Using a Marching Cubes Algorithm to Identify Volumetric Radar Features Associated with Hailstorms

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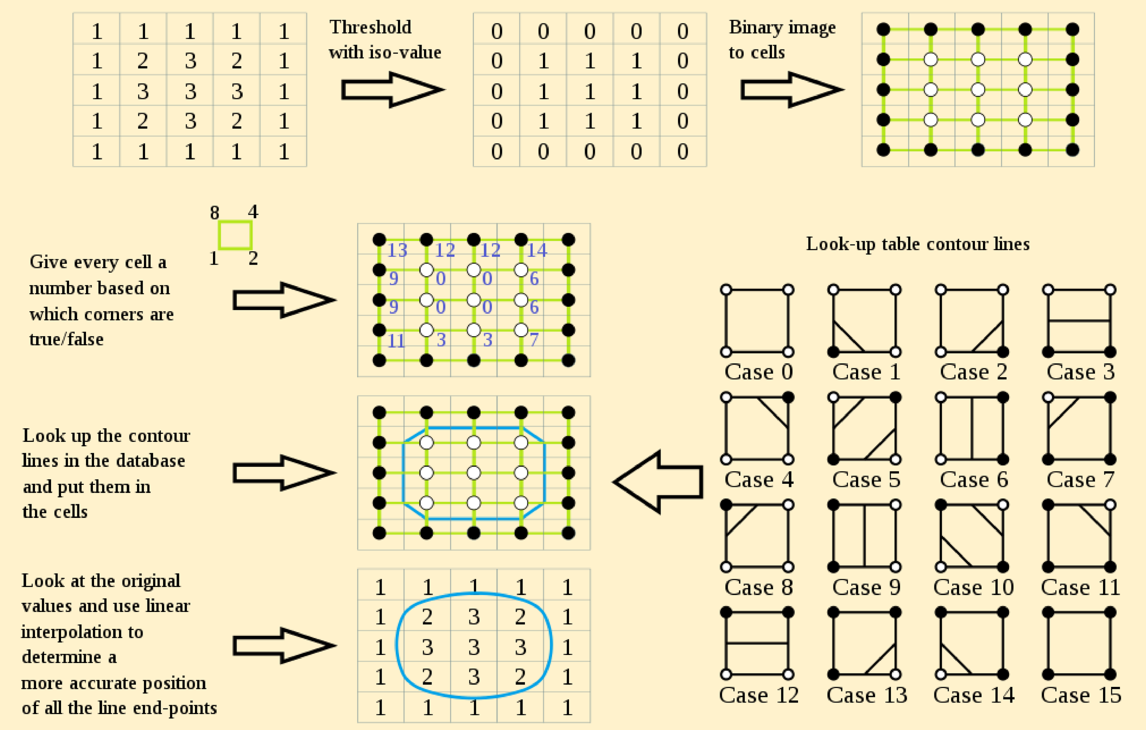
Introduction

- To date, hail-sizing algorithms have relied on 2D information, such as vertical integrations of reflectivity, to make predictions. These have proven in adequate in describing the size of hail.
- Polarimetric data conveys additional information about the mixture of hydrometeors in storms such as supercells. However, polarimetric features, such as KDP columns, are more complex than can be described by vertical integrations or pixel-by-pixel evaluations.
- Thus, it is thought that utilizing 3-dimensional (3D) data could lead to better hail-size predictions.
- WDSS-II algorithms merge data from multiple radars and create volumetric data fields that are output onto a 3D grid.
- In this work, an algorithm is created which transforms the 3D data fields into meteorological features. These structures include ZDR columns, KDP columns, ZDR rings, hail volumes, mesocyclones, 30 dBZ outlines, and storm top divergences.
- Information about each structure is collected and used in a random forest to predict hail size, where the dataset used is the hail dataset as recorded by the Severe Hazards Analysis & Verification Experiment (SHAVE)

Given that hail-sizing predictions to date have relied on just 2D information, this algorithm uses volumetric information to estimate the size of hail. This is done using the Marching Cubes Algorithm

Method: Marching Cubes

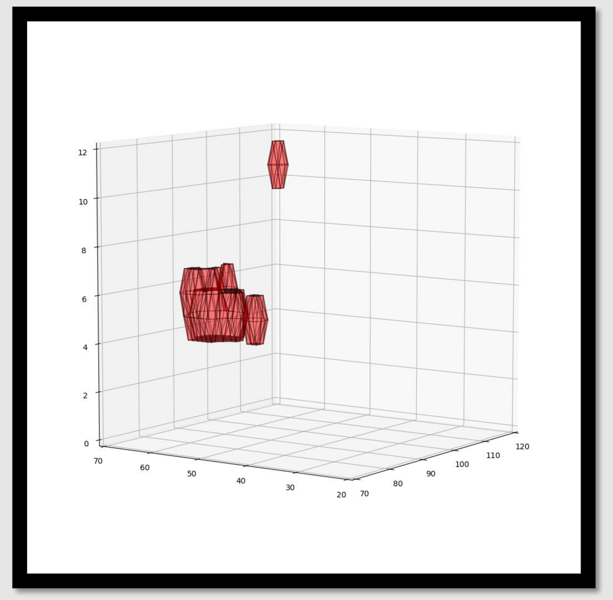
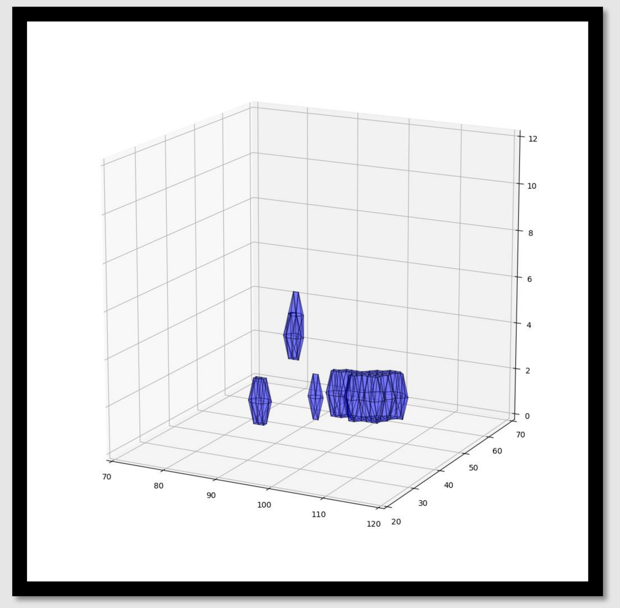
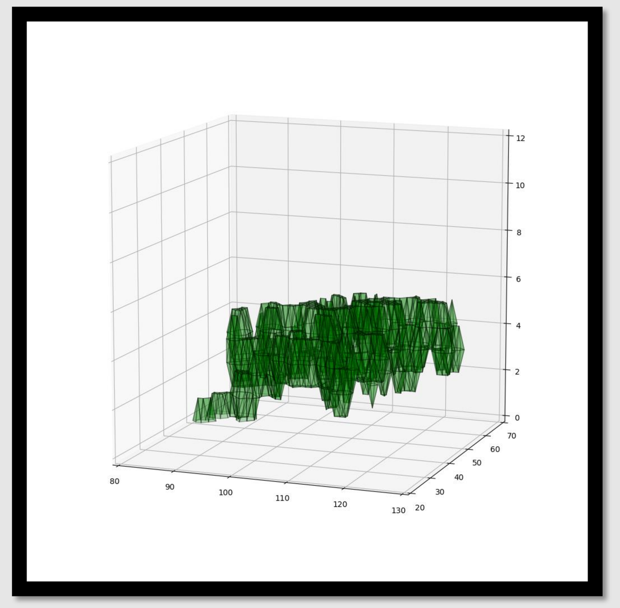
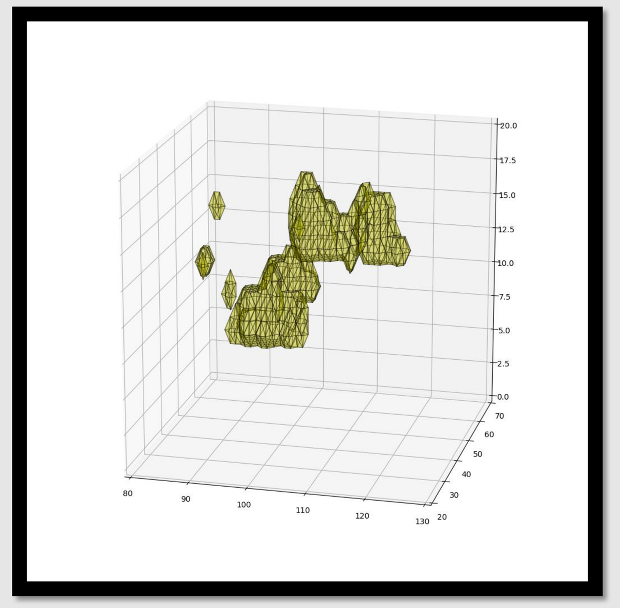


In marching squares (which is the 2D version of marching cubes):

- A threshold is chosen for the data field. In the example above, that threshold is 2.
- Every grid point below that threshold is set to 0, else it is set to 1.
- Isosurfaces are created at each 2 by 2 square according to 16 total geometries/cases. (256 cases in marching cubes)
- These isosurfaces connect into a continuous shape and, in 3D Marching Cubes, form the volume.

Example Structures and Thresholds

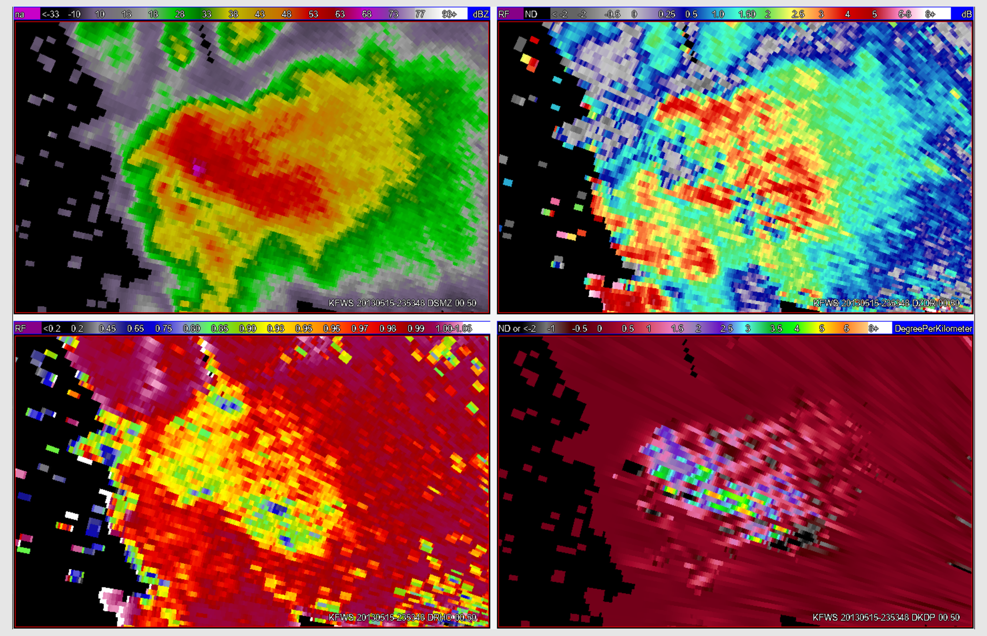
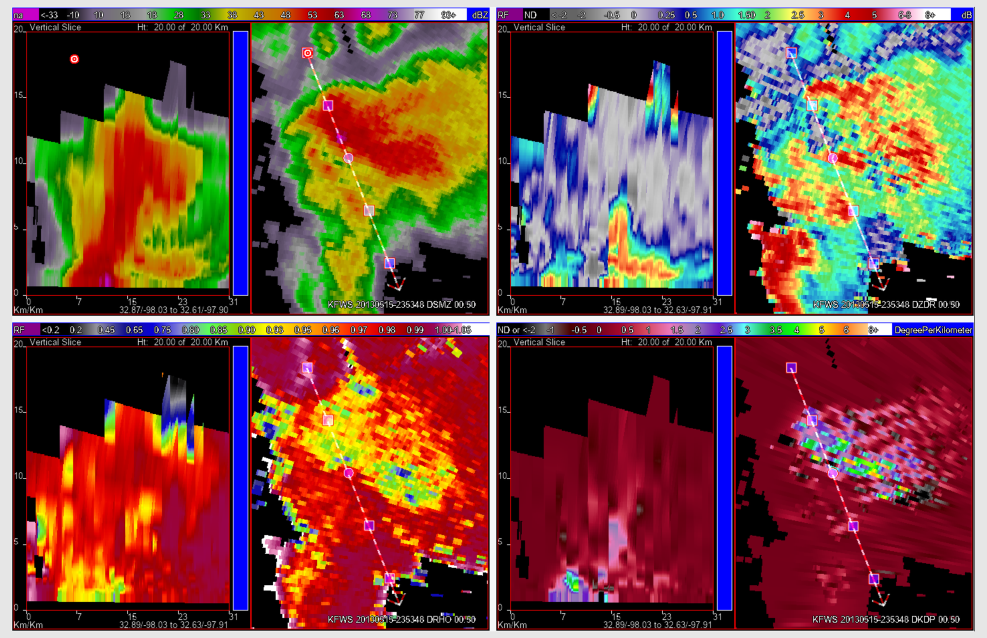
- ZDR Column:
  - ZDR above melting level > 0.5
  - dBZ above melting level > 50
- KDP Column:
  - KDP above surface > 2
  - dBZ above surface > 50
- Hail Volume:
  - ZDR below melting level > 4
  - dBZ below melting level > 45
- Midlevel Mesocyclone
  - AzShear above melting level > 0.004
  - dBZ above melting level > 20

Case Visualization – 05/13/2015

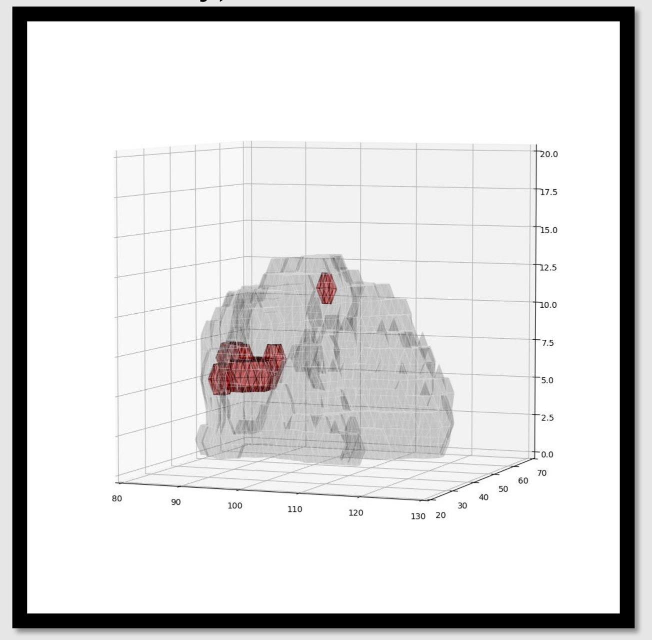
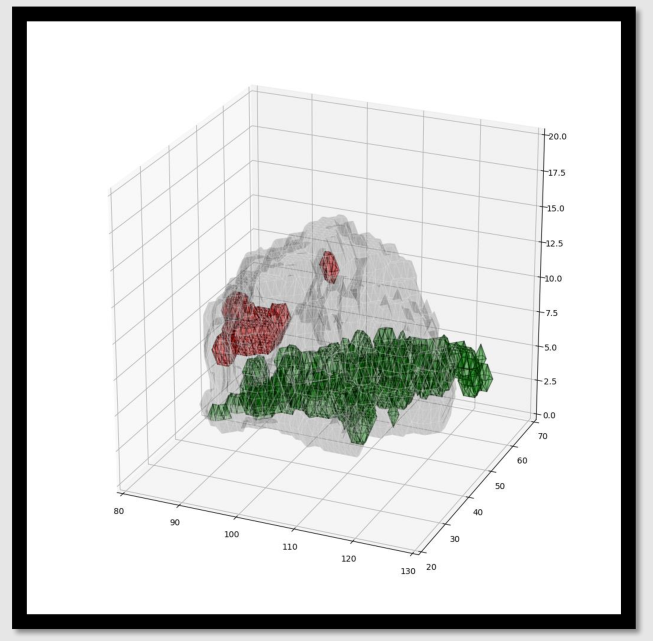
We worked on a set of cases from the SHAVE database. Here is a supercell from 05/13/2015. Hail sizes were estimated (by locals) to be, at some points, at 114 mm.

Below are the radar images, of cross sections and overhead view.

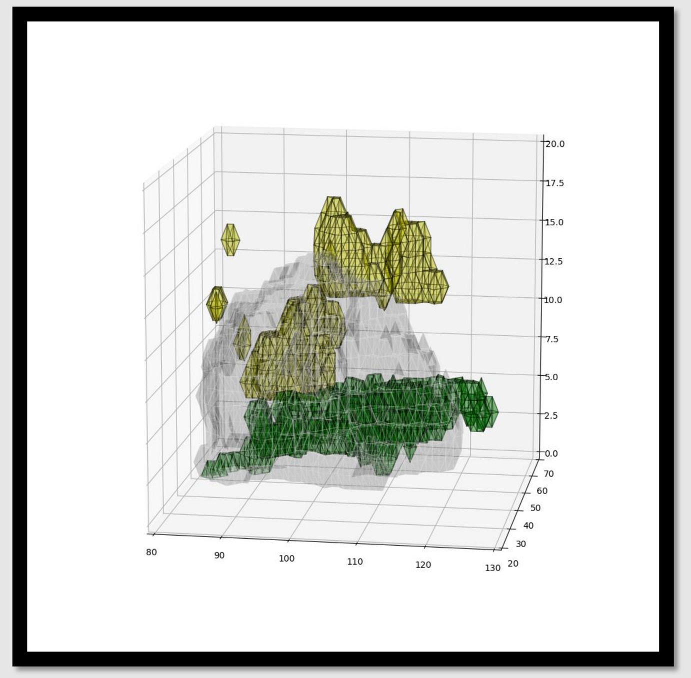
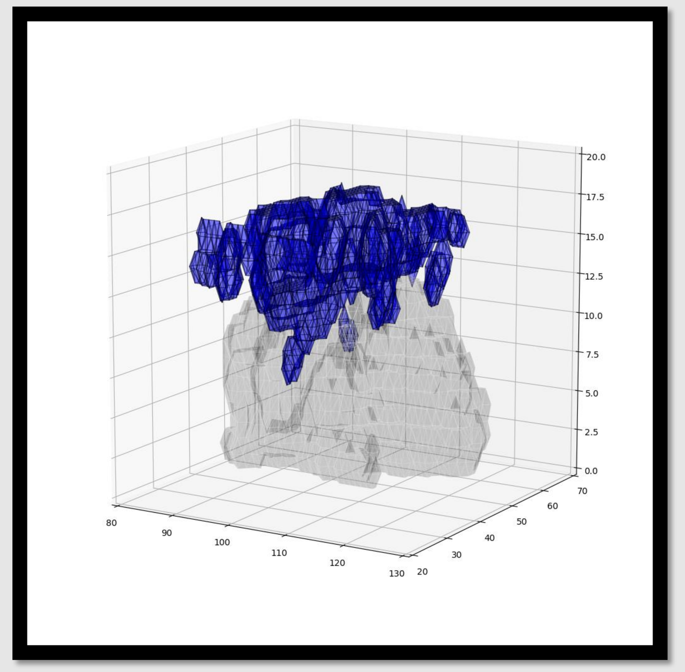



And here are the volumes formed using the marching cubes algorithm.

- ZDR column within 30 dBZ outline (left) and with hail (right) (separately for clarity)

- Mesocyclone and hail volume with 30 dBZ outline (left) and storm top divergence and 30 dBZ outline (right)

Data Collection

For each structure, the following was collected:

- Number of volumes
- Total volume
- Centroid of largest volume
- Depth and width of each volume

Additionally, for the largest volume, statistics were collected about the radar fields. For example, the following was collected for ZDR columns:

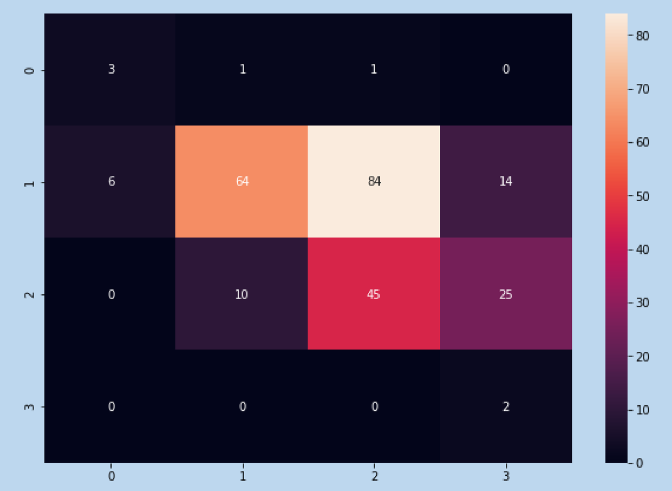
- Max ZDR
- dBZ at point of max ZDR
- Rho at point of max ZDR

Prediction & Results

These statistics were input into a gradient boosted tree. The max estimated size of hail, as recorded by the SHAVE dataset. The estimates were classified into 4 classes (small, medium, large, giant).

Calculate mean absolute error: target values/predicted values: 0.462

Yielding the following confusion matrix:



Future Work

- Run regression analysis and compare with other hail-sizing algorithms
- Integrate information used by other algorithms
- Integrate qualitative information from manual analysis of storm (such as presence of TBSS)
- Utilize visualizations for educational purposes

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