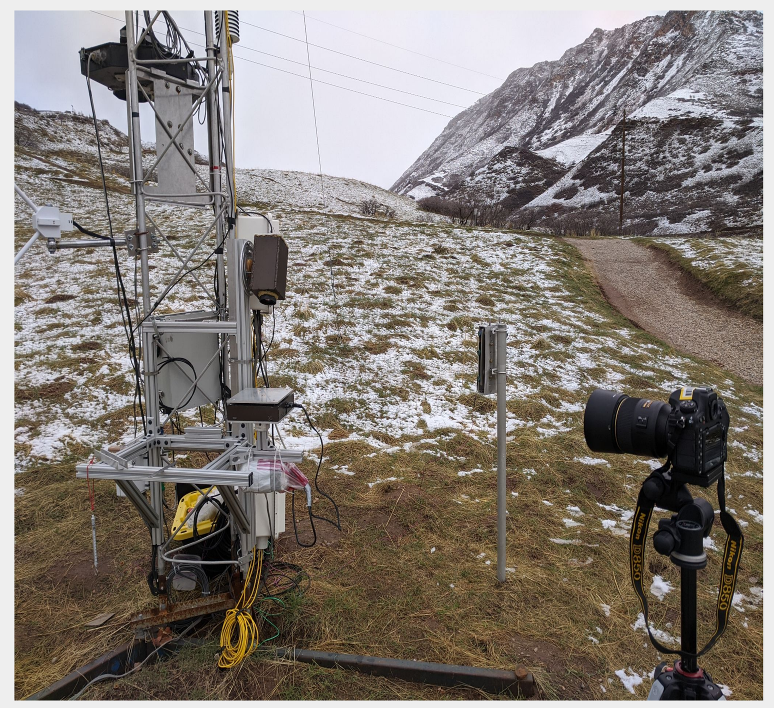
Abstract

Energy from turbulence in the surface layer can cause snowflakes to rotate, and finding a way to quantify how much energy could be important in understanding the life cycle of a snowflake. There is still much that is unknown about how snowflakes form and fall, and there is a particular lack of information about how turbulence affects the angular motion of a snowflake. The goal of this project was to track falling snowflakes using video imagery captured with the Snow Pixel instrument at Alta Ski Area, extract information on their rotation from the imagery data, and use that information to calculate the energy contributed by turbulence to the rotation of the snowflakes. The first attempt at analyzing the video imagery employed the *regionprops* toolbox in MATLAB. This was an issue, however, because there was no good way to properly track the snowflakes using just this toolbox. The *vision* toolbox gives access to machine learning algorithms for tracking moving objects, so a Kalman filter was used to track the snowflakes so that their properties could be analyzed.

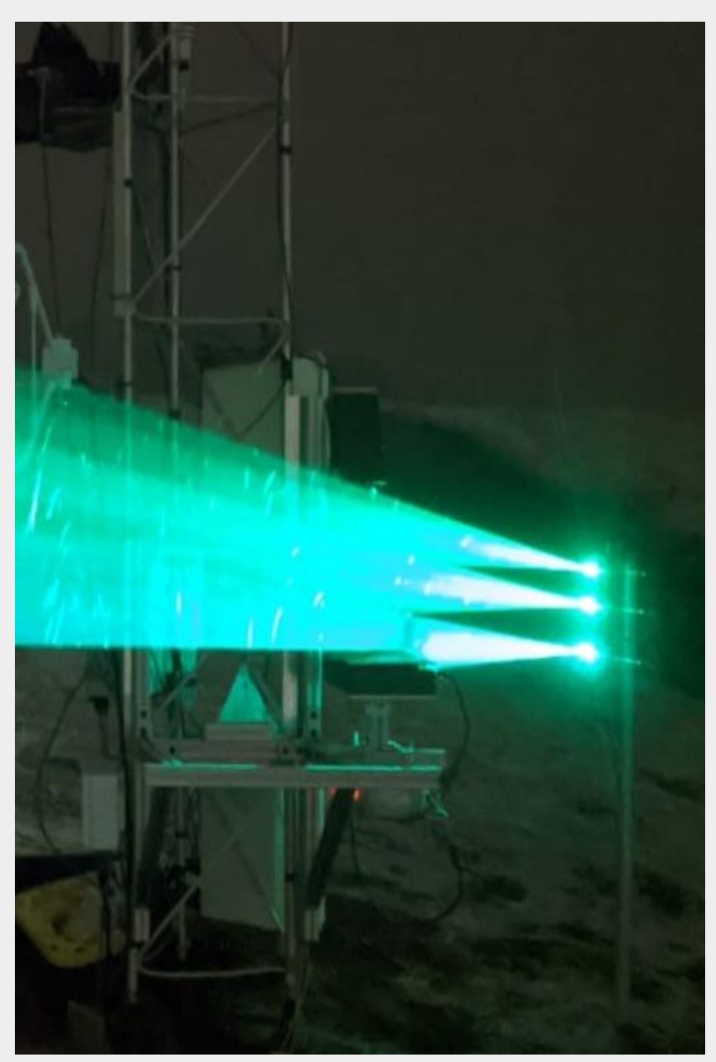
Background

The experiment in which this project is involved is designed to study snowflakes as they fall to gain a better understanding of how they accumulate. It employs several specially designed instruments, including the Multi-Angle Snowflake Camera (MASC), the Differential Emissivity Imaging Disdrometer (DEID), and the Snow Pixel. The MASC captures images of snowflakes from three different angles as they fall, which helps to determine the type of snow that is falling. The DEID is composed of a hotplate and a thermal camera, and it helps to determine the mass and density of a snowflake based on the time that it takes to evaporate. The Snow Pixel, which is of particular relevance to this project, is composed of three 10 watt lasers that create a sheet of light, illuminating the snowflakes that fall through it and allowing high quality video imagery of falling snow to be captured.

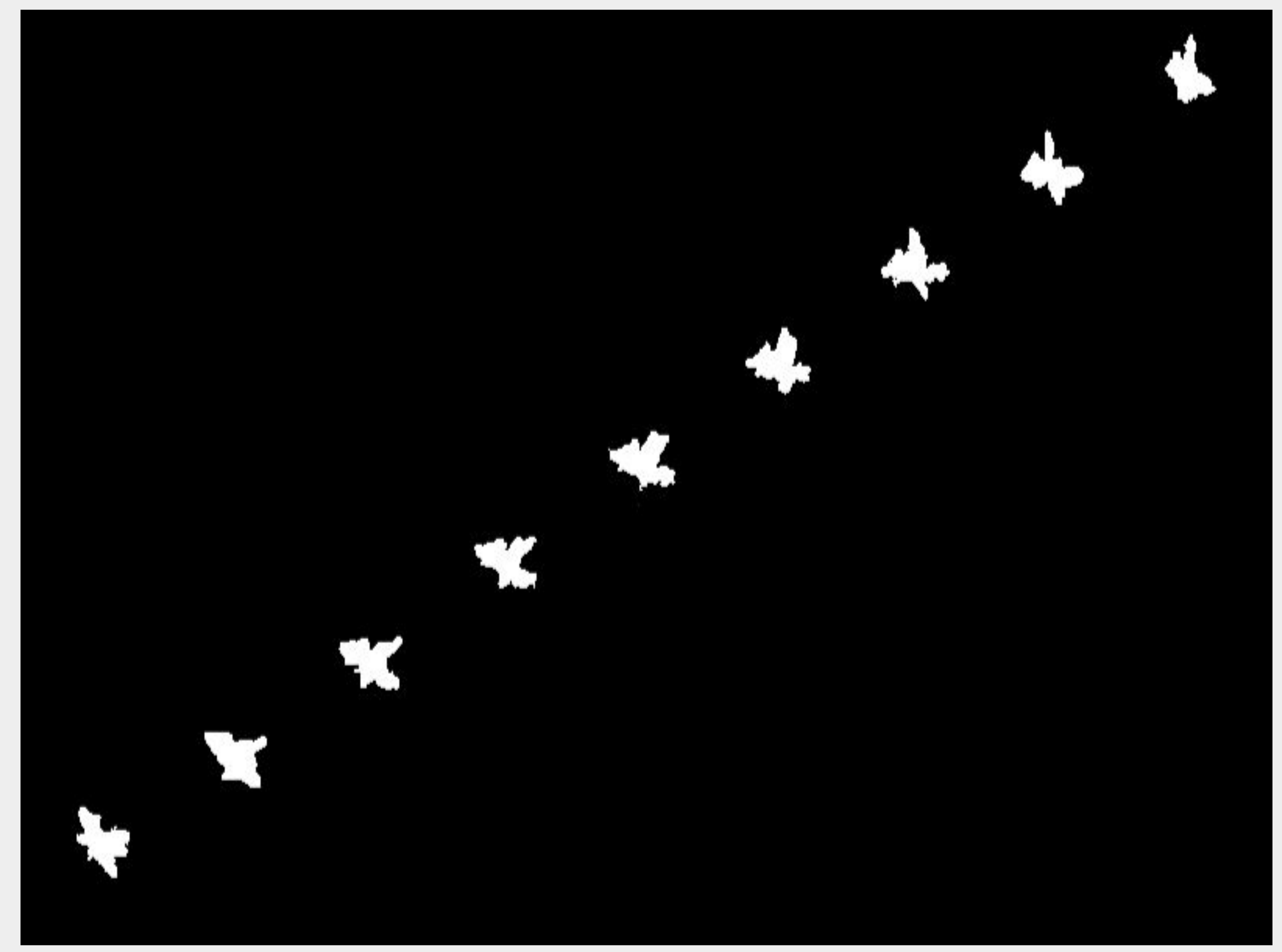
Data Collection

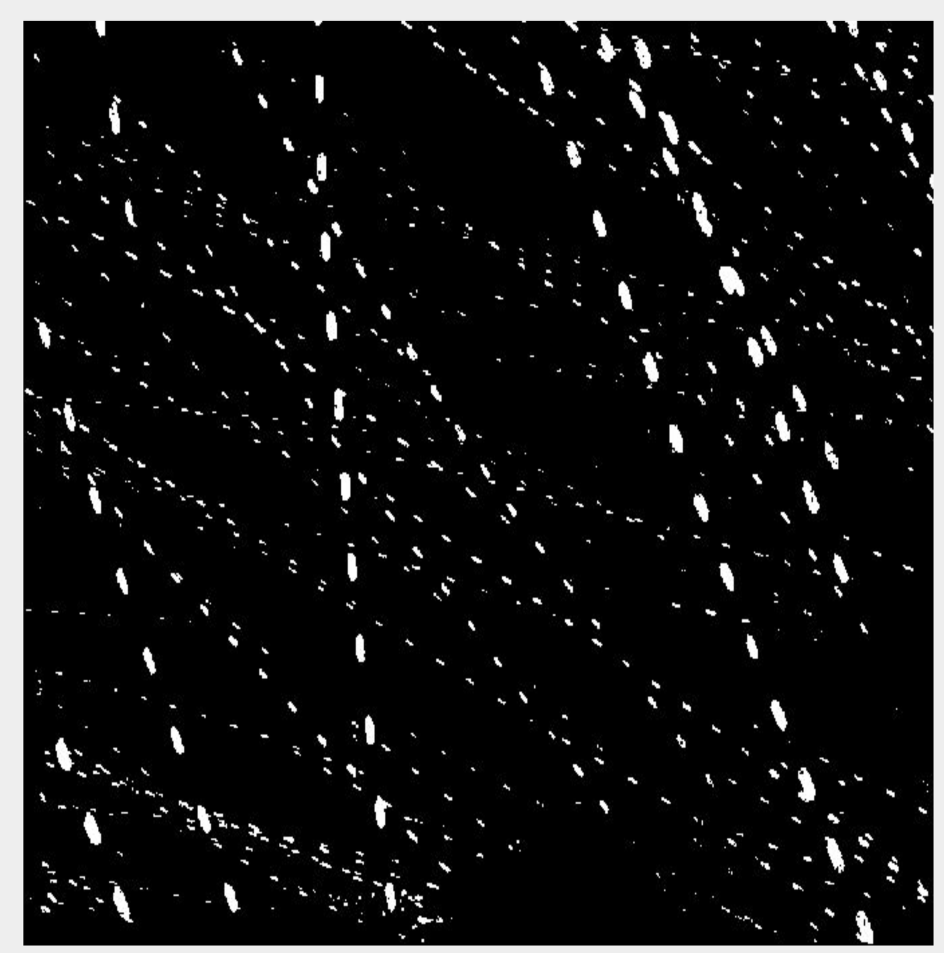


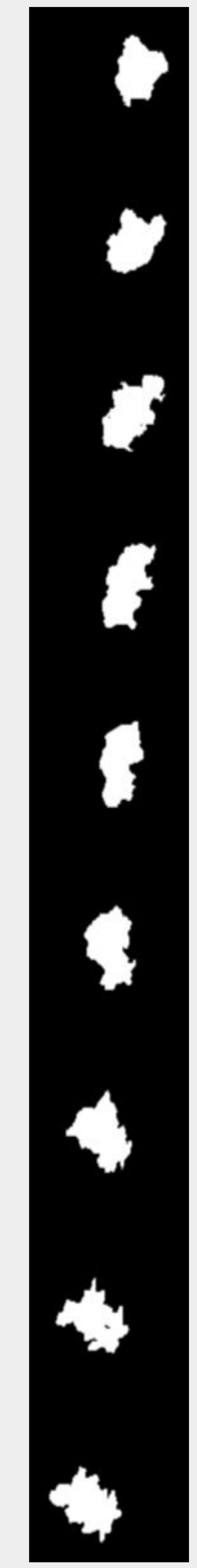
Instruments set up at Alta Ski Area, including the Snow Pixel, the DEID, the MASC, and instruments to measure environmental conditions.



A close-up of the Snow Pixel in use.







Composite images of rotating snowflakes.

- The kit of instruments used in this experiment was set up at the Alta Ski Area through the winter of 2020-2021.
- The Snow Pixel captures video imagery of snow falling through a sheet of light created by 10 watt lasers.
- This imagery can then be analyzed frame by frame as a set of binary images.

Methodology

- The goal of the project was to track snowflakes in the Snow PIxel imagery, identify the properties of each snowflake, and use those properties to quantify the energy drawn from turbulence in the air to rotate the snowflakes.
- The first attempt to writing a program used MATLAB's *regionprops* toolbox to identify snowflakes in each frame and calculate properties of the snowflakes such as the location of their centroid, their area, orientation, major and minor axes, and perimeter.
- This ultimately did not work because there was no effective way to incorporate a tracking algorithm that used the data extracted by *regionprops* into the program such that data collected on the snowflakes could be distinguished between snowflakes in each frame.
- A second attempt employed the *vision* toolbox from MATLAB, which gives access to a machine learning tracking algorithm that employs a Kalman filter to help predict the next location of an object based on its previous locations. The *BlobAnalysis* module from the toolbox calculates the properties of each object.
- This tracking algorithm was successful, but accessing the properties analyzed by the *BlobAnalysis* module has not yet yielded results.

Future Work

- The next step is to successfully extract information on the properties of each snowflake from the Snow Pixel imagery.
- This data will then need to be categorized by snowflake and frame, then exported into a data frame.
- After the data is processed into a usable format, calculations can be made to discover how quickly the snowflakes are rotating.
- Using information on the mass of the snowflakes supplied by the DEID, the energy that it takes to rotate the snowflake can then be calculated.

This research was partially accomplished via support from the U.S. National Science Foundation grant number PDM-1841870.