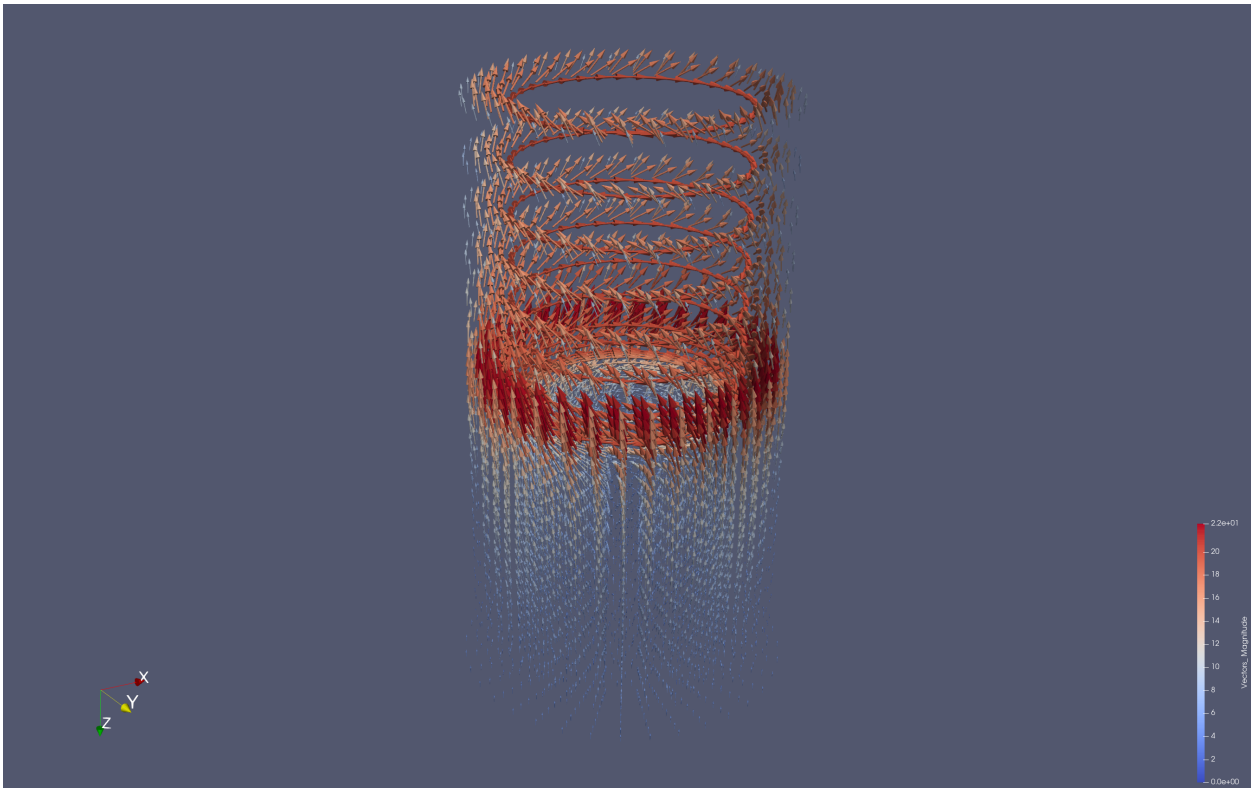
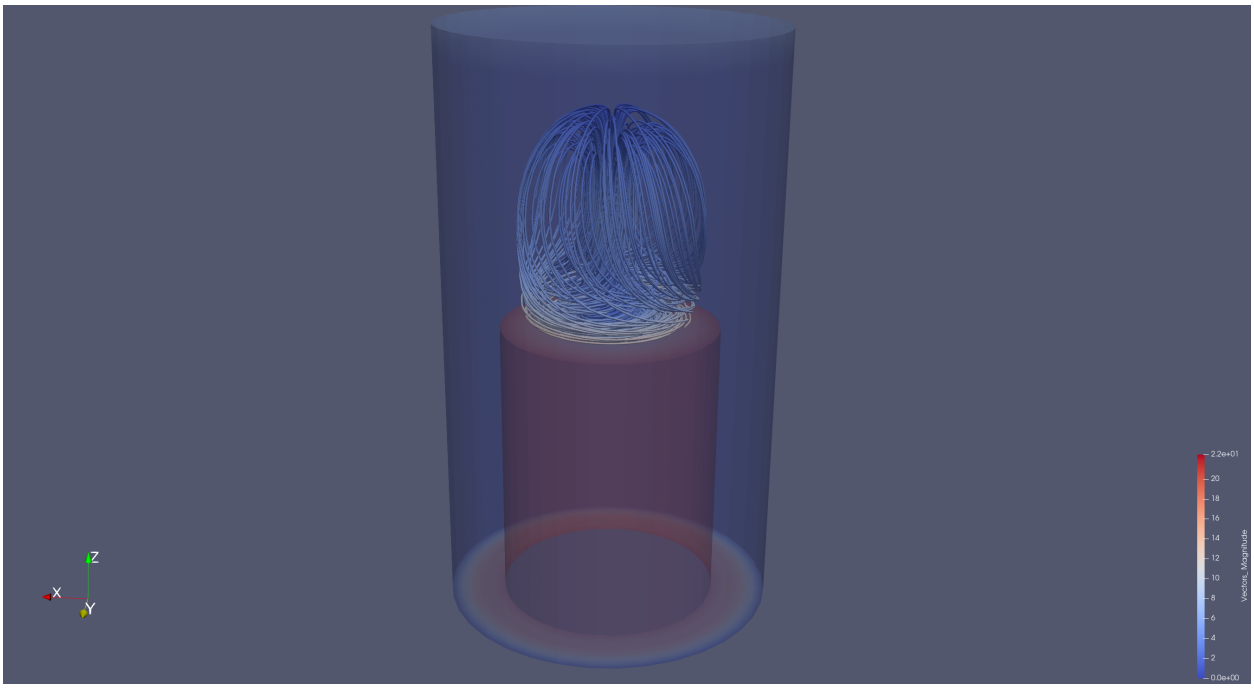
CS6635 - Assignment 4

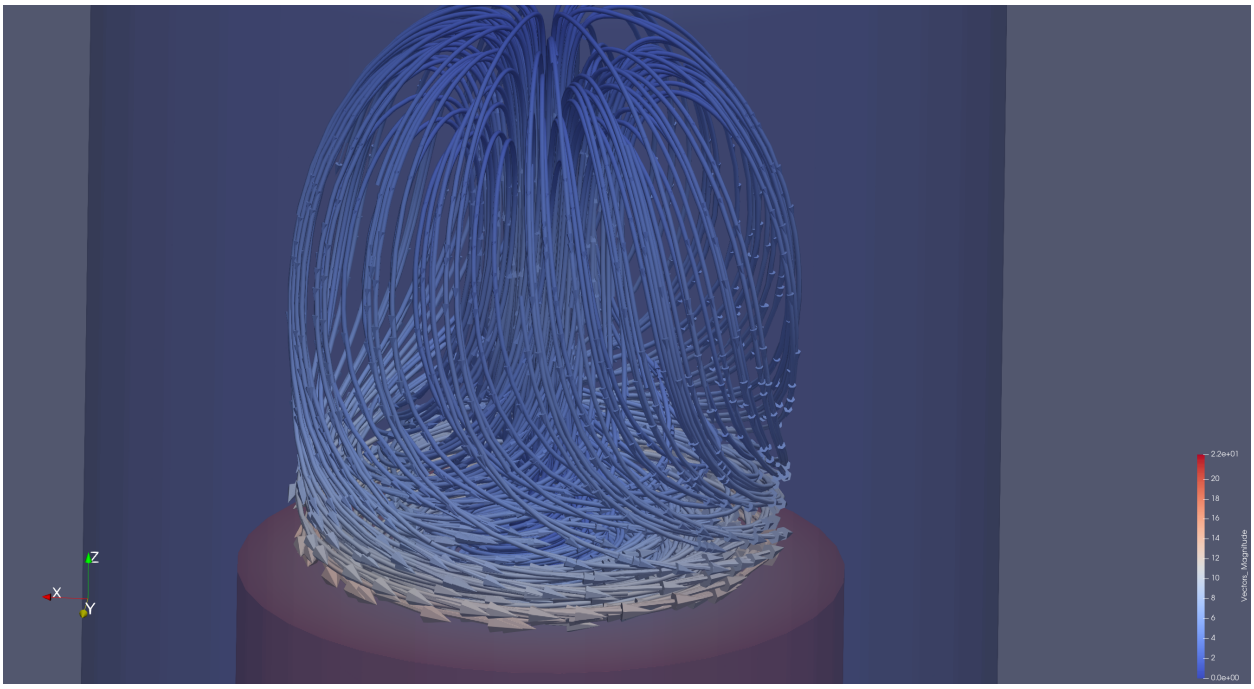
Question 1



As the question suggests, the image image has been obtained by using glyph mode on all points. Further, the glyphs are scaled according to vector magnitude and so is the colouring.



The above streamlines have been obtained using the point source seed. To enhance the visualisation tubular surfaces have been added.

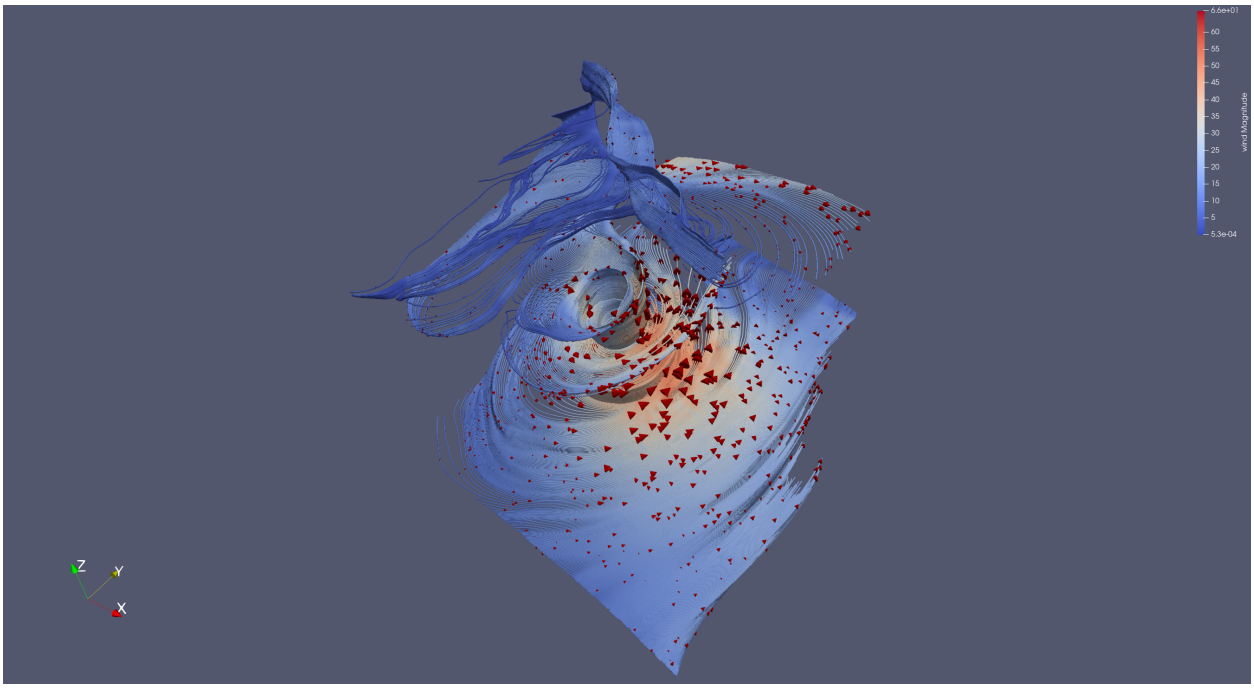


To interpret the magnitude and direction of the vector field along the stream lines, the glyph filter has been added. It has been scaled according to the vector magnitude and oriented as per the direction of the vector.

The pattern I observe is that the vector field seems point upward near the centre and then rotates and comes downward away from the centre. Naturally, the vector magnitude is lesser away from the heated disc and higher near the disc.

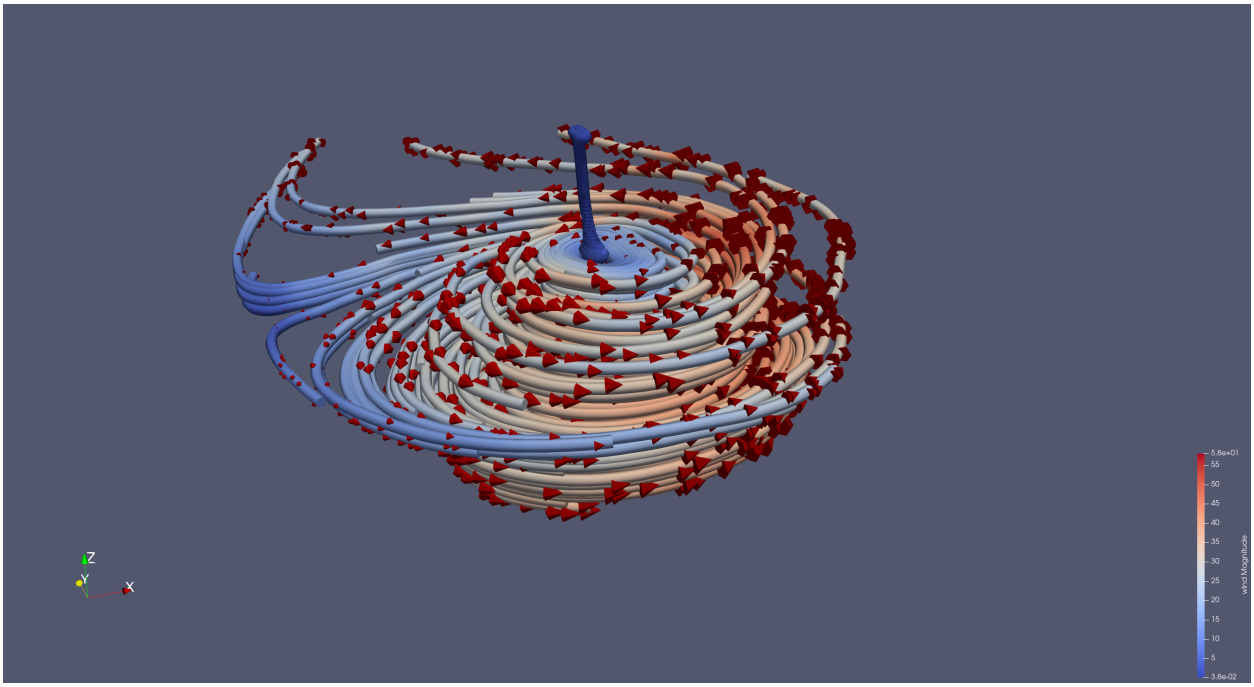
I think adding the glyphs on the streamlines was very useful to interpret the direction of heat flow, without which not too much can be inferred just from the streamlines. But, using streamlines is a lot more helpful compared just looking at glyphs without streamlines since streamlines highlight important paths of the heat flow quite evidently.

Question 2



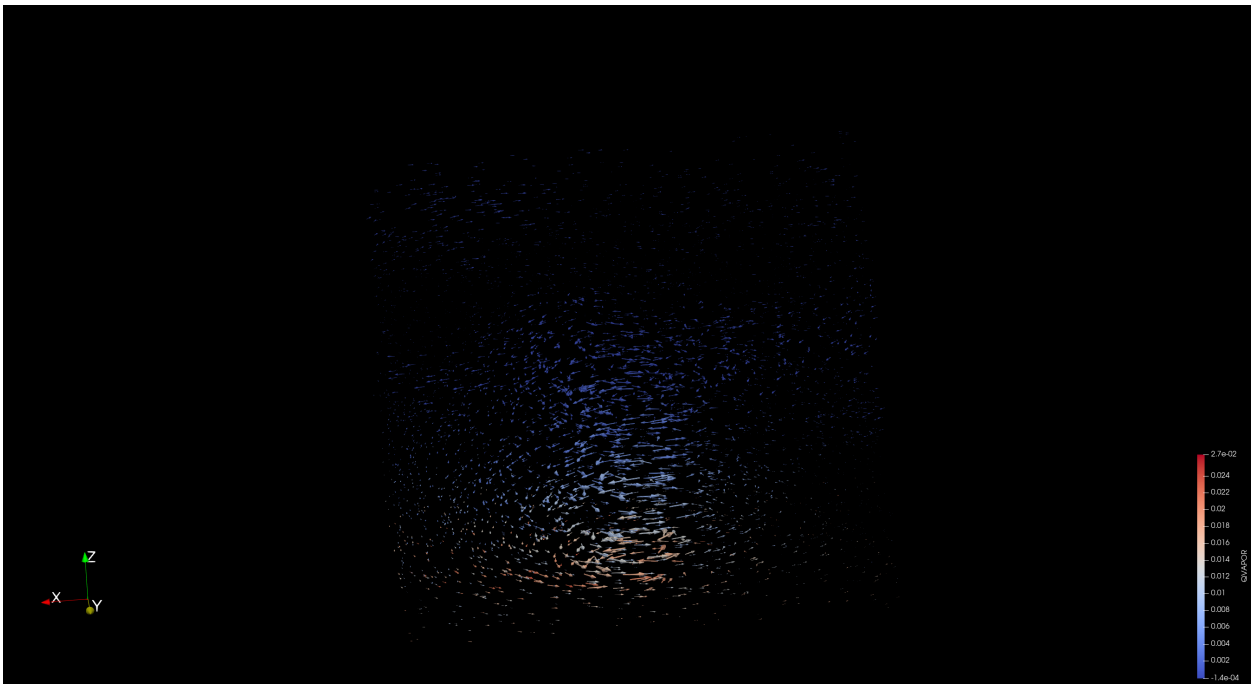
The above image has been obtained by using line seed, where the line is made to pass through the body diagonal of the dataset. The tube filter has been used to enhance the visualisation and set to appropriate radius, so that it does not look too cluttered. Even cone glyphs have been added to the stream tubes to help interpret the direction of the flow. They have scaled according to the vector magnitude.

From this image, it is evident that there is one large hurricane around which most of the air is rotating. Further, it is to be observed that the magnitude of the wind flow reduces as you go farther from the centre. Also, there seem to be some small hurricane like structures with lower curl like in the top right of the above image.



The above image has been obtained by using cloud seed, where the sphere is placed in the centre of the dataset. The tube filter has been used to enhance the visualisation and set to appropriate radius, so that it does not look too cluttered. Even cone glyphs have been added to the stream tubes to help interpret the direction of the flow. They have scaled according to the vector magnitude.

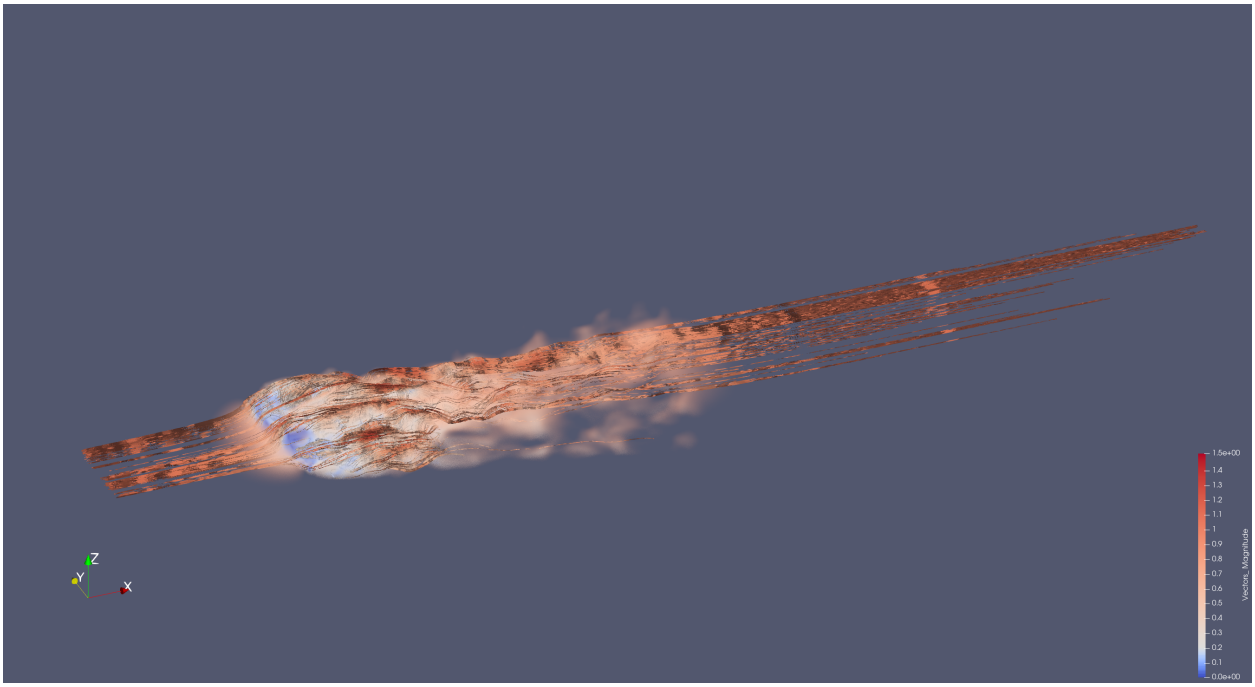
In the above image, we observe that most of the air is rotating around an axis. This can be confidently interpreted as a hurricane. Compared to the line seed this gives us a more focused image to understand the local behaviour of the hurricane. For instance, it is evident from this visualisation that wind seems to flow inward towards the centre of the hurricane and in the anti-clockwise direction.



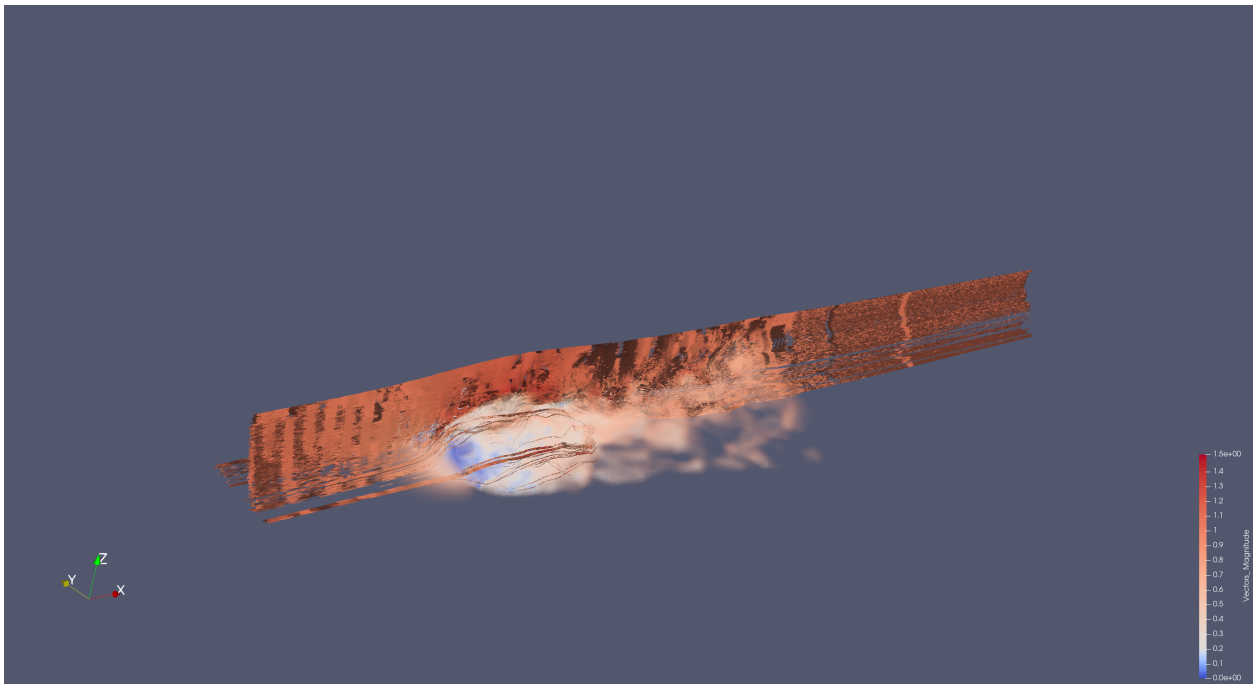
The above image has been obtained by randomly sampling glyphs thought out the volume. The vectors are scaled as per their speed and so is the colour.

This image also shows that wind is majorly rotating around a centre implying that it is a hurricane. An interesting observation from this is that the flow is in the anti-clockwise direction in the bottom but then becomes clockwise as you go up. The wind is moving inwards in the bottom and outwards as we go up. Similar to the trend evident in the first image, the magnitude of the wind reduces as it goes away from the centre.

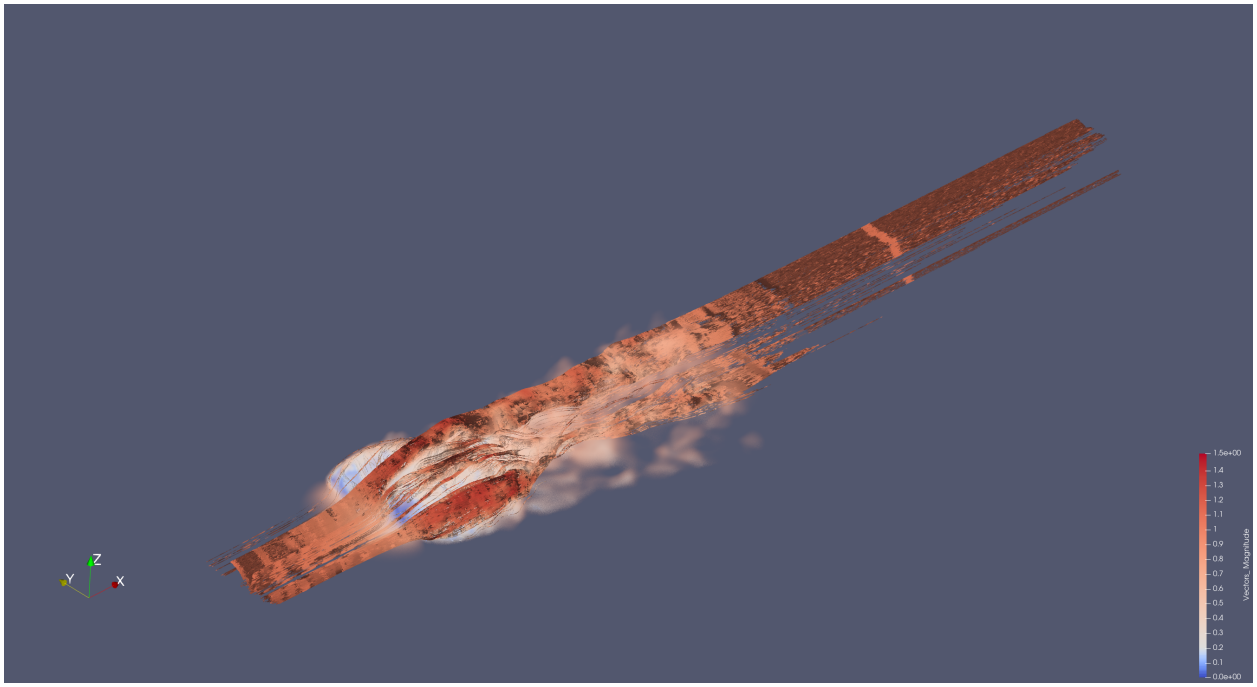
Question 3



The above image has been obtained by using the line seed orthogonal to the moving direction i.e along the y-axis.



The above image has been obtained by using the line seed along the z-axis.

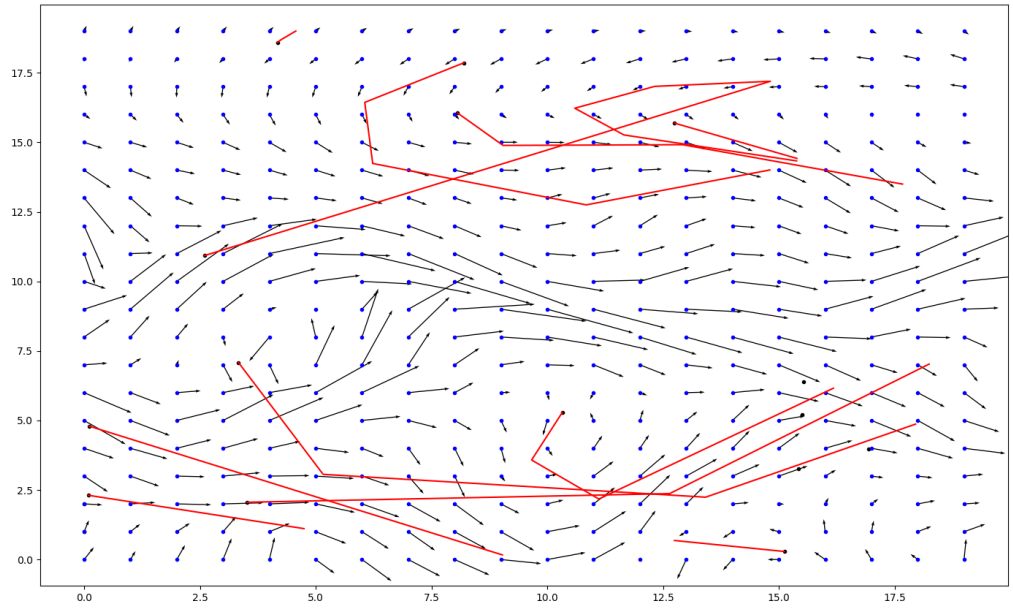


The above image has been obtained by using the line seed along the x-axis, i.e in the direction of motion.

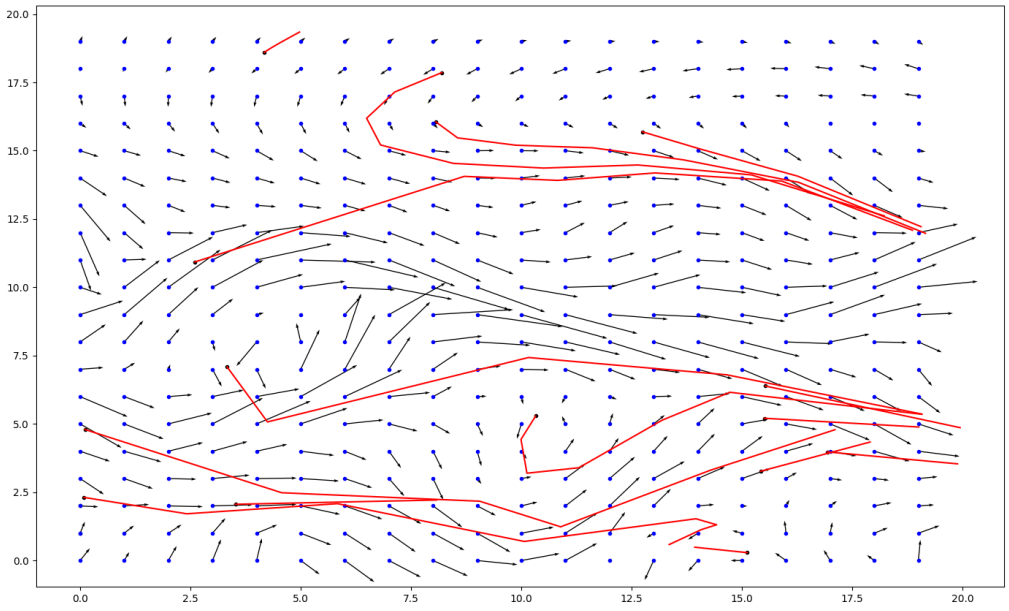
From all the images, the main observation is that the air flow is the highest above the car and on the sides of the car. This can be inferred because the ribbon streams are most evident above and on the sides of the car. There is naturally also a lot of air flow in front and behind the car along the direction of motion.

Question 4

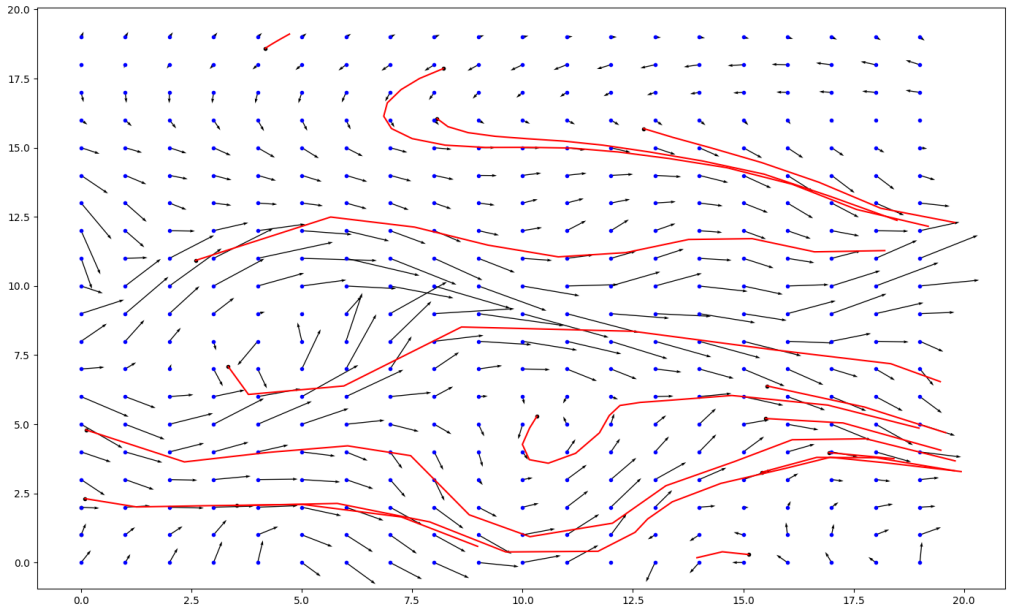
Euler's Method:



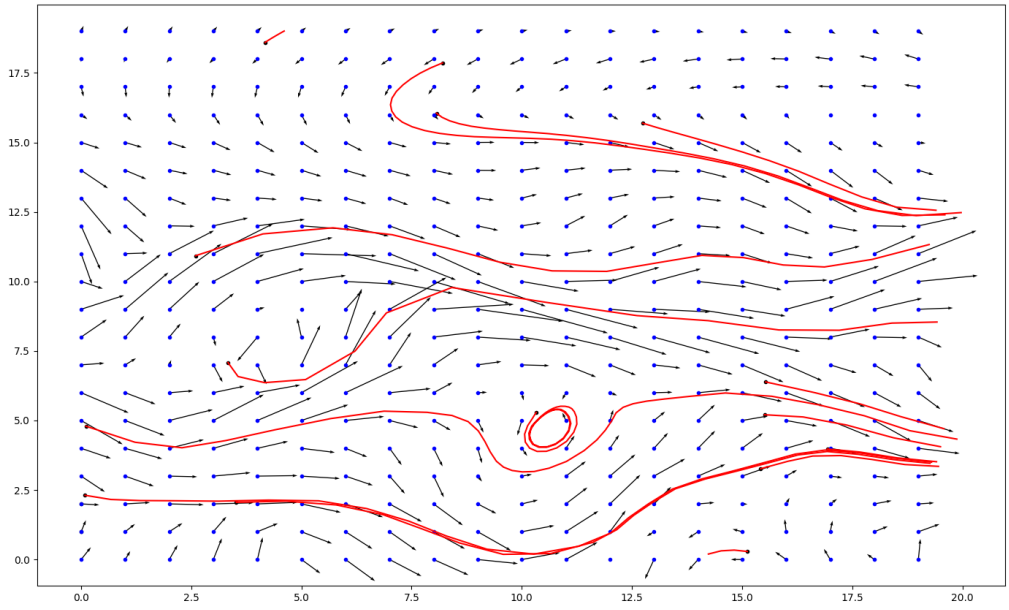
The above image is for timestep value 0.3 and for 8 steps.



The above image is for timestep value 0.15 and for 16 steps.



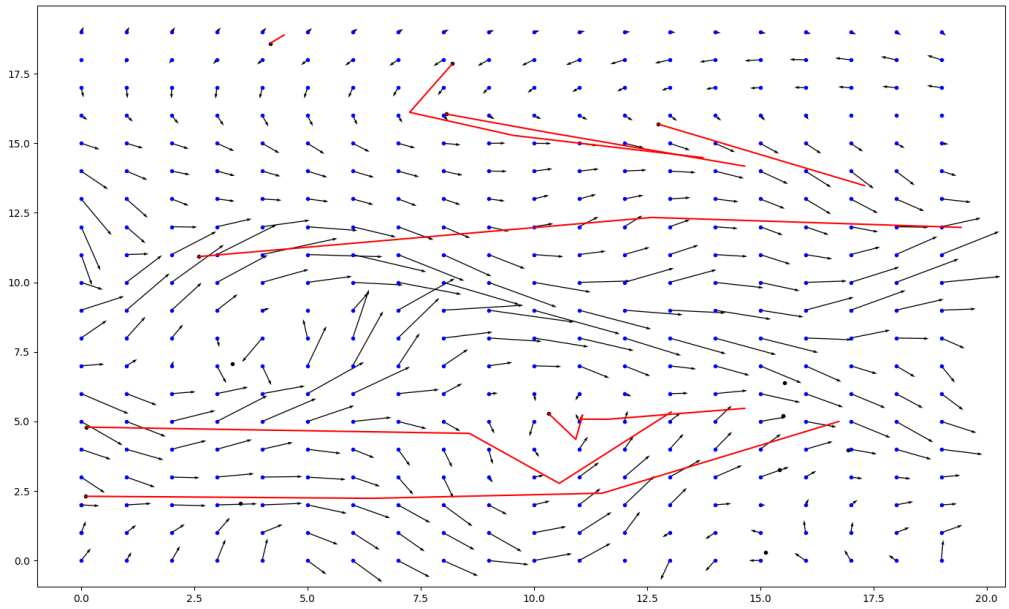
The above image is for timestep value 0.075 and for 32 steps.



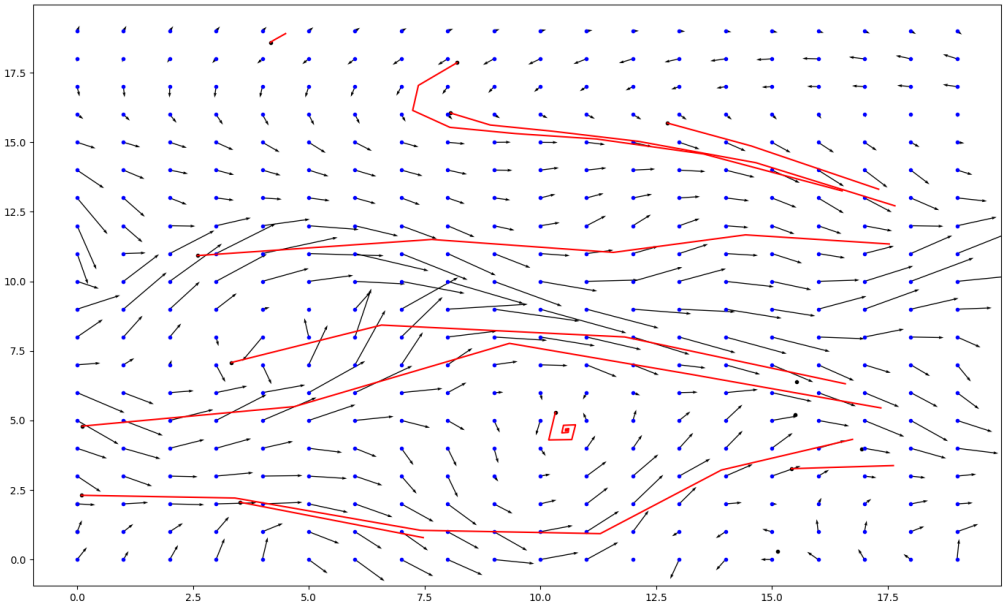
The above image is for timestep value 0.0375 and for 64 steps.

Divergence can be thought of as the amount by which the Euler streamline differs from the true streamline. And it is know that this error is of O(t^2) where t is the time step value. It is quite evident from all the above images that as they is reduced the streamlines seem to mimic the vector field a lot better.

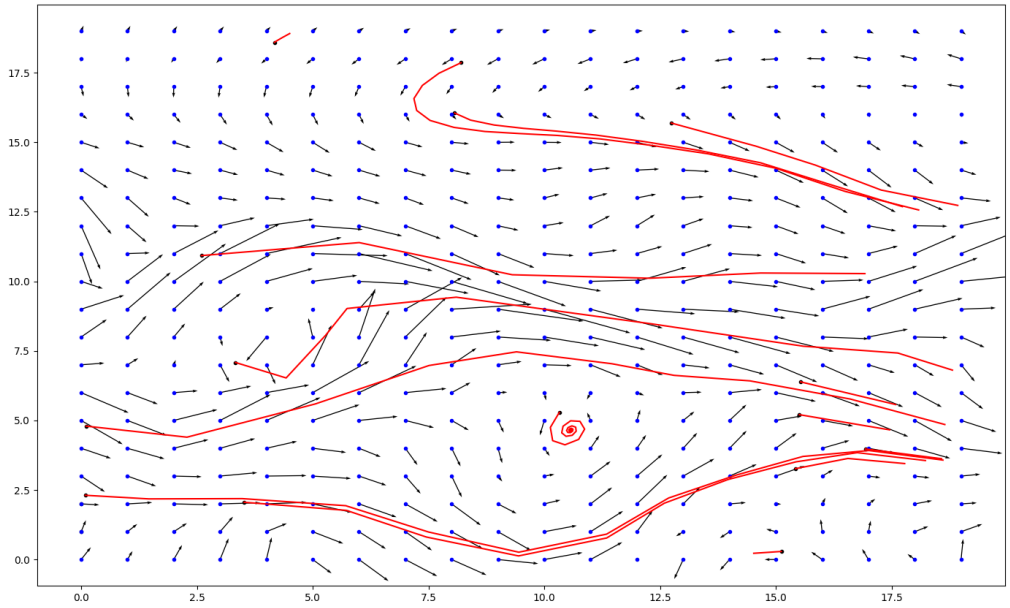
Runge Kutta:



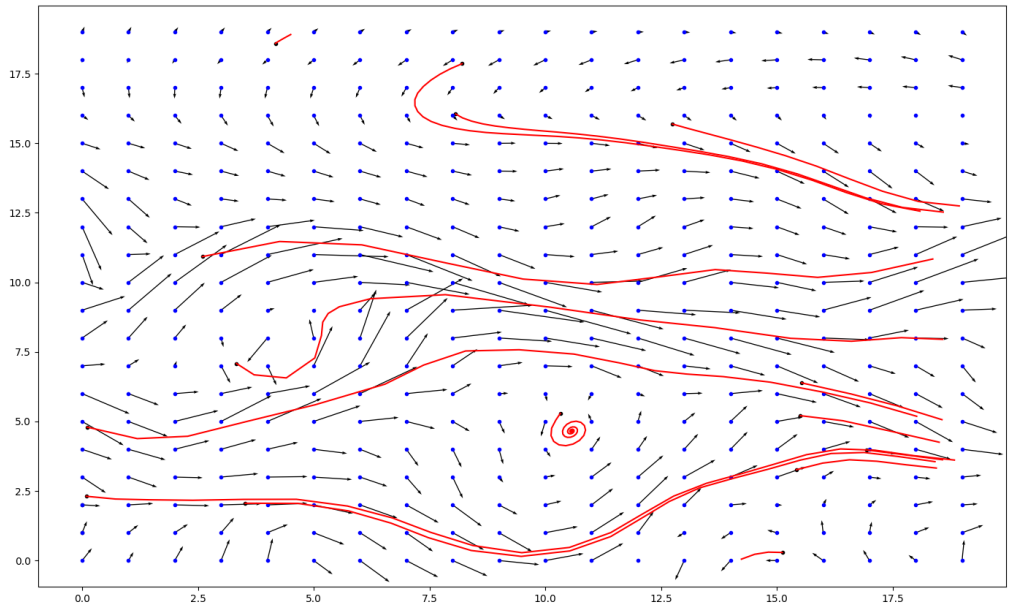
The above image is for timestep value 0.3 and for 8 steps.



The above image is for timestep value 0.15 and for 16 steps.



The above image is for timestep value 0.075 and for 32 steps.



The above image is for timestep value 0.0375 and for 64 steps.

The streams in all the above images have been obtained from 15 random seed points. And bilinear interpolation has been implemented. In both the methods, it seems a lot better to reduce the timestep value since only then the streamlines are properly capturing the trends of the vector field. If the timestep value is too large, then streamlines are just jumping over the local trends of the vector field.

The main difference between Euler and RK4 is that that RK4 gives lot smoother streamlines and seems to be better in capturing the minor details of the vector field. Further, RK4 does a lot better than Euler for larger timestep values.

Question 5

1) Steady flows are flows in which the vector field does not change with time i.e at a given point the vector at the point is constant across time. While unsteady flows are flows in which the vector field changes with time. Pathlines represent the path taken by a particle in the vector field over a certain period of time, taking into account that the vector field changes with time. Streamlines on the other hand represent the path taken by a particle if the vector field is hypothetically assumed to be fixed at a particular timestep.

2) Point Based Direct Methods: This visualisation is just done by looking at the vector field trends at points or their vicinity and showing them to a user.
Particle Tracing Methods: This visualisation is done by computing characteristic/ useful curves such as pathlines, streamlines from the underlying vector field by

particle tracing. And these curves are shown to the user.
Feature Based Methods: The data is preprocessed to obtain useful trends/features and only these are shown to the user.

3)

Topology-Based Visualisation: This technique majorly extracts useful topological details from the underlying vector field and shows it to the user. For instance, the critical points and sepratrices show most of the directional trends of the vector field. This can be thought of as a Morse-Smale complex. These techniques can be used for tracking the changes in the topology of vector fields across time. Another massive use case for these methods is that of simplification of vector fields by pairing critical points which occur due to noise.
Vector Field Clustering: Multiple vectors which are close to each other can be clusters and represented by a single vector which attempts to approximately represent all the vectors in a coarser resolution. This is very useful for cleaner visualisation.

Another feature based vector field visualisation method is **Shock Waves.**

Feature based visualisation is very useful, since the method innately highlights important features which makes the job of a user significantly easier instead of going through the entire data manually and identifying useful trends. This method of visualisation reduces clutter and makes data more interpretable for people.

Conclusion:

This assignment helped me learn vector field visualisation and a lot of its use case scenarios. Also, when to use the relevant filters in paraview for depicting what is necessary. I feel that vector field visualisation is extremely useful and very interesting by looking at the variety of datasets shown in this assignment.

Remarks:

All the state files and code is there in this repository:

https://github.com/DhruvMeduri/CS6635.git