Exploring Snowfall Data Captured by the Differential Emissivity Imaging Disdrometer (DEID)

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https://github.com/dataviscourse2023/final-project-snowflakes

1. Background and Motivation

Alex and Grace both have backgrounds in the atmospheric sciences and data science. We have both done undergraduate research in the atmospheric sciences department at the University of Utah. Alex is earning his data science graduate certificate and working on classifying snowflake image data using machine learning. He also has prior experience working with the dataset and instrument during his time as an undergraduate research assistant. Grace is a fourth-year undergraduate and is using machine learning for fog prediction.

Our mutual interest in Professor Tim Garrett's hydrometeor measurement research led us to discussing potential projects with him. He encouraged the development of visualizations from a dataset that is derived from a novel meteorological instrument he helped develop. The Differential Emissivity Imaging Disdrometer (DEID) is a new evaporation-based optical and thermal instrument designed to measure the mass, size, density and type of individual hydrometeors as well as their bulk properties (Singh et al., 2021).

The DEID is essentially a thermal imaging camera that captures images of hydrometeors falling upon an aluminum hotplate. The significant difference in emissivity between the hotplate surface and hydrometeors allows for precise measurements to be derived for each individual snowflake. This novel approach results in higher resolution measurements than that of traditional disdrometers as well as a resistance to environmental factors that have plagued its predecessors.

The DEID has been commercially developed and is beginning to be used by the Utah Department of Transportation for avalanche forecasting. Professor Garrett emphasized the importance of creating visualization tools useful for avalanche forecasters, and we hope these visualizations can serve as a starting point.

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2. Project Objectives

The primary questions we are hoping to answer are about the characteristics of storm events. Visualizing various snowfall metrics will allow users to understand the qualities of the accumulated snowpack such as density, mass, and stratigraphy. Avalanche forecasters use these parameters to advise avalanche danger warnings. Increasing the presentation clarity of DEID data will allow them to better utilize snowfall data and provide the public with better forecasts.

3. Data

Our data will be derived from a DEID recording taken on March 6th, 2023. We will use the raw movie file as a visual aid. We will also have data for individual snowflakes that fall onto the hotplate such as where and when they land, mass, etc. and aggregate variables such as snow depth and snow water equivalent (SWE). This data is calculated directly from the recording based on how long the snowflakes take to evaporate. This data is not publicly available but will be sent to us by one of the developers of the DEID.

The meteorological data incorporated into visualizations will be sourced from mesonet data reported by MesoWest. The data is publicly available and can be downloaded from MesoWest as a CSV file. The collocated Alta-Collins (CLN) weather observation station maintained by the Utah Department of Transportation. Available data include Temperature, Precipitation (1hr), Snow Depth, and Snow Interval.

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4. Data Processing

We plan to do minimal data processing for the basic visualizations because the data has been used in prior research and should be nearly ready to be used. The process of calculating data from the recording has quality control measures, including corrections for snowflakes that fall close to each other and appear as one melted snowflake to the camera. There should not be any issues with formatting or missing data that we would have to address.

If we visualize snow layers or the accumulation of particles, then we would have to calculate a spatial field of how deep the snow accumulates across the hotplate by processing the individual snowflake data. An alternative is to just use the average snow quantities already calculated and reported in the other spreadsheet. We will do any data pre-processing in Python.

If we were to animate individual snowflakes falling and accumulating, we could potentially process frames from the recording into a binary matrix to use in plotting. Another researcher has previously plotted individual snowflakes using this method (Rees et al., 2021, Figure 2). However, we would have to do additional processing for our animation, including calculating how they accumulate onto the hotplate, interact with the borders of the 3D column, etc.

5. Visualization Design

We will display the DEID data on an interactive dashboard that provides an overview of a studied period during the snowfall event. This dashboard will be a starting point to access time series comparing meteorological parameters, 2D plots illustrating snowfall layer density, and 3D animations of snow accumulation on the hotplate. Ideally, data can be displayed for different time intervals in the storm event such as 1- or 2-minute intervals. The dashboard will also include mesoscale and synoptic details for the storm event, as well as a summary of the DEID and Alta field campaign.

The best way to convey local meteorological data will be through comparative time series over the duration of the storm event. Snowfall characteristics can be described as a distribution for the entire event, as well as a time series over the duration of the event. This applies specifically to the layer density visualizations, where layers can be stacked atop one another for a holistic look, or they can be expressed as density change in a time series.

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6. Must-Have Features

- Static map of the Alta-Collins site and background information
- Line graphs of SWE and snow depth from DEID data
- Line graphs of meteorological data
- Verified precipitation data to compare DEID calculations against
- At least a basic ability to select a time from the line graphs and view additional information, such as a plot of the accumulated snowpack at that time

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7. Optional Features

- Contour plot of layers in the snowpack (static, based on time selected)
- Distributions of mass, complexity, etc. of snowflakes at a given time
- One of the following:
  - Static plot of snowflakes up to some height above the hotplate at some time
  - Animation of just snowflakes falling
  - Animation of snowflakes falling into simplified, averaged layers that still accumulate
  - Animation of snowflakes falling and accumulating, with smoothing and edge cases handled

8. Project Schedule

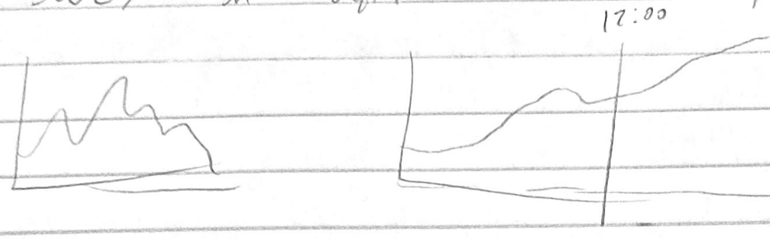
- 10/2-10/6: Finish exploring the datasets, decide what time intervals to visualize, finalize the correlations and comparisons to show (e.g., accuracy of DEID precipitation, distributions of snowflake statistics, interesting events to highlight)
    - Tasks to distribute: calculate descriptive statistics
    - Make time series plots in Python
    - Compare MesoWest precipitation measurements with DEID calculations
- 10/16-10/20: Calculate layer statistics in Python–average mass/density and spatial distribution accounting for at least minimal smoothing
    - Determine smoothing scheme
    - Handle edge cases
    - Aim to plot layers in Python, color mapped by density, with contour lines
- 10/23-10/27: Determine the feasibility of different animation options and have experimented with all options
    - Have a static plot of individual snowflakes
    - Experiment with animating that still frame through a 3D column
    - Have snowflakes disappear out of boundaries gracefully
    - Add snowpack layers to the bottom of the column
- 10/30-11/3: Have a fleshed out visualization prototype running with the website structure in place
    - Get the website on GitHub with basic graphs populated
- **11/3: Project Milestone due**
- Based on the progress made for the project milestone, fully implement the chosen ideas and integrate them into a polished website. The work done in this month depends heavily on limitations of the data and our comfort with JavaScript at this point.
- **12/1: Final Submission due**

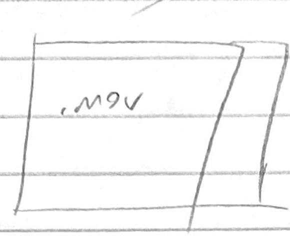
.mov
playing

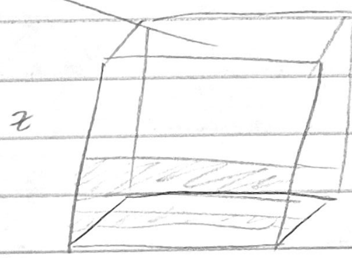
~~Level~~ Flow

DV Project Proposal

· SWE, snow depth compare T, wind, precip



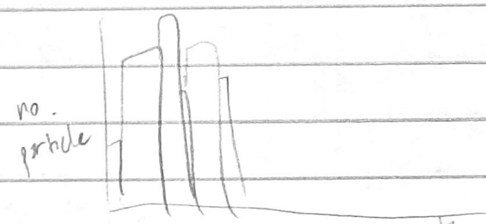




~~average~~
areal mass/p
layers

color code by density?

focus on snowflakes
for edu?
snowflake props → snowpack

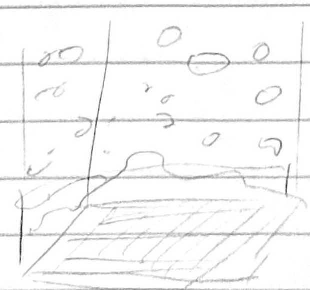


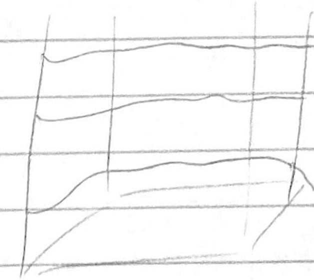
pdf of particle stats

pull up individual particle ~~info~~? data

Most ambitious animation:

less ambitious, static:





layer by layer

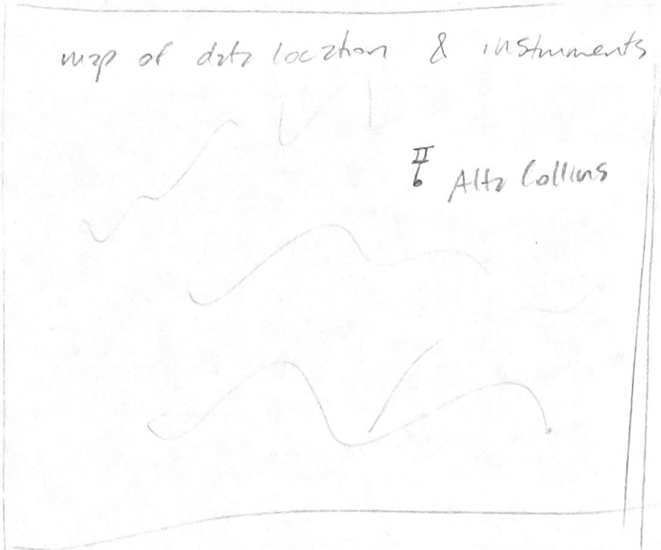
illustrative vs
vs. data-driven

do dashboard, or have both

SVG ~10 000 objects,
100 moving
minimize no. objects, aggregate

Animation
D3 tick function to update
lots of edge cases
set up fns for objects, update

Explore a snowstorm at Alta:



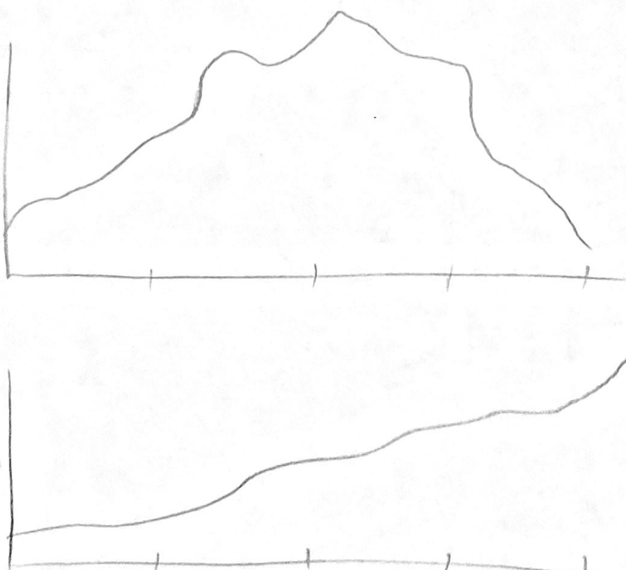
background on the experiment

- time range
- data collected

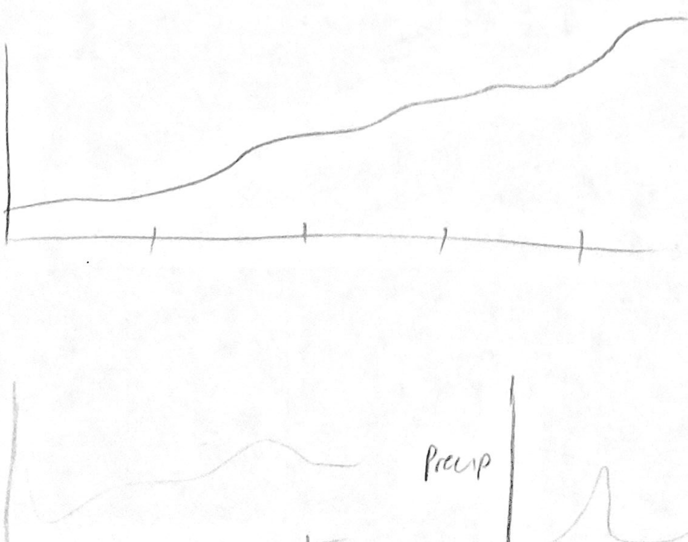
Click at a point along my time series to view - - - -

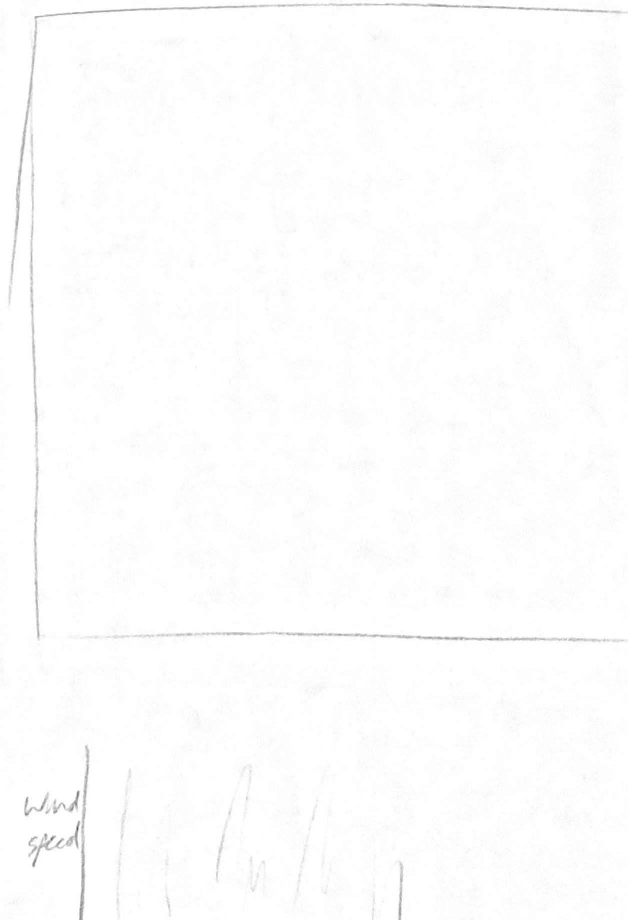
Snow data:

SWE



Snow depth





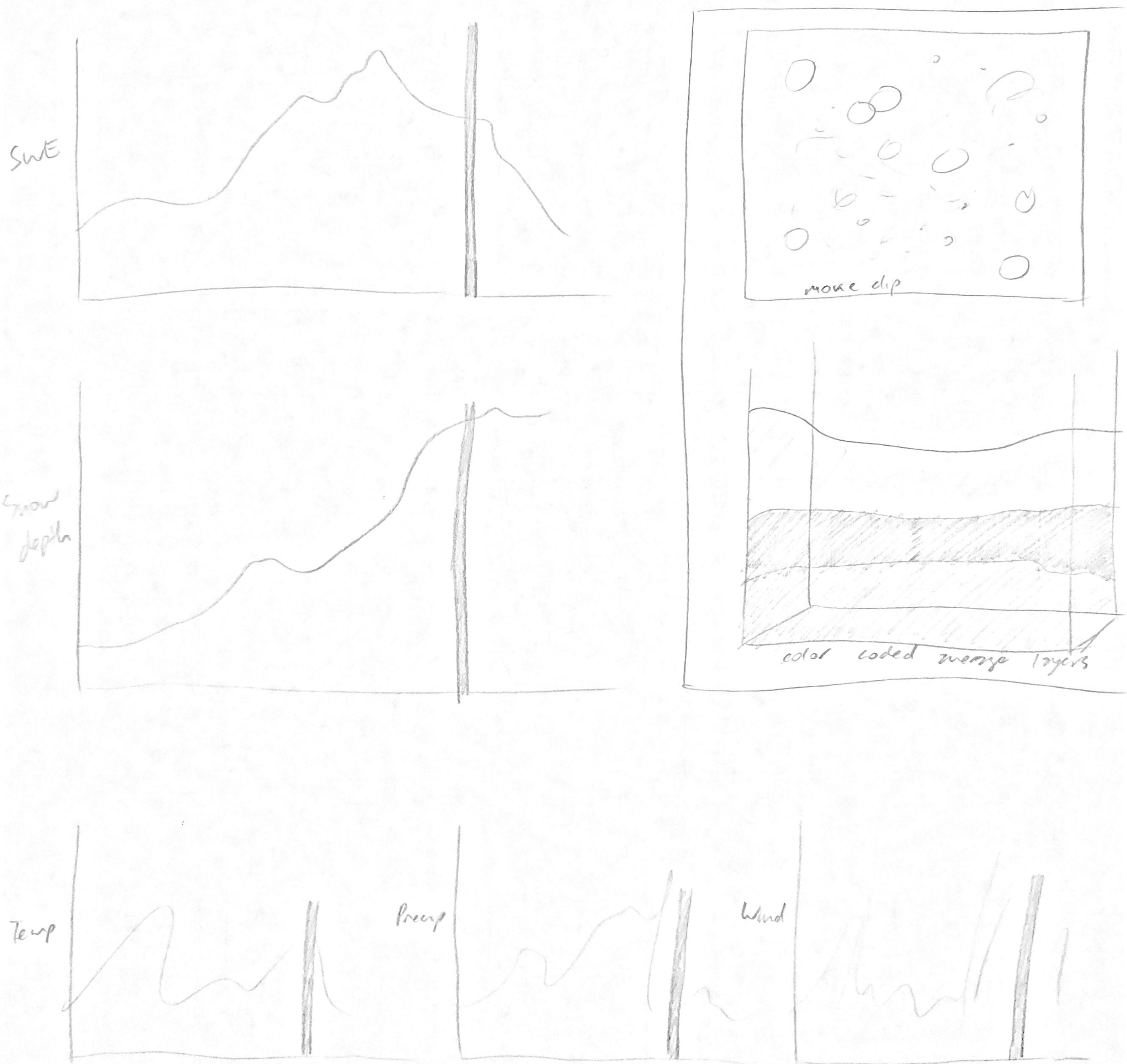
Temp

Precip

Wind speed

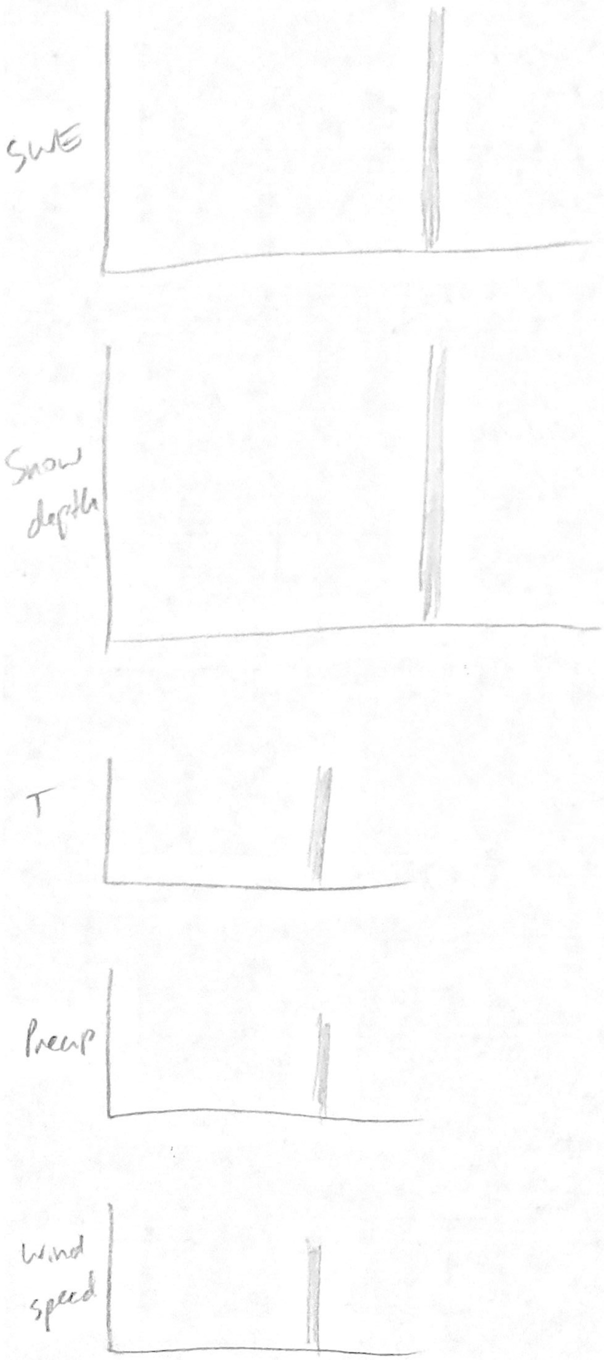
Dashboard when a time is selected

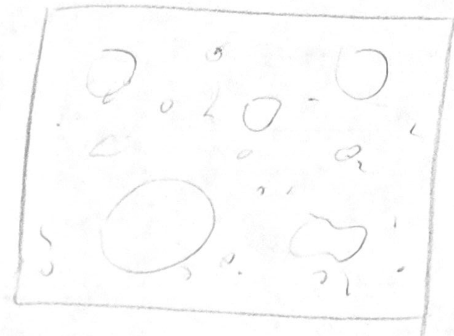
Click at a point ...

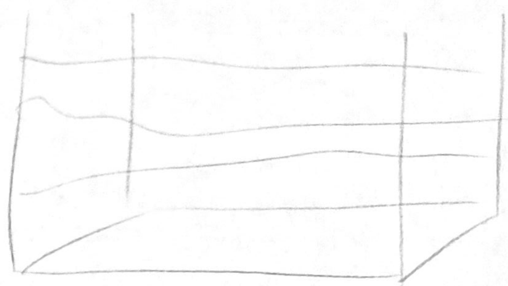


If we have more graphs by time

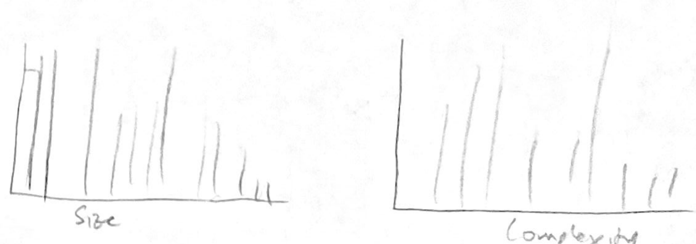
Click at a point...



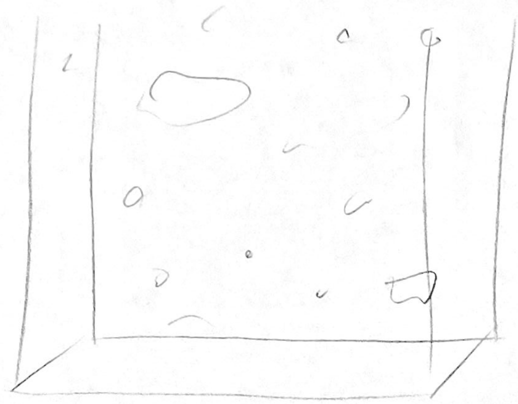




visualization of layers

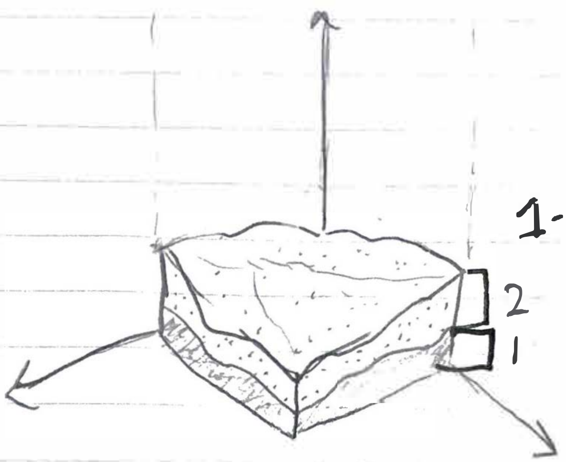


Individual snowflake stats/distributions

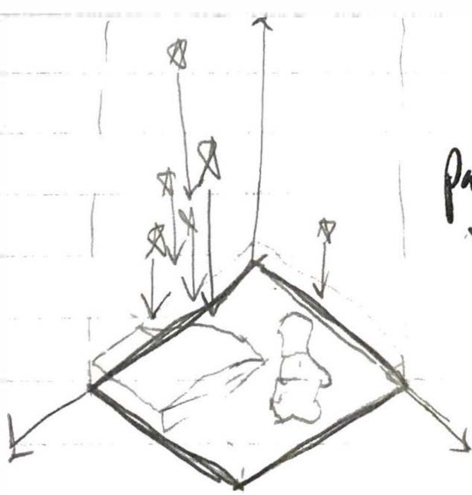


column visualization

Potential column animations



1-min layers



particle by particle
w/ smoothing & layering