Team 1: Shelby Marcarian, Brock Sponenburgh, Nate Thomson

Overview and Goals:

We will aim to draw conclusions about how a storm will interact with the Tangoroa Research Vessel when it is being hit from the side. This is a vulnerable position for a ship to be in, as they are less stable being impacted from the side than head on. We are interested in visualizing how the body of the ship affects wind currents based on simulations.

Background:

The Tangoroa is a New Zealand owned research vessel for ocean floor and marine life surveys. https://niwa.co.nz/videos/rv-tangaroa-new-zealands-world-class-research-vessel#:~:text=Tangaroa%20is%20New%20Zealand's%20only,often%2Dchallenging%20Southern%20Ocean%20environment. It employs a dynamic positioning system, meaning it can maintain its own course and position using propellers and thrusters in uncertain conditions. https://www.nautinst.org/technical-resources/technical-library/dynamic-positioning.html. A greater understanding of how wind currents move around the body of the vessel could potentially allow a more efficient dynamic positioning system to be developed. Taking into consideration how the shape of the vessel affects these currents could allow the engineer of the positioning system to increase and decrease capacity of propellers and thrusters beforehand instead of using compute power on the fly to figure out where power is most needed.

Project Description:

We used data from a simulation of wind currents around the Tangoroa Research Vessel over 200 timesteps. The scientific questions we answered were how the shape of the vessel affected wind currents flowing over it, and how the flow changed over time (i.e. by becoming more turbulent). An unanswered question in our project would be how to improve the shape of the ship to allow the stability system to function more efficiently. Without other shapes or the ability to modify the ship ourselves, this question is a little tricky to answer confidently.

Implementation Details:

Our primary tool was Paraview. The data came to be separated into three scalar values, so we began by combining them into a 3-dimensional vector field. We used this vector field to create streamlines on the data, and found the areas of interest by moving point clouds around on the data. We found the data to be extremely turbulent behind the vessel, and focussed our analysis on that area.

Our first visualization was to look at the streamlines of the vector field we created. We reduced the opacity of the vector field to keep the shape of the ship visible without ruining visibility of the streamlines, and colored them according to the magnitude of the vectors. We found that the streamlines flow over the body of the ship with a slight curve over the top, then move erratically once they reach the other side of the ship.

We then colored the streamlines by vorticity to get a better understanding of how the particles move once they reach the other side of the vessel. This explained the erratic movement, showing high vorticity in areas with lots of loops in the flow, meaning they were spinning. The high vorticity of the flow helps to explain also the turbulence in the flow over time. It grows more and more erratic over time. We used forward integration for both the streamlines and vorticity.

Our next visualization was topology analysis. We kept this same lower opacity of the vector field to still view the ship. We added a contour filter to find the topology of the data. The reason for this is because by creating a surface that follows a specific scalar value within the data, you can identify important topological features that can affect the boat's performance.

When looking at the visualization as the timeline progressed, it was easy to see that the contour grew, showing the more erratic behavior of the airflow as it passed the ship. Because of the direction and speed of the wind changing over time, this is why the visualization grows, knowing that, we can see that the speed of the wind is affected by the ship by slowing the speed of the air lower and closer to the water, but up by the top of the ship, we can see the speed increase and change direction.

We originally intended to analyze persistence based on high and low points of the topology, but the ttk library we were attempting to use crashed all of our machines.

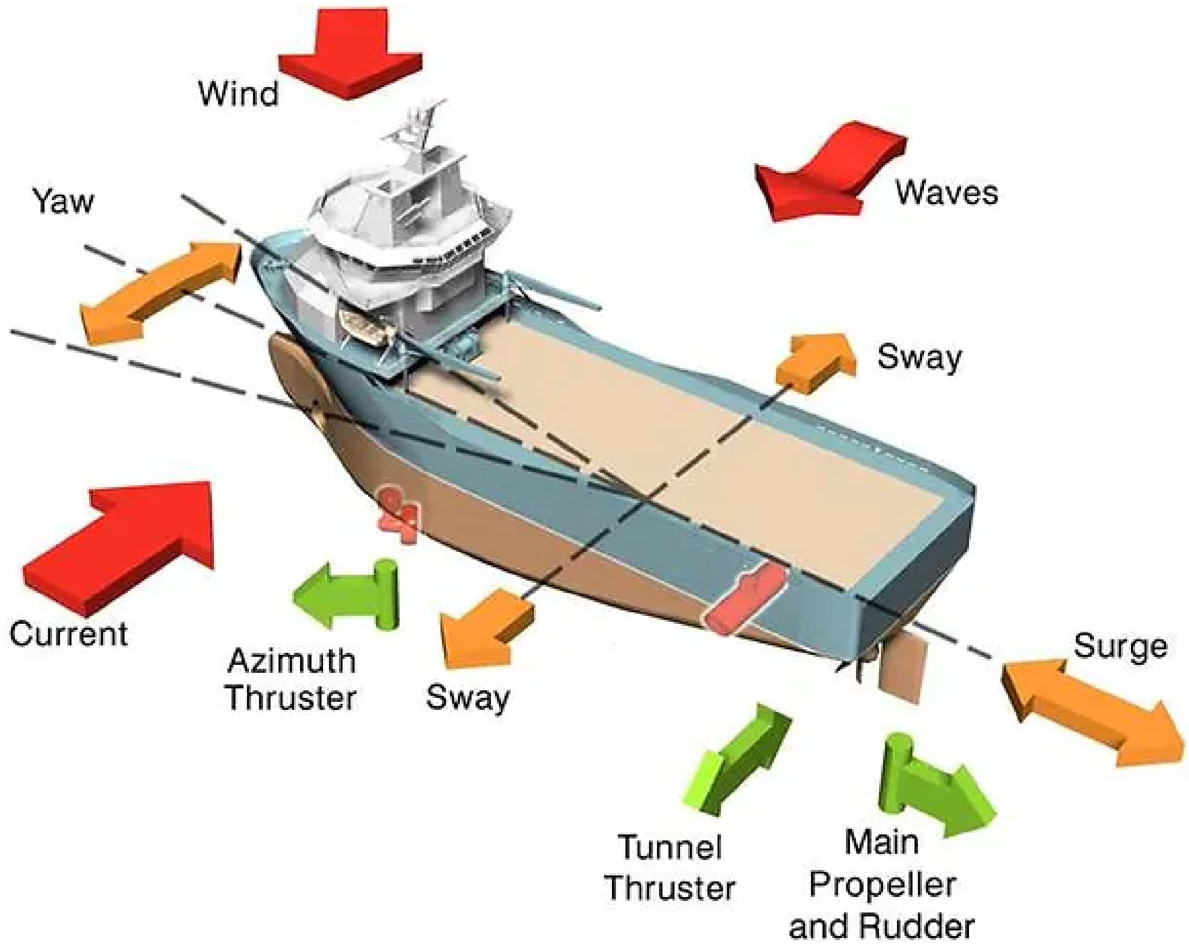
<u>Lessons Learned:</u>

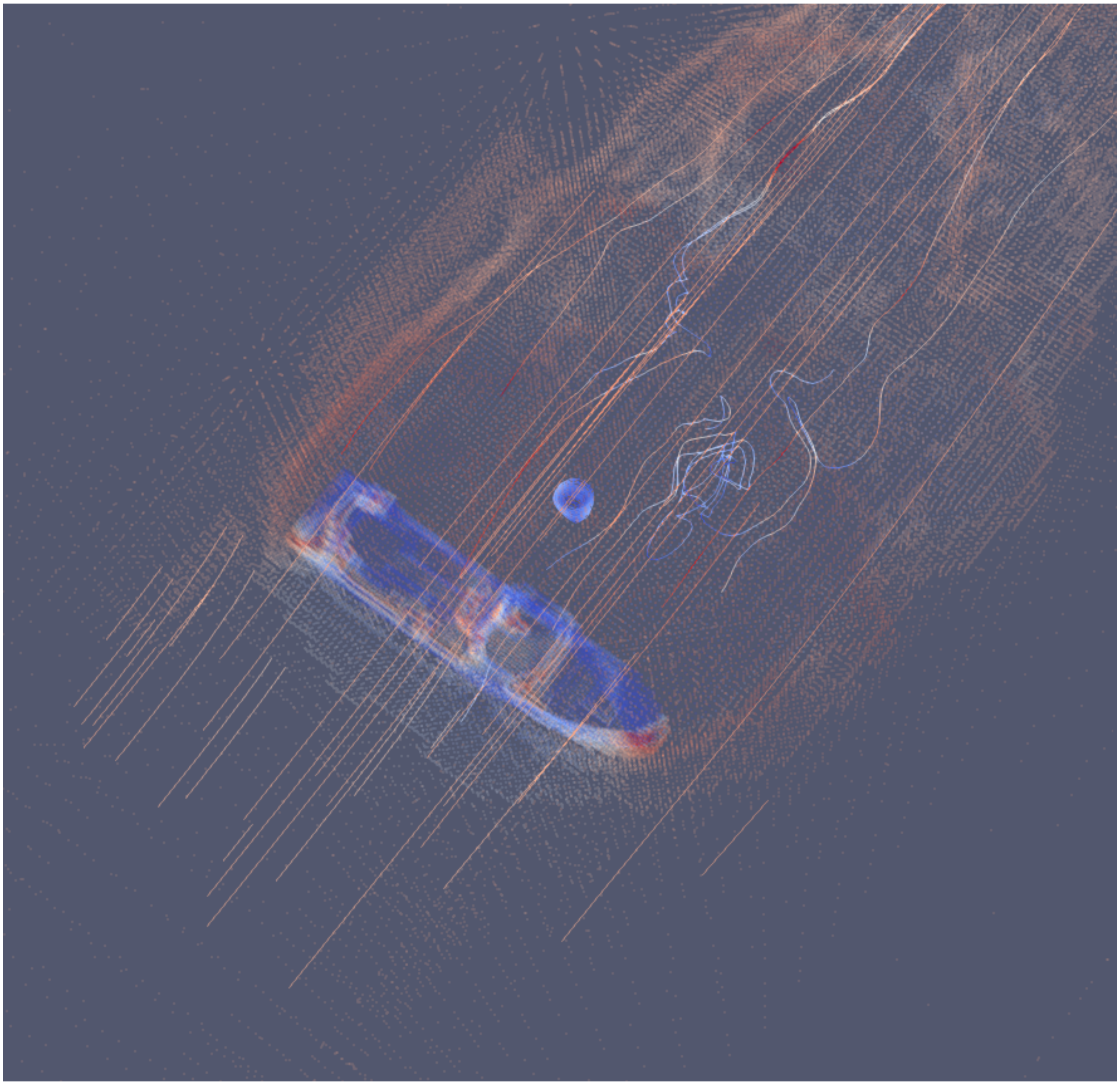
The first lesson learned was how to work with multiple fields that needed to be combined into a single vector field. We also learned how to visualize the topology of the flow, and the persistence of the data, which we were mathematically unpracticed in prior to this project.

<u>Expected vs. Actual Outcomes:</u>

We had originally expected to make conclusions about how to improve the shape of the boat to affect the flow differently. However, without other vessels to compare the results of the simulation and analyses to, we could not make any claims about how the shape of the boat affected the flow one way or another. Instead, we gained a solid understanding of the flow itself, and where it was strong or turbulent. This allows us to support claims about which propellers and thrusters need more power than others.

The biggest outcome of our analysis is that we can see that the flow becomes most turbulent and strong behind the cabin of the ship.This would lead us to advise an engineer to provide more power to the Azimuth thrusters to compensate for the taller aspect of the ship.





Project Evaluation:

Our project was moderately successful. One weakness is that we believe it would be more useful in the hands of someone that understands the engineering behind ships more thoroughly than we do. However, we were still able to determine which areas of the ship are more likely to be affected by the flow of air than others. A strength of our implementation is that it is intuitive; you can easily look at the visualizations and see what is happening in the data at any point in time.

Work Distribution:

We all worked together to figure out how to combine the data and make it usable in Paraview. From there, we split it up by visualizing streamlines and vorticity (Shelby), topology (Brock), and persistence (Nate). We split up the presentation based on who developed which part of the solution

Software

Software Used:

Paraview

How to Reproduce the Work:

Clone the repository found here: https://github.com/bsponny/CS5040-FinalProject.

Download the dataset (Unstructured grid version) here: https://cgl.ethz.ch/research/visualization/data.php. Make sure to change the source file names to your own machine. Paraview groups the dataset incorrectly by default because of the decimals in the file names. We recommend running this bash script in the folder as an easy way to remove the decimals.

```
$ for f in *.vtk; do mv "$f" "$(echo "$f" | sed s/[.]//)"; done
```