Hurricane Visualization

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1 Introduction

Our project consisted of visualizing Hurricanes, and we narrowed our data down to Hurricane Isabel(2003) and Hurricane Katrina(2005). We used Paraview to help us visualize and analyze the data.

The project was broken down into several steps:

1. Data Preparation
2. Visualization
3. Analysis (This report is the analysis)

Data Preparation

This first step involved gathering data related to Hurricanes in addition to understanding the formatting. The latter was the most difficult part of the entire project. Since we settled on Hurricane Isabel and Hurricane Katrina, we needed to find data that would allow us to work with it in the Paraview environment. The Katrina data was readily provided to us in class as part of a previous assignment. Thus, it was not to difficult to explore further.

However, the Hurricane Isabel data was found from the 2004 IEEE Viz Contest[1]. The data set for this contest is a simulation of Hurricane Isabel from the National Center for Atmospheric Research (NCAR)[2]. The data consists of several time-varying scalar and vector variables. The size of the data was the first hurdle. NCAR provides each individual variable and time step zipped, and this amounted to 625 .gz files at roughly 40GBs. We then wrote a script to unzip each file and convert the data to .raw format so Paraview would be able to read it. The data summary for the 2004 IEEE Viz Contest mentions the data being in float format, however after numerous attempts to use the data in float format, we eventually learned that the data was in fact, in integer format, except for the wind data.

Visualization

Our project was successful in visualizing the storms by using the following techniques learned in class:

1. Volume rendering
2. Surface rendering
3. Flow and vector field visualization
4. Paraview filters, animations, and other tools

By using these visualization techniques we were able to analyze the data.

2 Goals

The goal of the project was to provide a visual understanding of how certain variables operate in Hurricane environments, and how they change over time. Hurricanes are tropical cyclone storms, and while living in the state of Utah, we don't see storms of that nature in this region. However, due to climate change, there has been an increase in both frequency and strength of these storms[3]; and we believe it is important for those living outside of tropical storm regions to be aware of the structure of the storms and ensuing damage they create. In addition, since we used one of the data sets in a class assignments, we had a goal of going a bit further with the data, by adding some sort of animation.

3 Analysis

The nature of this project is more focused on visualization or hurricanes, however a brief understanding of what a hurricane is may be needed.

Depending on their location, Tropical Cyclones can be referred to by different names, including: hurricane, typhoon, or tropical cyclones. In our case, we used data from two Atlantic Ocean storms, therefore they are referred to as hurricanes. Tropical cyclones in the northern hemisphere rotate in a counter-clockwise direction, and clockwise in the southern hemisphere. This opposite rotation is due to the Coriolis Effect[4]. In addition, hurricanes are low pressure systems, where the atmospheric pressure is lower than that of surrounding locations. Low pressure areas are typically associated with inclement weather, and high pressure systems are associated with low winds and clear skies[5]. There are five categories to classify hurricanes. They are based on sustained wind speeds.

1. 74-95 mph

2. 96-110 mph
3. 111-129 mph
4. 130-156 mph
5. 157 mph or higher

Clouds

The easiest way to visualize a hurricane is to start with its cloud formation. A couple key features of the cloud formation are know as the "eye" of the storm, and its "rain bands". Since these storms rotate in a counter-clockwise direction around a low pressure they create whats known as an eye. Typically the eye of the storm is a short break in inclement weather. The rain bands are the bands of clouds that reach from the eye of the storm in a radial direction, while the storm rotates.

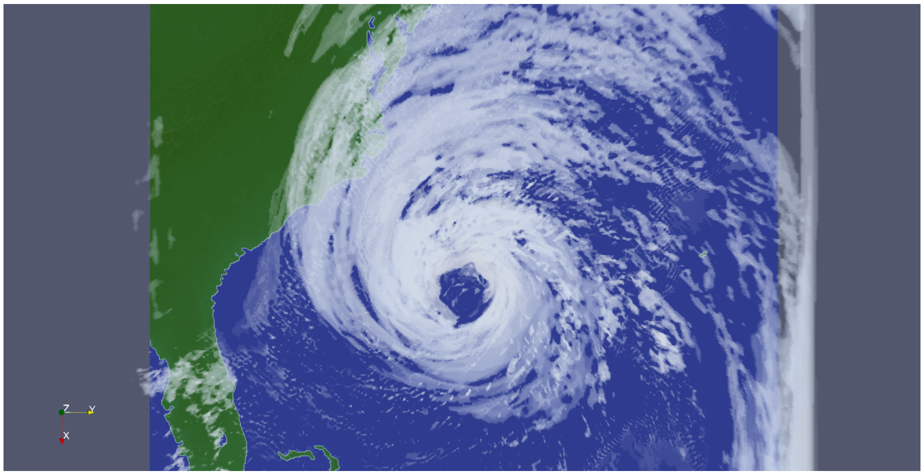

Figure 1: The eye of Hurricane Isabel

These images were created using volume rendering. We created transfer functions to filter out noise, and only show cloud formations. We also manipulated the opacity so that the upper layers of the cloud formations would not block what remains below. Like stated before, the cloud visualization is a simple way to get a basic understanding of what these hurricanes looked like to the naked eye. However, hurricanes consist of other meteorological variables.

Vector Visualization of Wind Flow

Probably the most interesting part of a hurricane is the strength and direction of its wind flow. The Hurricane Katrina data set was conveniently formatted for us to work with immediately. We started off by creating stream lines around

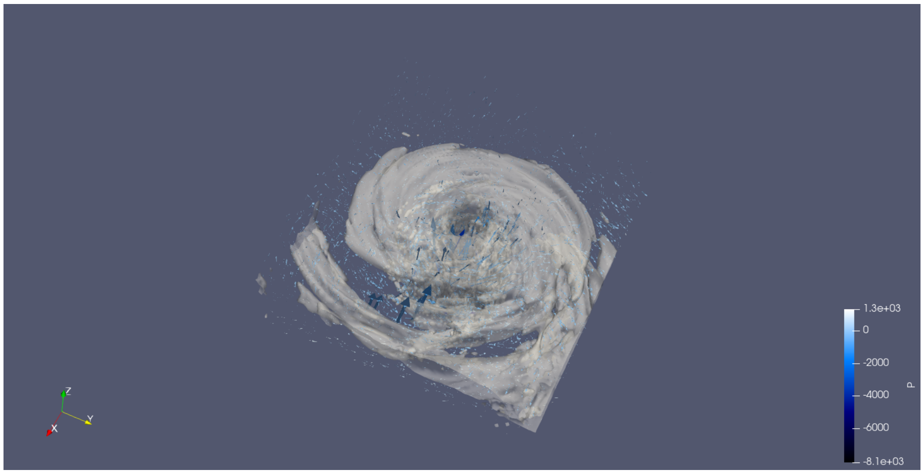

Figure 2: The eye of Hurricane Katrina

the eye of the storm. The eye is typically the most interesting and recognizable part of the storm because it is the center of the system, in addition to being where the most damaging winds are located[6].

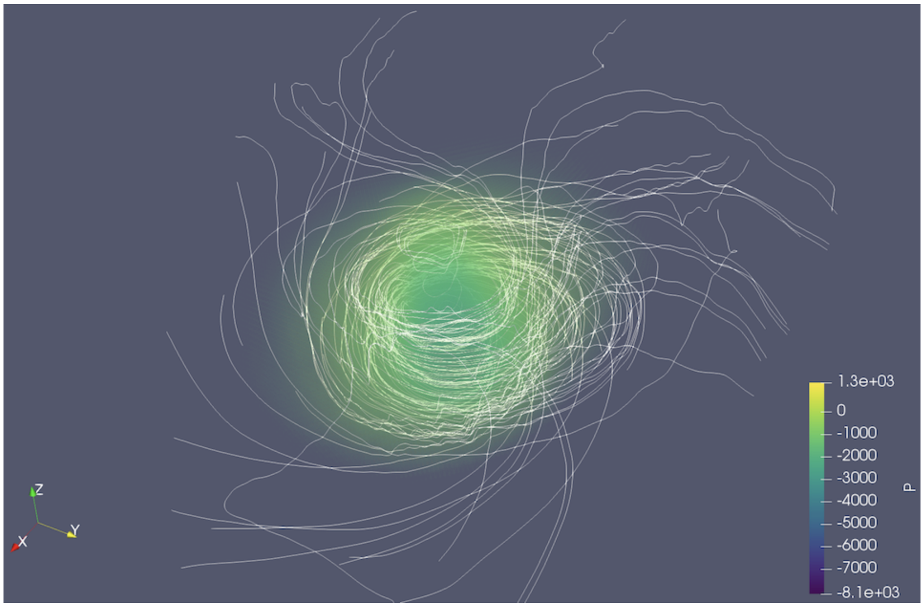

Figure 3: Hurricane Katrina Stream Lines using Point Cloud Seed. In addition the systems Pressure is measured.

In figure 4, there is evidence of the strongest winds being at the eye wall.

Another thing to note about the wind flow of a hurricane is the upward and draft that is created at the center of the storm. Hurricanes need warm water in order to form, and that is why they begin to form out in the Atlantic ocean during the months of June-November[7]. These storms use the warm waters to suck up moisture and it creates an upward draft. Figure 5 shows an example of upward draft occurring in Hurricane Isabel. In addition, in figure 5 you can also see glimpses of the strongest winds just outside the eye wall.

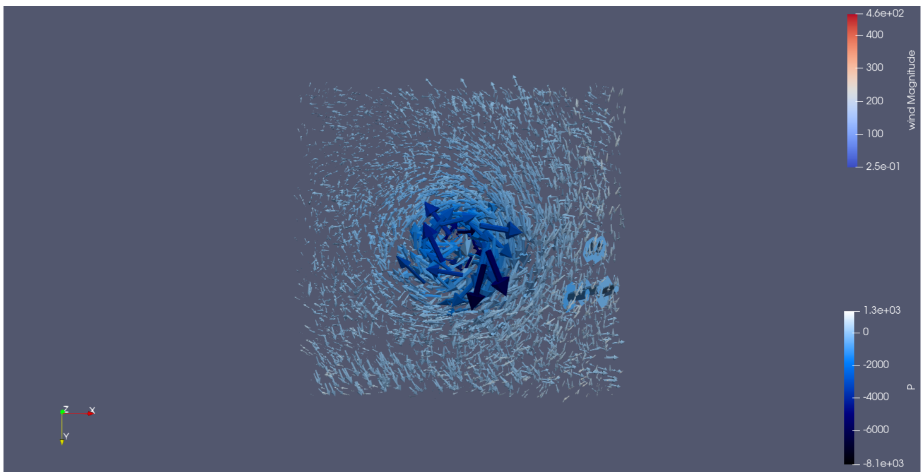

Figure 4: Hurricane Katrina wind flow. Arrow Glyphs using wind scalars to show wind magnitude.

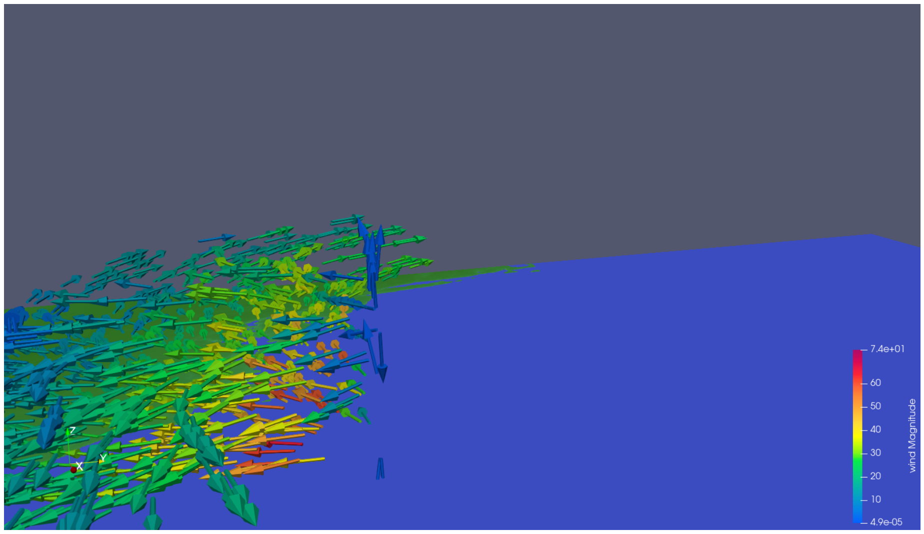

Figure 5: At the center of Hurricane Isabel. An upward draft.

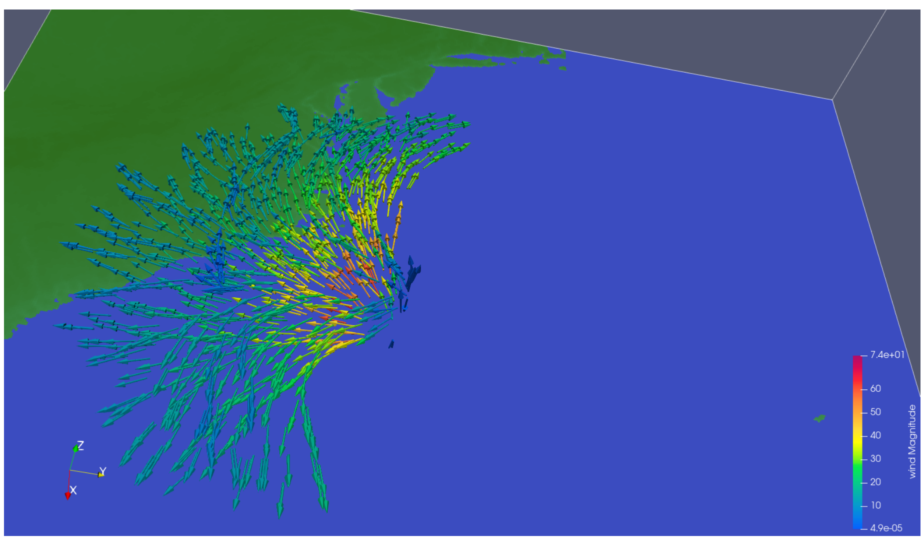

Figure 6: Counter-clockwise wind direction on the north side of the storm as well as evidence of upward draft.

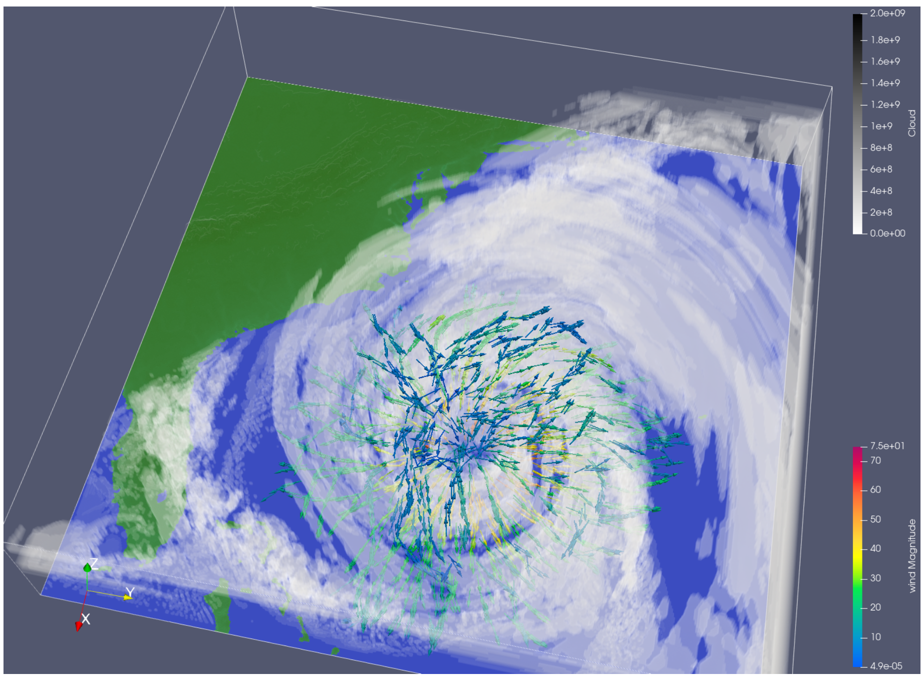

Figure 7: Multi-field visualization using volume rendering for clouds and vector field visualization for wind flow. For the wind flow, a stream trace filter using a point cloud seed at the eye of the storm.

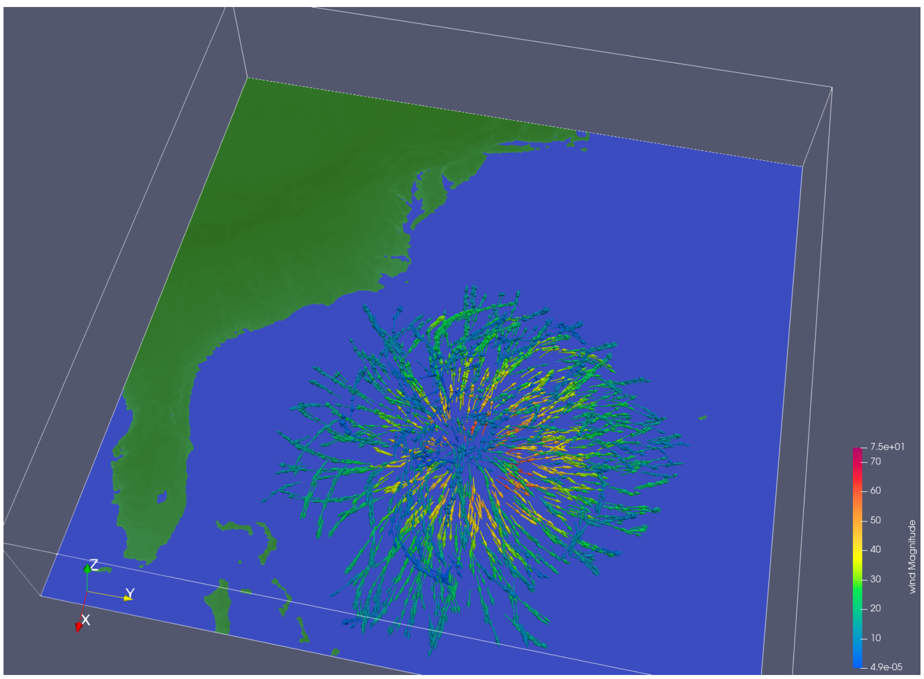

Figure 8: Wind flow via vector field visualization. This image is the same as figure 7, except the cloud rending was removed.

Since warm ocean water is what fuels the hurricane, it makes sense that once the storm makes landfall it will being to weaken.

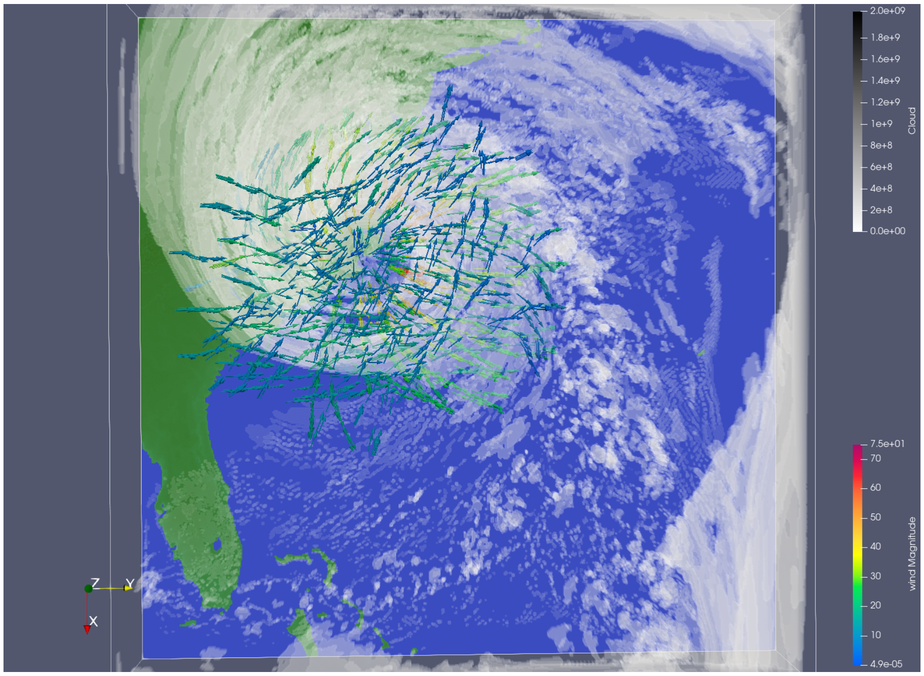

Figure 9: Wind flow as Hurricane Isabel makes landfall

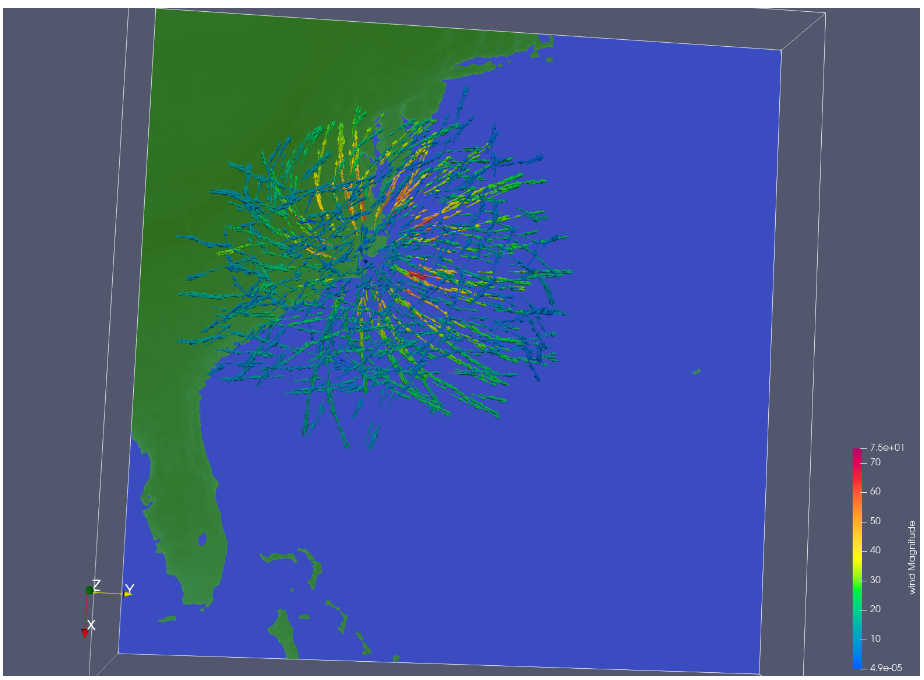

Figure 10: Wind flow as Hurricane Isabel makes landfall without cloud rendering

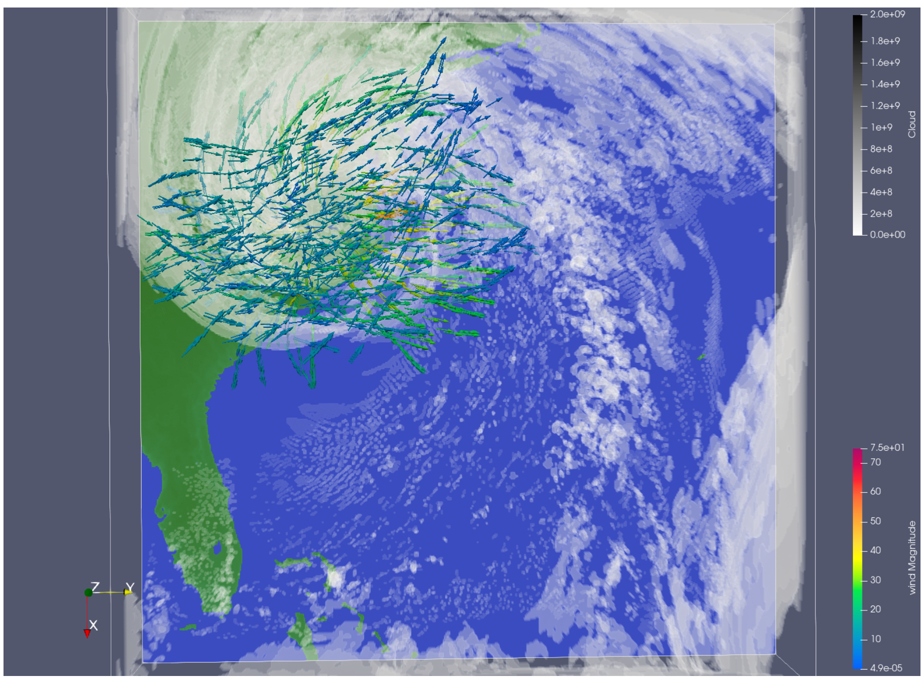

Figure 11: Wind flow of Hurricane Isabel over land with cloud renderings

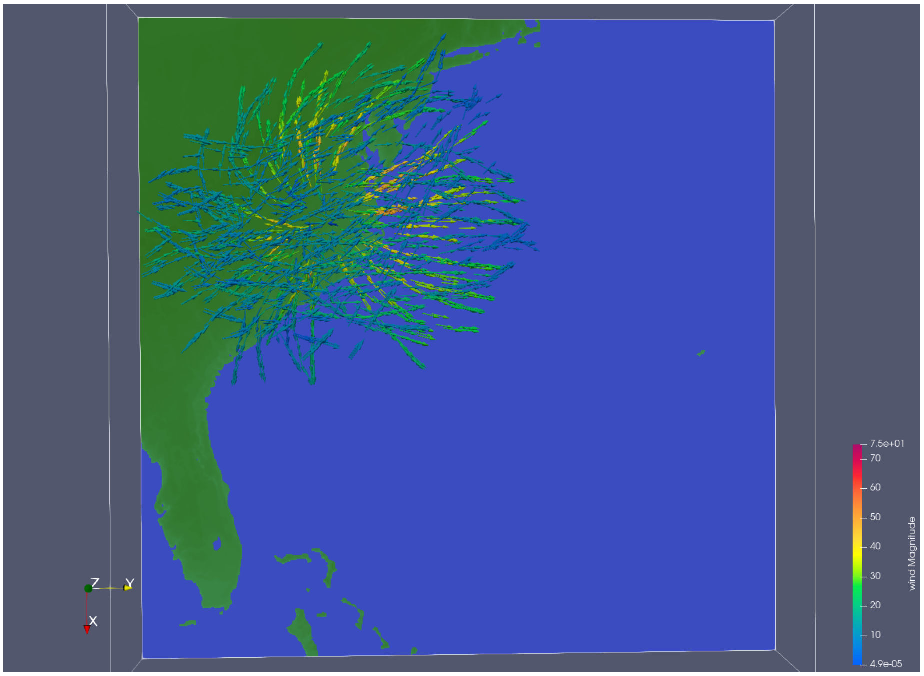

Figure 12: Wind flow of Hurricane Isabel over land without cloud renderings

Comparing figure 10 and figure 12, you can begin to see the wind speeds are starting to decrease.

4 Precipitation

Hurricane Isabel was the most costly, deadliest and most intense hurricane of the 2003 Atlantic hurricane season. Isabel made landfall over the Outer Banks of North Carolina and quickly weakened as it made its way up the East Coast of the United States. Damage was greatest in the state of Virgina. Virginia reported a peak 20.2 inches of rain causing sever flash flooding and $1.85 billion in damage[8].

In addition to the intense wind that comes with a hurricane, there is also immense precipitation. The rain bands of a hurricane are the outer bands that radiate out from the from eye of the storm. As mentioned before, the Isabel data has 48 different time steps with each time step being one recorded hour. Rainfall over the ocean is not as interesting as rainfall over populated regions of land. However, we still visualized the amounts of precipitation falling at hour 11 over the Atlantic.

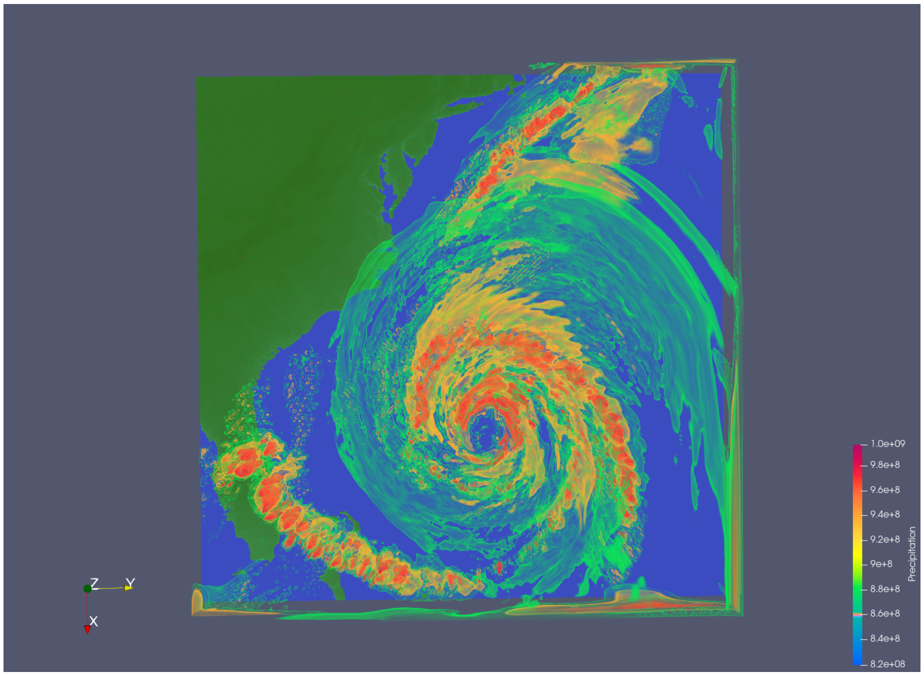

Figure 13: Volume rendering of Precipitation at hour 11

The storm is at its strongest over the ocean and as a result the amount of rain is towards the upper threshold of the scale at the bottom right of figure 13. There was immense amounts of precipitation as the storm made land fall. In figures 14 and 15, you can see that even though wind speeds are decreasing, see figure 12, there is still a large amount of precipitation.

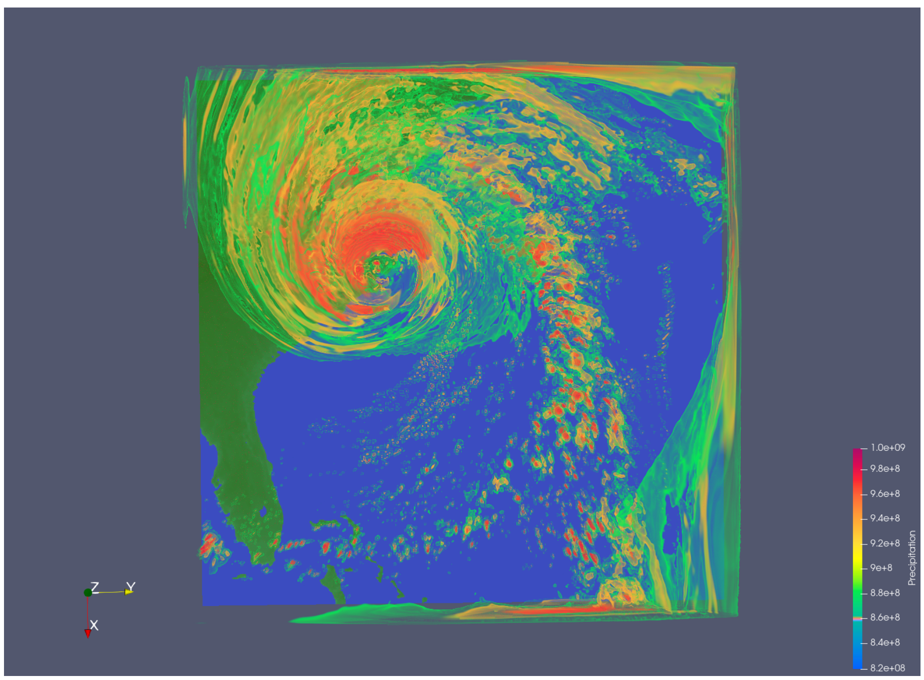

Figure 14: Volume rendering of Precipitation as Isabel makes landfall

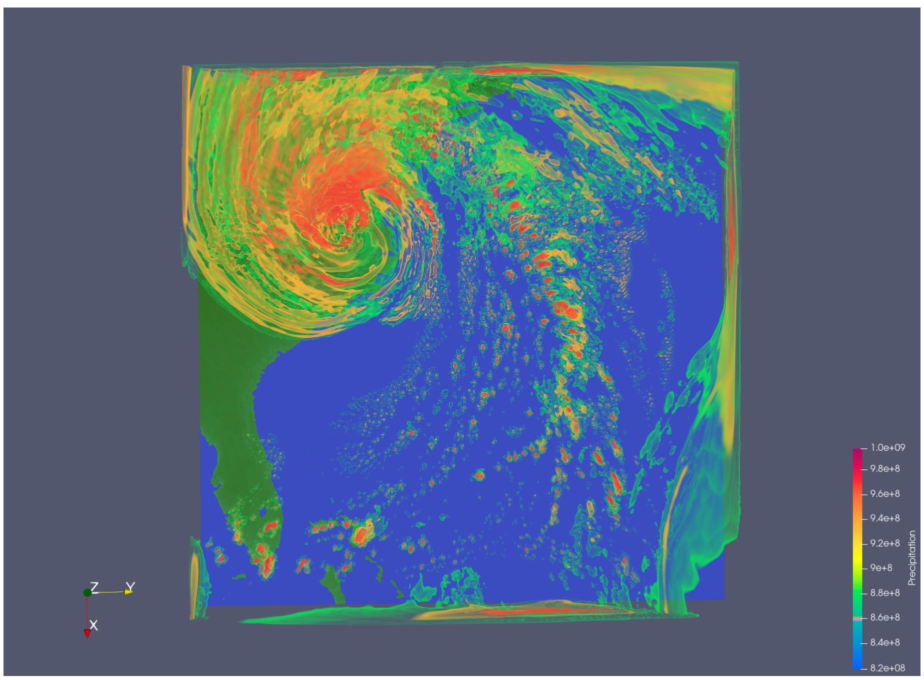

Figure 15: Volume rendering of Precipitation as Isabel makes landfall

5 Temperature

The remaining sections are visualizations we deemed important but less important than the former sections. While still important variables in hurricane formation and structure, they are simply less visually interesting.

As mentioned before, hurricanes form over warm ocean water. In figures 16 and 17 you can see the warm temperature closer to the ocean surface with cold air higher up in the atmosphere. Towards the eye of the storm there is a slight bump likely due to the upward draft that the storm creates at its center, pulling up the warm ocean moisture it needs for fuel.

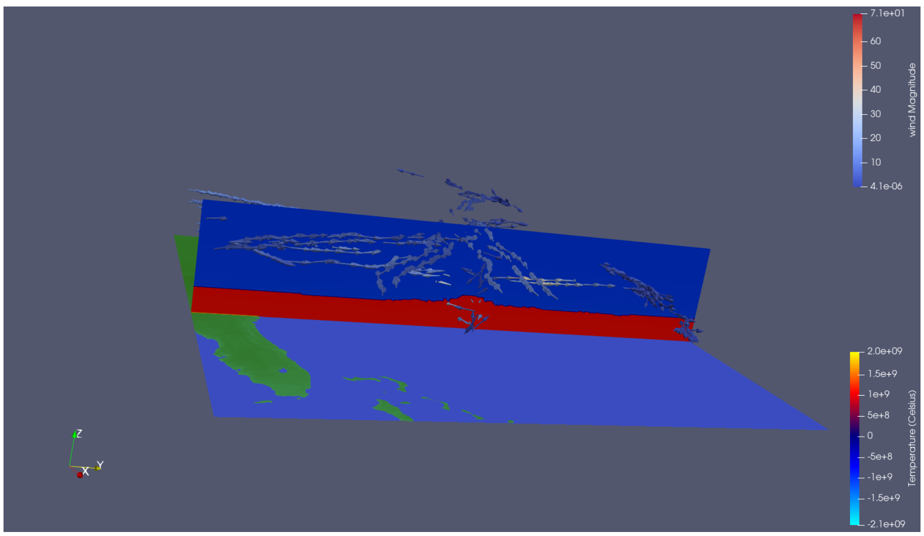

Figure 16: A slice filter applied to the temperature variable in addition to glyphs showing wind flow

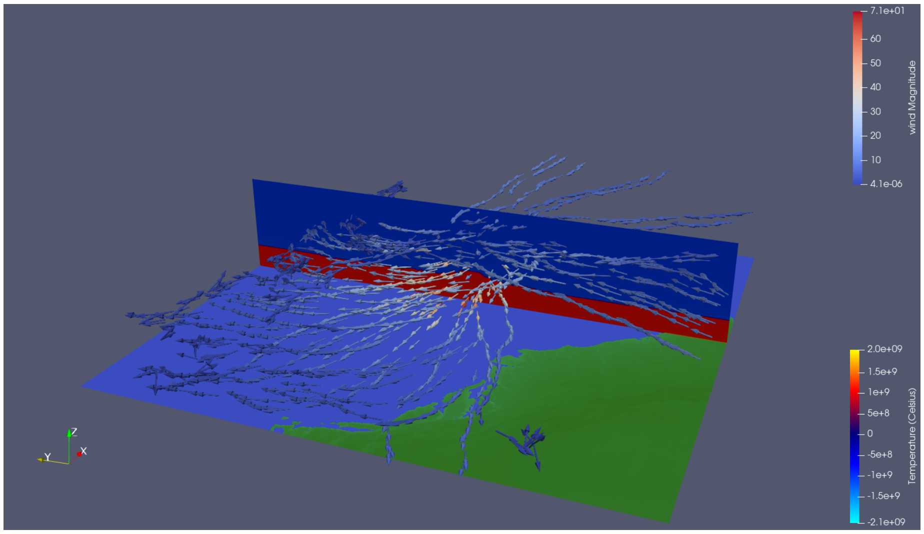

Figure 17: The other side of figure 16

6 Pressure

Remember that hurricanes are low pressure systems, which are atmospheric areas of low pressure surrounded by high pressure. The eye of the storm is where the pressure is lowest[6].

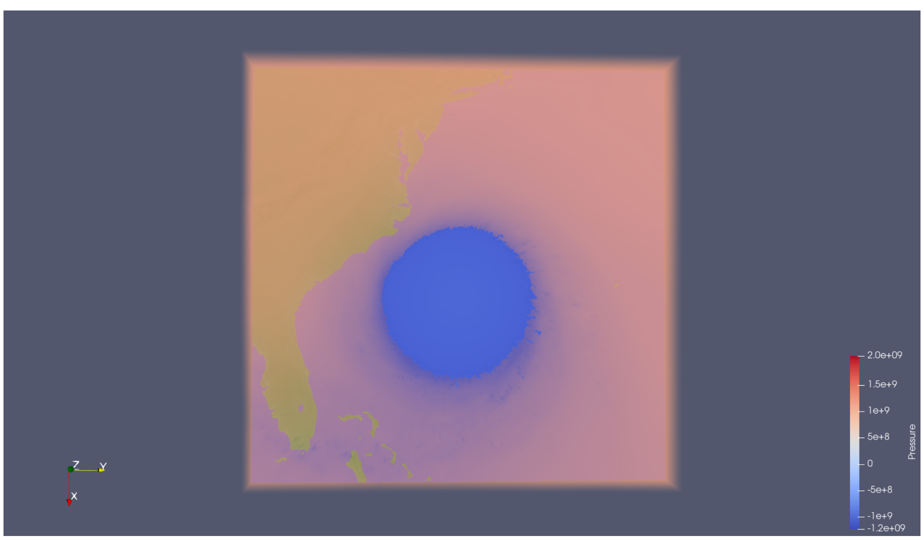

Figure 18: Hurricane Isabel pressure visualization at hour 24

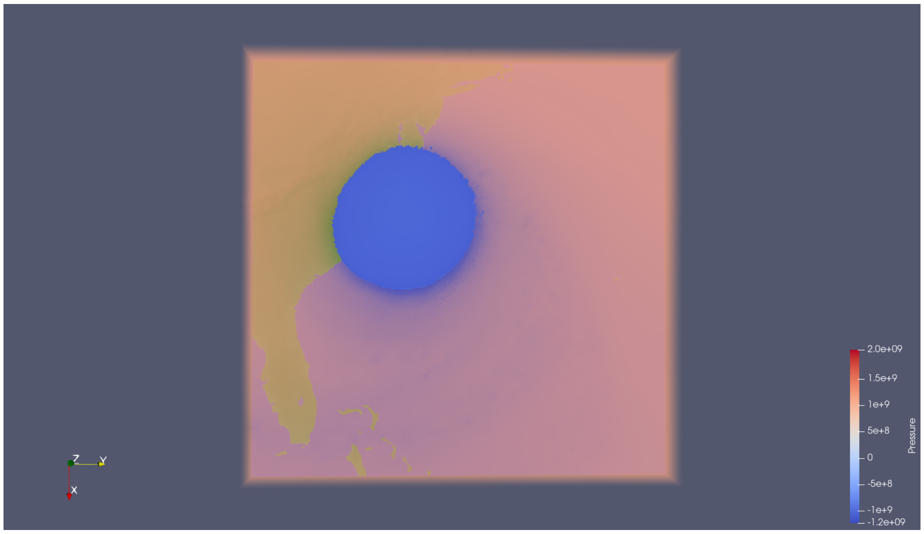

Figure 19: Hurricane Isabel pressure visualization

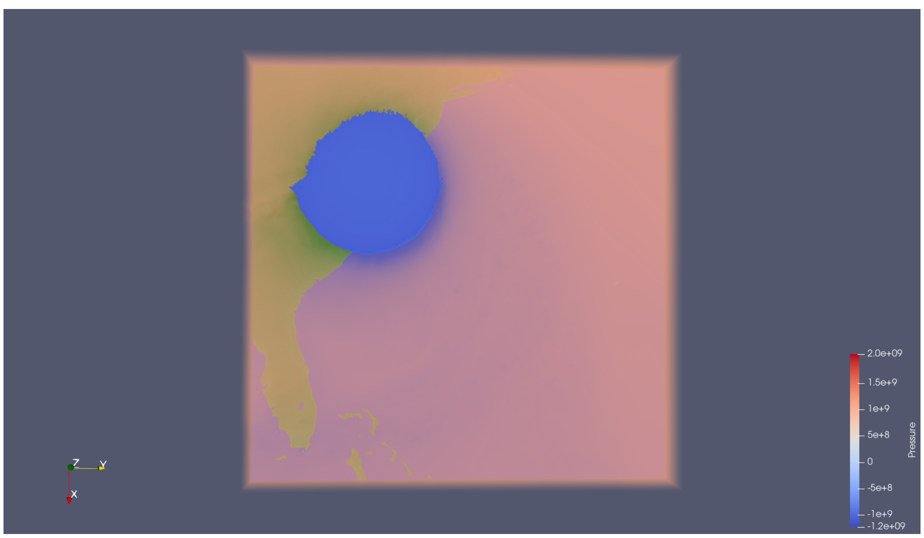

Figure 20: Hurricane Isabel pressure visualization at hour 48

7 Conclusion

This hurricane visualization project was a significant undertaking that resulted in the creation of a number of valuable scientific visualizations. We believe we achieved our goal and created a successful project. This project also demonstrated that Paraview is a powerful visualization software and without it we likely would not have been able create the images we did.

In addition, there are a few key things we learned from this project. One being the importance of using high quality data and as mentioned before, powerful software capable of handling the data. Also, it is important to understand your data before working with it. We spent hours trying to understand just the format of our data. Since these data sets are so large, there is a significant amount of data packed into a single file, and figuring out how to access it can be time consuming.

In conclusion, we believe we created useful scientific visualizations of Hurricane Katrina and Hurricane Isabel. We achieved the goals we set at the start of the project and learned some valuable skills along the way. Unfortunately we can not include the animations in this written report. A link is provided in the Links section to all the images used in the report as well as the files for the animations. There is also a link to our repository to view the code used for downloading and converting the data, as well as a few scripts to automate the loading into Paraview process, and the .pvsm files.

8 Sources

1. http://vis.computer.org/vis2004contest/data.html

2. https://www.earthsystemgrid.org/dataset/isabeldata.html

3. https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

4. https://en.wikipedia.org/wiki/Tropical_cyclone

5. https://en.wikipedia.org/wiki/Low-pressure_area

6. http://ww2010.atmos.uiuc.edu/(Gh)/wwhlpr/hurricane_eyewall.rxml?hret=/guides/mtr/hurr/stages/cane/home.rxml

7. https://www.nhc.noaa.gov/

8. https://en.wikipedia.org/wiki/Hurricane_Isabel

9 Links

Github Repository
https://github.com/kunal911/CS-6635-5635-Final-Project

OneDrive
https://uofutah-my.sharepoint.com/personal/u1419704_umail_utah_edu/_layouts/15/onedrive.aspx?id=