Background

Over the course of this 9-week internship, I worked on studying how avalanche fatalities were related to atmospheric rivers in the western United States. Through this research process I gained a better understanding of hydrometeorology, data analysis and data visualization.

Introduction

The 2017 paper was the first paper linking avalanche fatalities to atmospheric river (AR) events.[1] The goal was more oriented towards finding which fatalities were AR related rather than if they were related. Some findings from the paper included the percentage of AR related fatalities and gathering statistics related to the weather conditions during AR related avalanches.

My task for this internship was to extend the avalanche fatalities catalog from 2015-2021, as well as update the SNOTEL dataset to perform statistical analysis. In addition, I also followed the methodology used in the 2017 paper for determining if an avalanche was AR related or not. Lastly, statistics of the weather conditions were gathered at the very end, however due to time constraints, this was not explored in full.

Data

The first task to be done was data gathering, this came mainly from avalanche reports, Snow Telemetry (SNOTEL) data and the Rutz AR Catalog[4]. The following data was collected from the reports: latitude, longitude, number of fatalities and date.

Next, SNOTEL data was retrieved from snotelr, which is a R toolbox to facilitate easy SNOTEL data exploration. In total 886 SNOTEL sites were used, and the following weather data was gathered: snow water equivalent (SWE), max temperature, min temperature, precipitation, and cumulative precipitation.

The data was then saved into netCDF files and quality control was performed on them. The main goal of the quality control process was to remove any data that would be physically impossible to record. For instance, negative precipitation or temperatures greater than 50^{o}C up in the mountains. This data was set to NaN, or a missing value rather than 0 to not affect the average values later.

Methodology

With all the data gathered and quality control has been performed on them, it was time to shift focus towards each individual avalanche event. Only SNOTEL sites that were within 0.125-1.0 degrees radius of the avalanche was chosen. This range is still being explored to find the right number of sites.

After the sites have been spatially selected, the next step was to select which dates of the weather conditions to look at. A range of 8 days was observed, 6 days before the avalanche and 1 day after. The reason for 6 days is because it is expected that some form of precipitation or storm would have occurred resulting in a heavier snowpack and thus an avalanche. One day after is to consider any date mismatching that might have occurred or if there was issue with the data on the day of the avalanche itself.

The simplest way is by observing if there was presence of an AR in the 8-day range within ±2 degrees upstream and 2 degrees west of the avalanche itself. Essentially making a grid as seen in Figure 1.

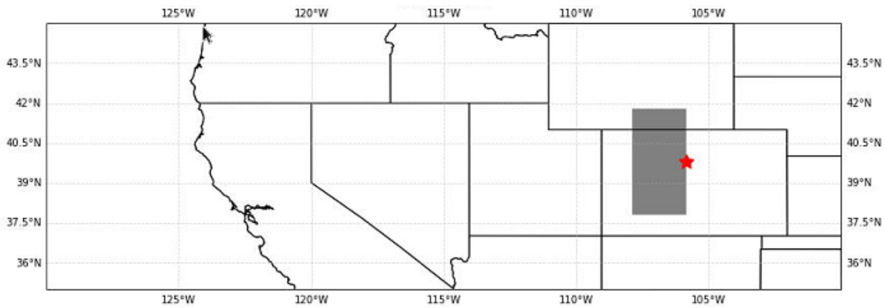

Figure 1: Grid of AR Detection Region

This method is further improved by plotting the AR Mask from the Rutz Catalog and IVT plots produced by NOAA Physical Sciences Lab. As shown in Figures 2 and 3. Lastly, if the figures were still ambiguous, the final step would be to check the avalanche reports themselves to see if there was any information provided about the weather conditions before the avalanche.

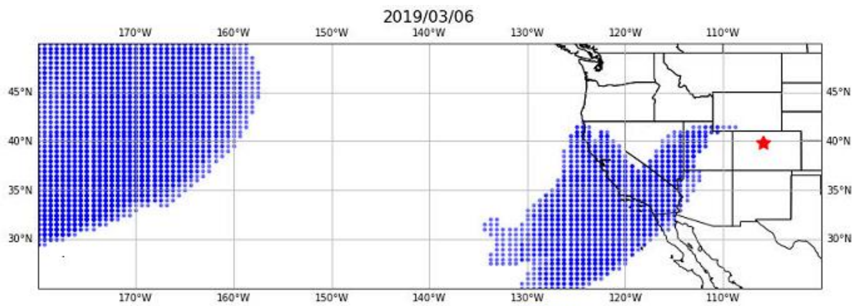

Figure 2: Visual Representation of Rutz Catalog

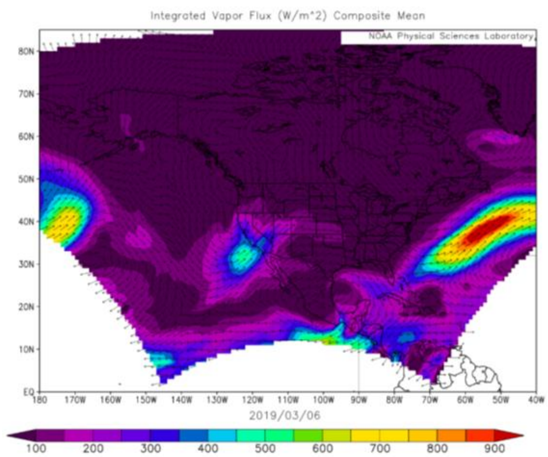

Figure 3:Plot of IVT (NOAA Physical Sciences Laboratory)

Once all the avalanche incidents have been classified and the SNOTEL data has been gathered, the final step would be the statistical analysis. The weather conditions during AR related avalanches are gathered and compared to the weather conditions year-round.

Results and Future Work

After all avalanche fatalities have been recorded, a visual representation of their locations can be mapped as shown in Figure 4.

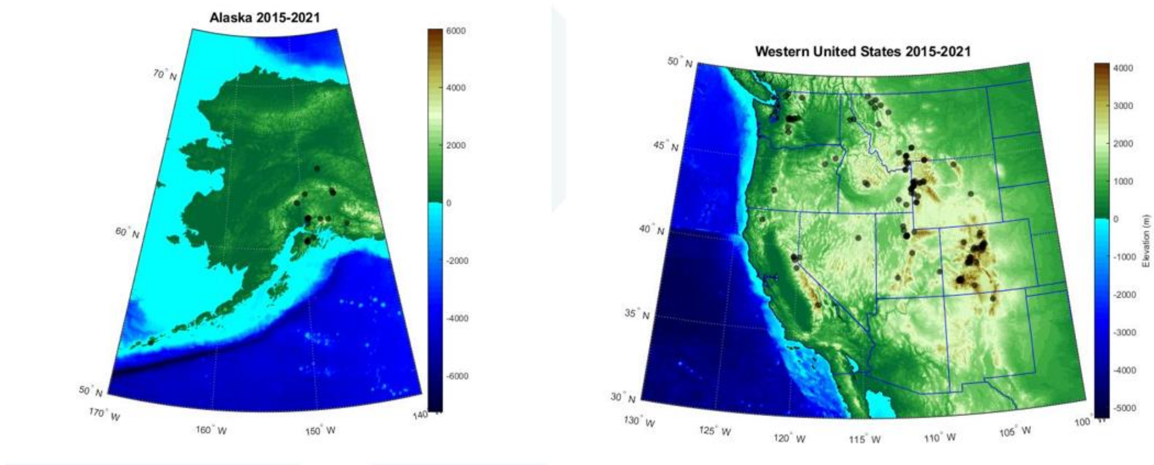

Figure 4: Map of avalanche fatalities in Western US. Black dots indicate the avalanche incident

Based on the 2017 paper, it is expected that the number of black dots would fall by about two-thirds after each avalanche has been evaluated to be AR related or not.

Once that has been done, statistics regarding the avalanche weather conditions can be better visualized, for instance using a CDF plot.

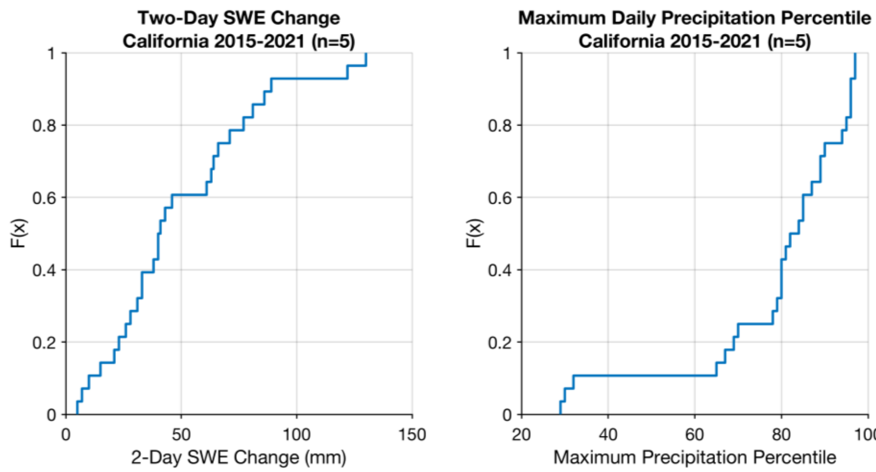

Figure 5: CDF Plot of Two-Day SWE Change and Max Daily Precipitation Percentile for all avalanche events in California

These figures will then be compared with the paper from 2017 to see if there are any differences in the weather conditions from 1998-2014 and 2015-2021.

Finally, I would like to thank my mentors, Kristen Guirguis, Benjamin Hatchett, Tamara Shulgina and Alexander Gershunov, for mentoring me through this internship experience and also Cody Poulsen, Will Chapman and the entire CW3E internship team for organizing this summer program.

Appendix

Python, R and MATLAB were used in throughout the methodology and results. For a closer look I have uploaded my code to this repo on GitHub and will be updating it.

Bibliography

1. **B. J. Hatchett (2017). *Hydrological modelling using artificial neural networks*, Journal of Hydrometeorology, 18 (5), 1359-1374**
2. **Alexander Gershunov, Tamara Shulgina, F. Martin Ralph, David A. Lavers, Jonathan J. Rutz. (2017) *Assessing the climate-scale variability of atmospheric rivers affecting western North America,* 44 (15), 7900-7908**
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4. **Jonathan J. Rutz, W. James Steenburgh, and F. Martin Ralph (2014) *Climatological Characteristics of Atmospheric Rivers and Their Inland Penetration over the Western United States.* Monthly Weather Review*,* 142 (2), 905-921**