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OpenFoam Assignment | The Lid-Driven Cavity

Justin Campbell

Amanda Hiett

Archithaa Mohan

Akhil Sadam

Abstract

-SAMPLE ABSTRACT-

Keywords: computational fluid dynamics, CFD, incompressible, Paraview, R, Python, coe347, spring 2022.

1. Motivation

The flow around an infinite, circular cylinder is a well-studied, but yet not completely understood problem in CFD (computational fluid dynamics). A simple exploration of the steady and unsteady flow at low Reynolds numbers is undertaken here, to provide a light overview of the problem.

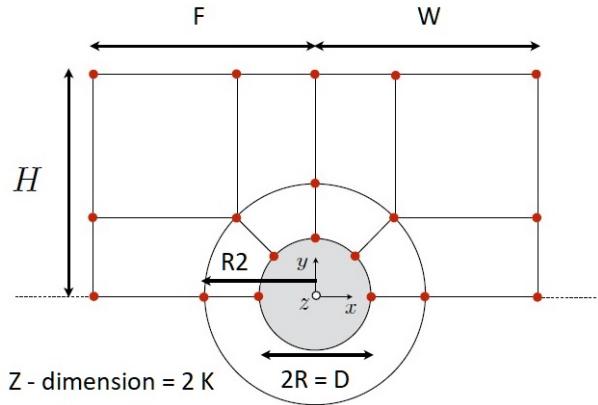
2. Implementation

We implement all simulation with OpenFoam, analysis with Paraview and Python3, and documentation code in R [Xie, Dervieux, and Riederer \(2020\)](#).

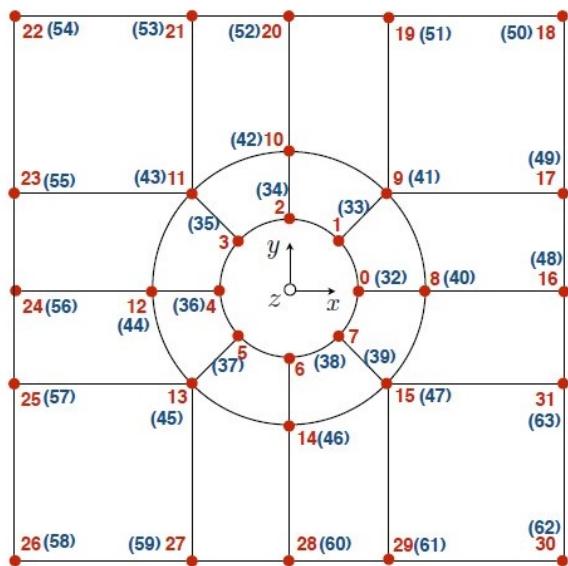
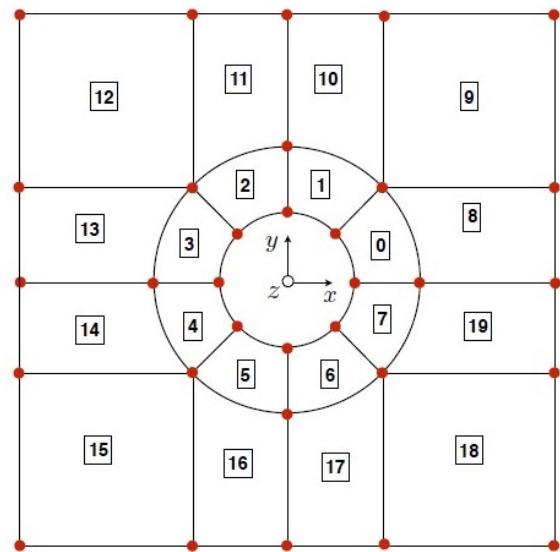
3. Mesh Assembly : Preliminaries

We assemble a set of preliminary meshes for simulations with Reynolds number 20 and 110, consisting of an inner cylindrical segment and outer rectangular segment as follows. The following mesh schematics list dimension parameters and block configuration, courtesy of Dr.Fabrizio Bisetti, UT Austin.

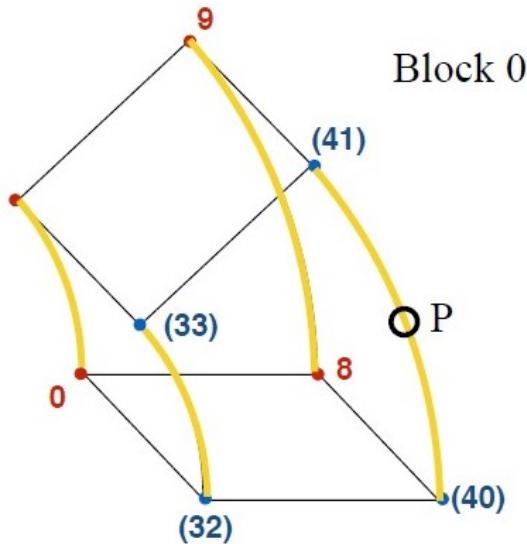
3.1. Mesh Schema



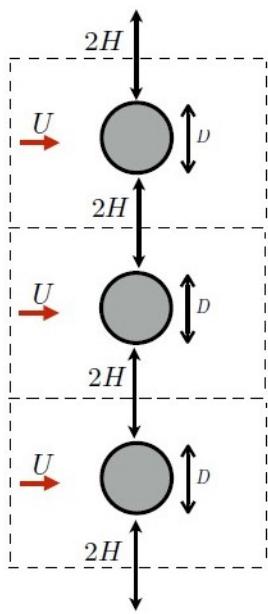
The blocks and block vertices are as follows. The blue vertices denote the other Z-plane.



The edges are defined by listing points P as follows.



A symmetry plane is defined in OpenFoam s.t. boundary effects do not significantly affect results. So the resulting simulation will look as below.



For all the meshes unless otherwise noted, the parameters are as follows, with units in meters for all dimensions on the diagram, and Re denoting the Reynolds number.

- f : blockMeshFactor (decreases cell dimensions in each direction by this factor), set by default : `int(max(10, Re/3))`
- R : cylinder radius, default: $1/2$
- $R2$: ring block outer radius, default: $3/2$
- H : height, default: 4
- F : forward distance, default: 4
- W : wake (backward) distance, default: $4 + Re*(1/15)$
- K : +/- distance in Z-axis — mostly irrelevant for anything in this project, default: 4

The preliminary meshes `run_20_1` and `run_110_1` simply follow the default settings.

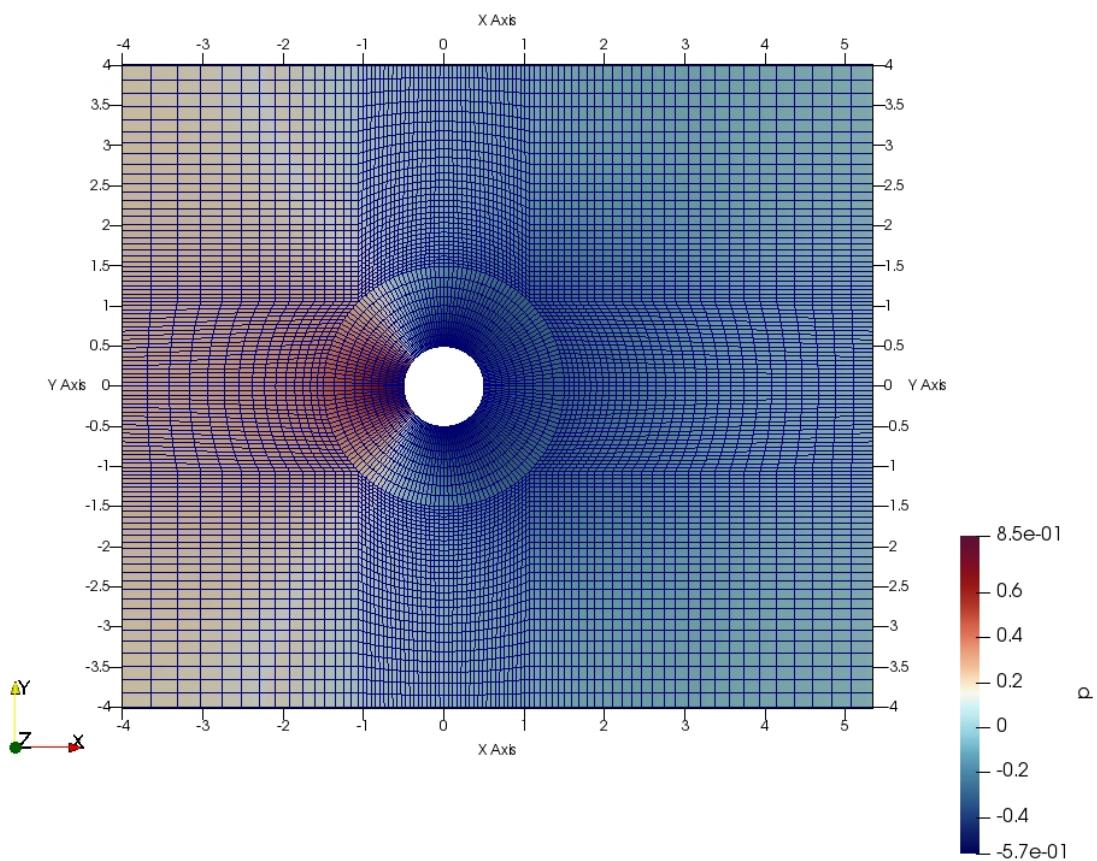
3.2. Mesh Files

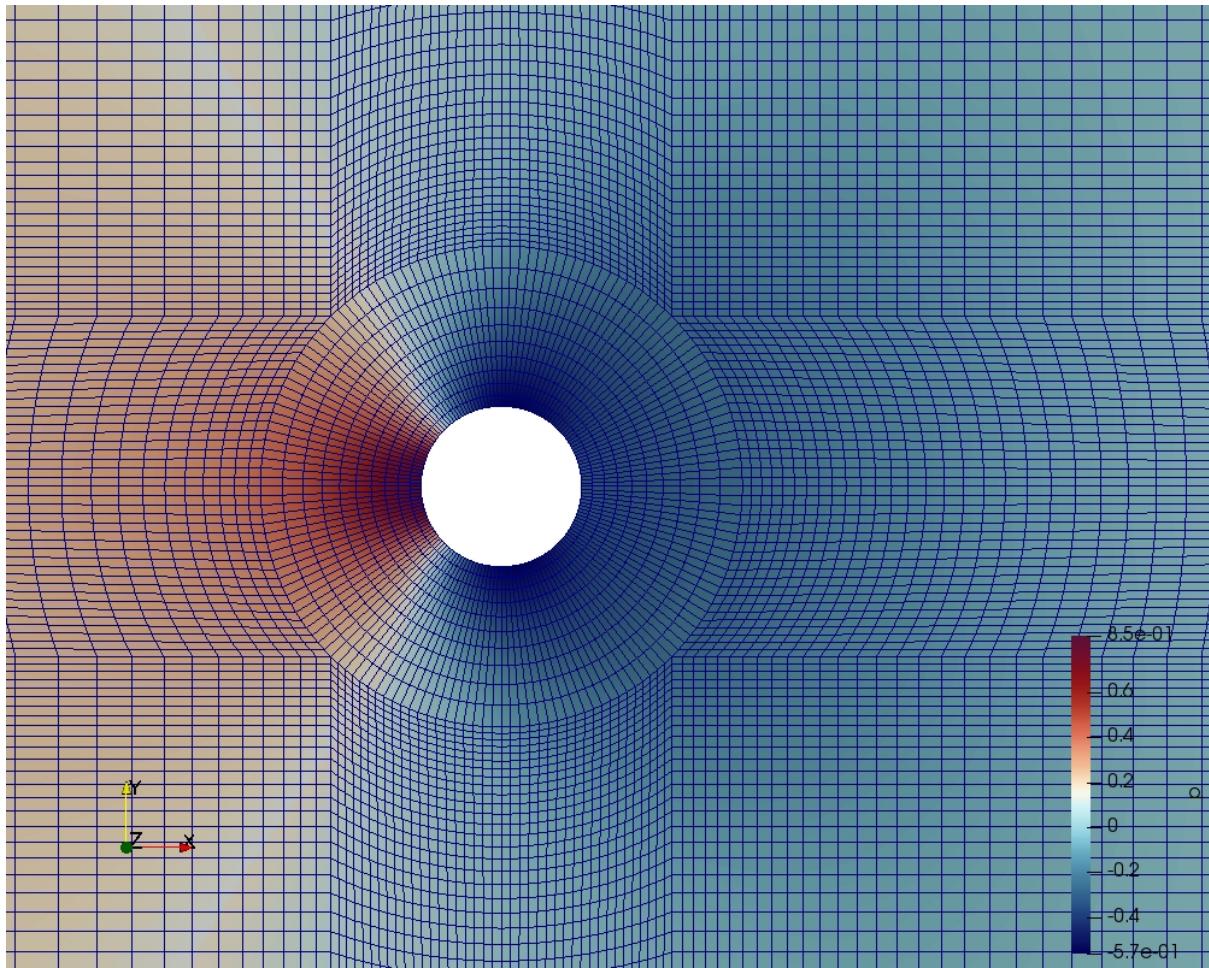
BlockMeshDict files are available here: [run_20_1](#) and [run_110_1](#), blockMesh logs are available here: [run_20_1](#) and [run_110_1](#),
checkMesh logs are available here: [run_20_1](#) and [run_110_1](#).

3.3. Mesh Figures

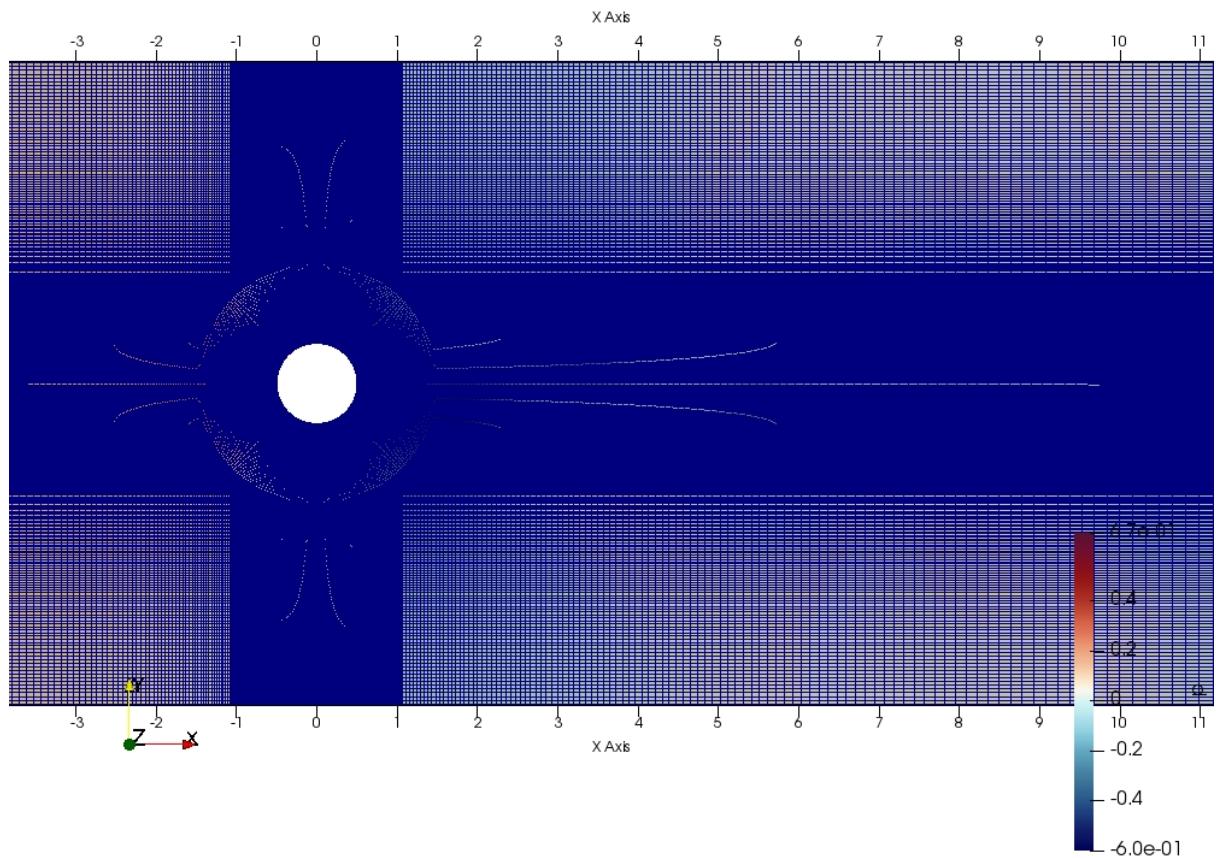
Mesh images are shown here, for detail comparision. We will show the [run_20_1](#) mesh first and then the [run_110_1](#) mesh.

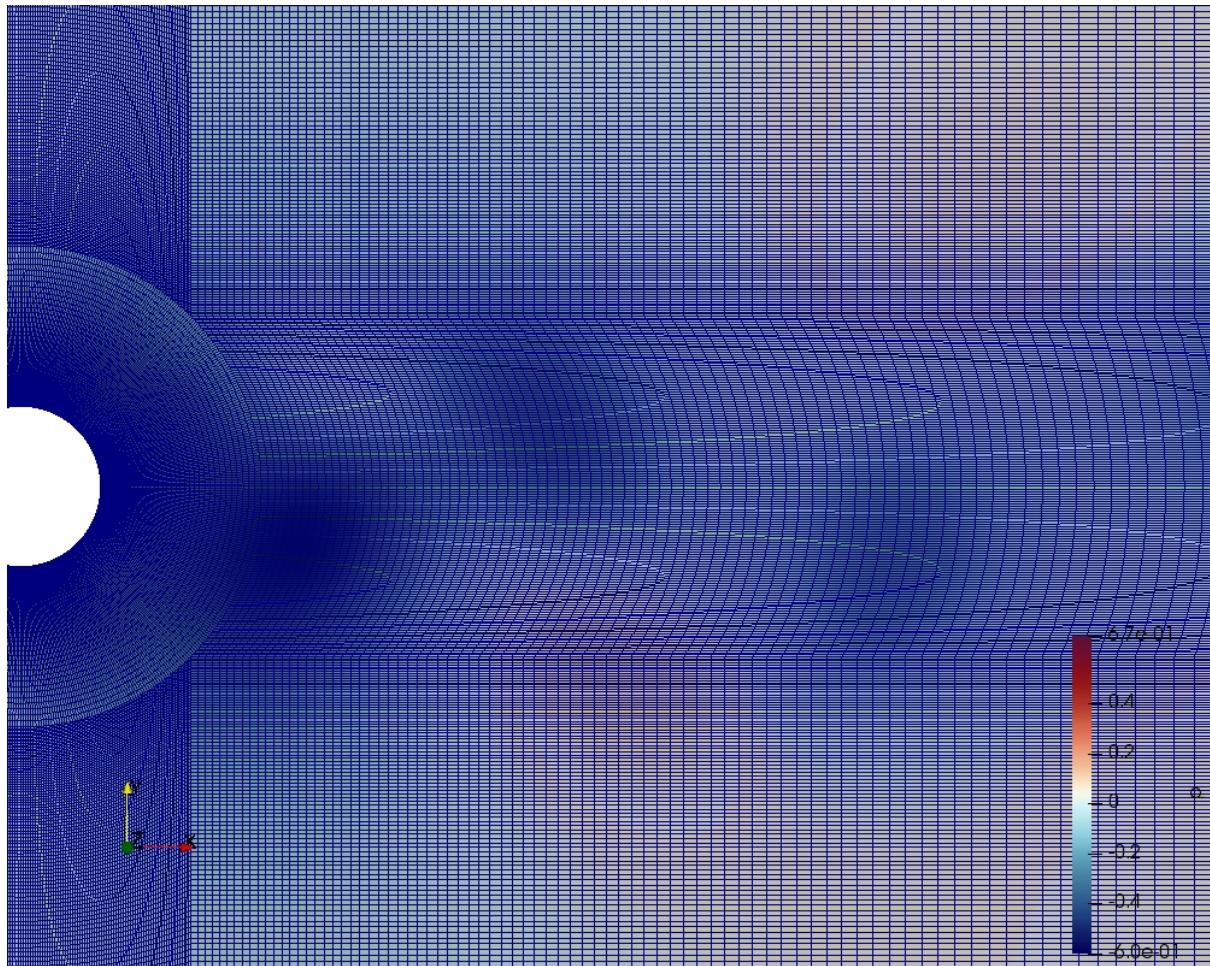
- [run_20_1](#):





- run_110_1:





4. Preliminary Solutions

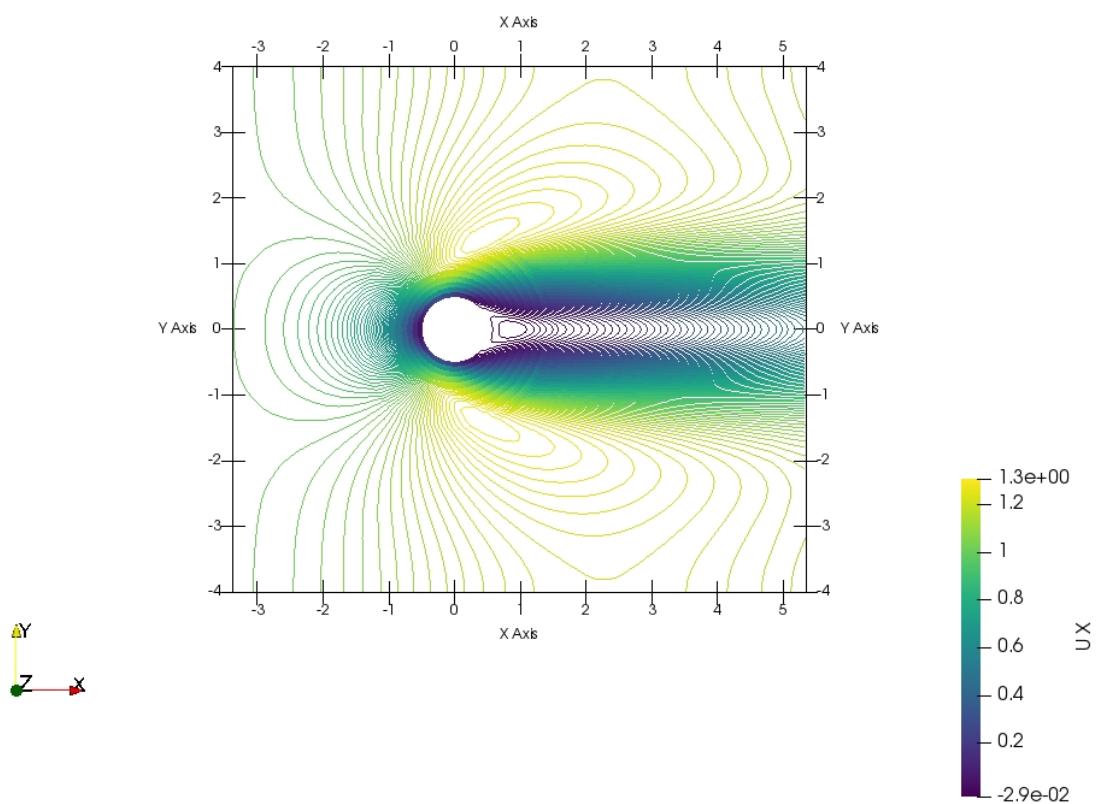
We assemble a set of preliminary solutions for Reynolds number 20 and 110 (the previous meshes). The Re=20 mesh will be shown first.

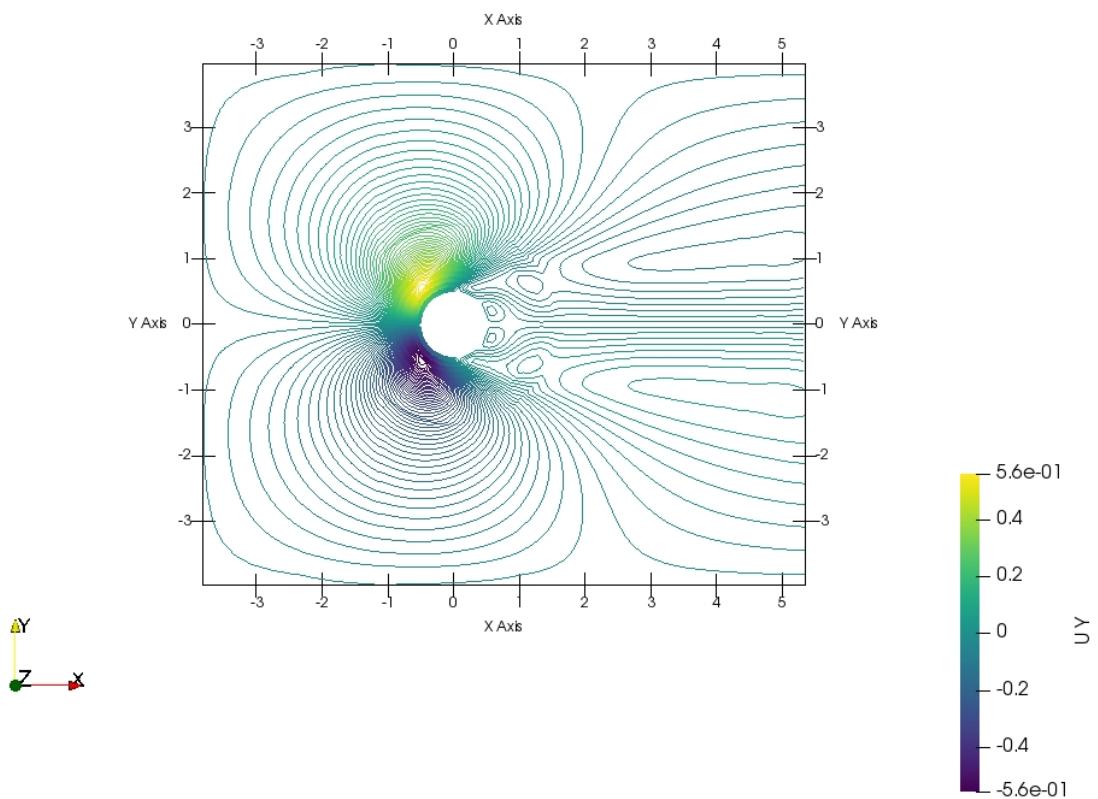
Three contour plots will be shown: $\frac{u}{U}$, $\frac{v}{U}$, $\frac{p}{\rho U^2}$, along with a streamline plot.

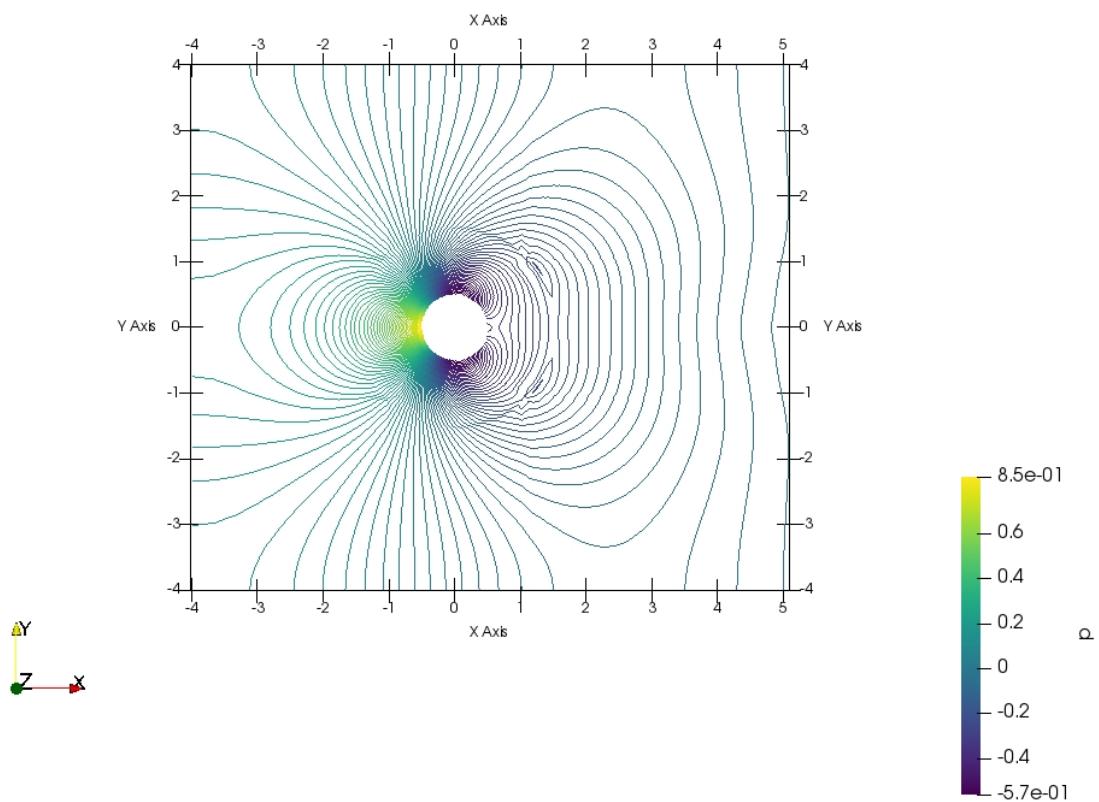
For Re=110 (the unsteady case), a time history of $\frac{u}{U}$, $\frac{v}{U}$, $\frac{p}{\rho U^2}$ at $(x, y) = (5.5, \pm 0.5)$ versus normalized time $\frac{t}{D/U}$.

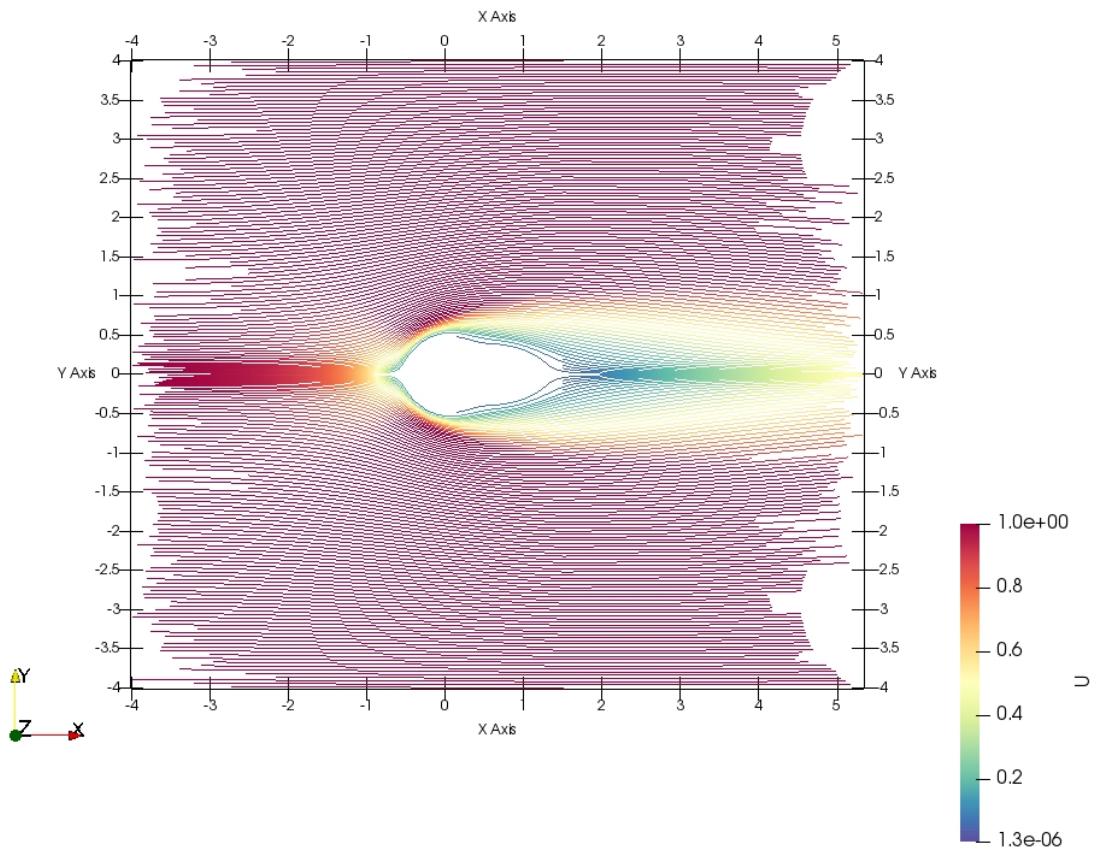
Note data for a couple of points (about 0.1%) was imputed due to file errors.

- `run_20_1`:

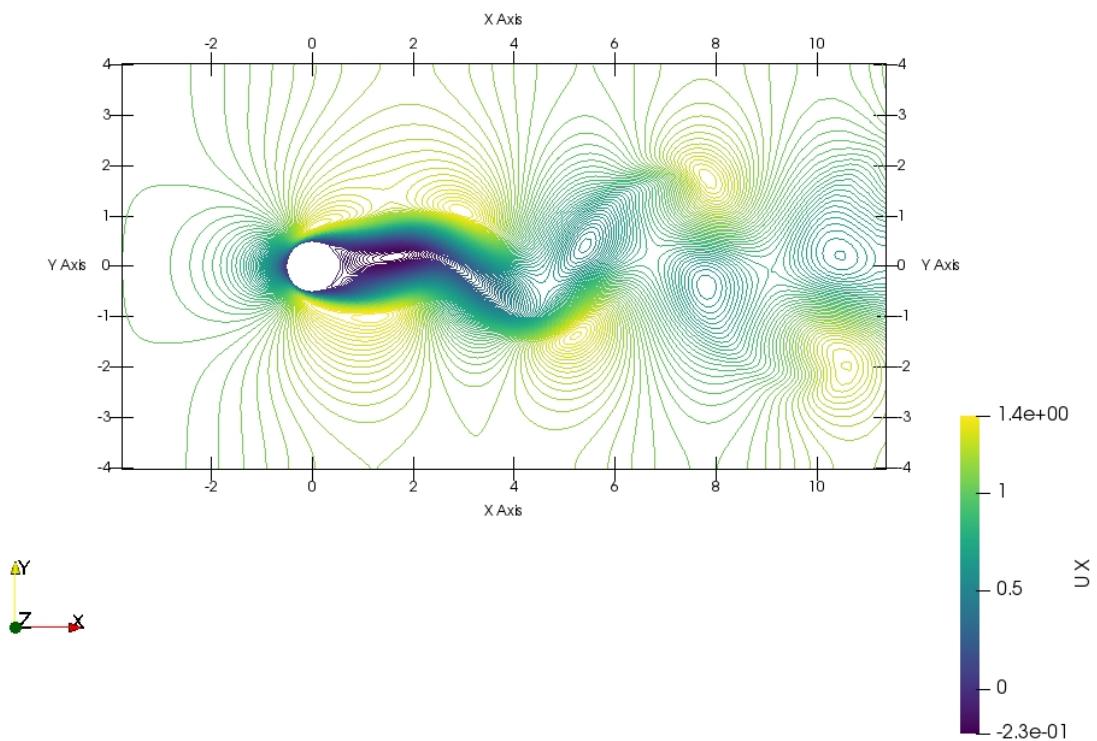


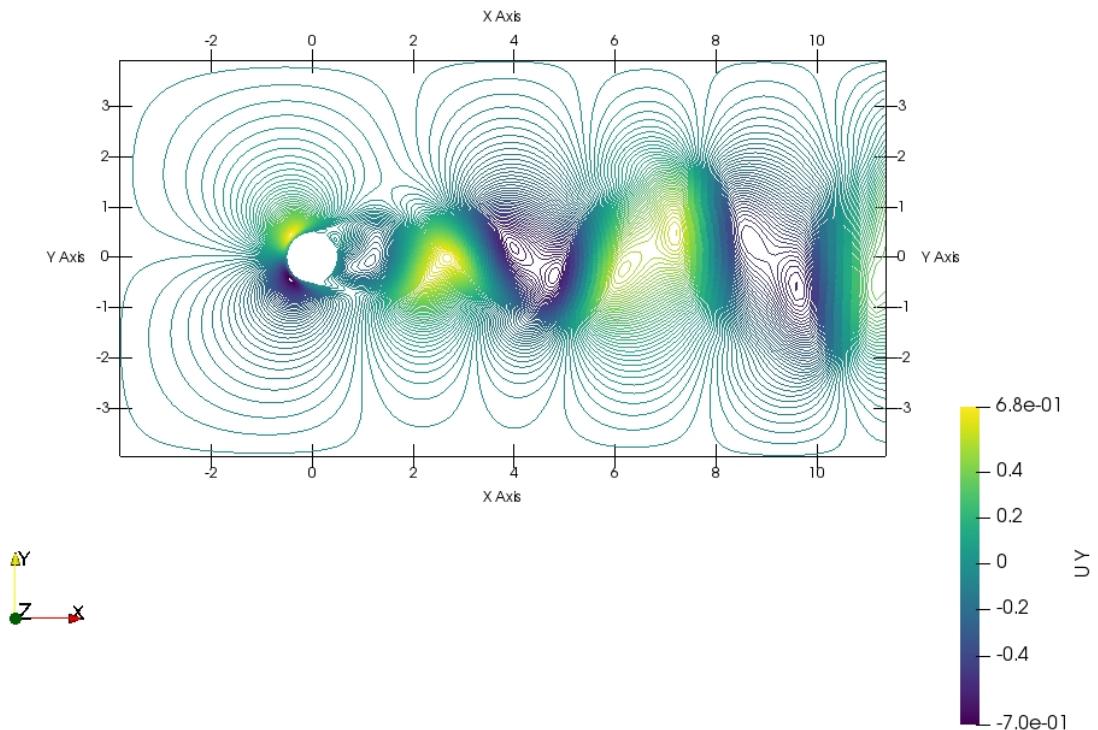


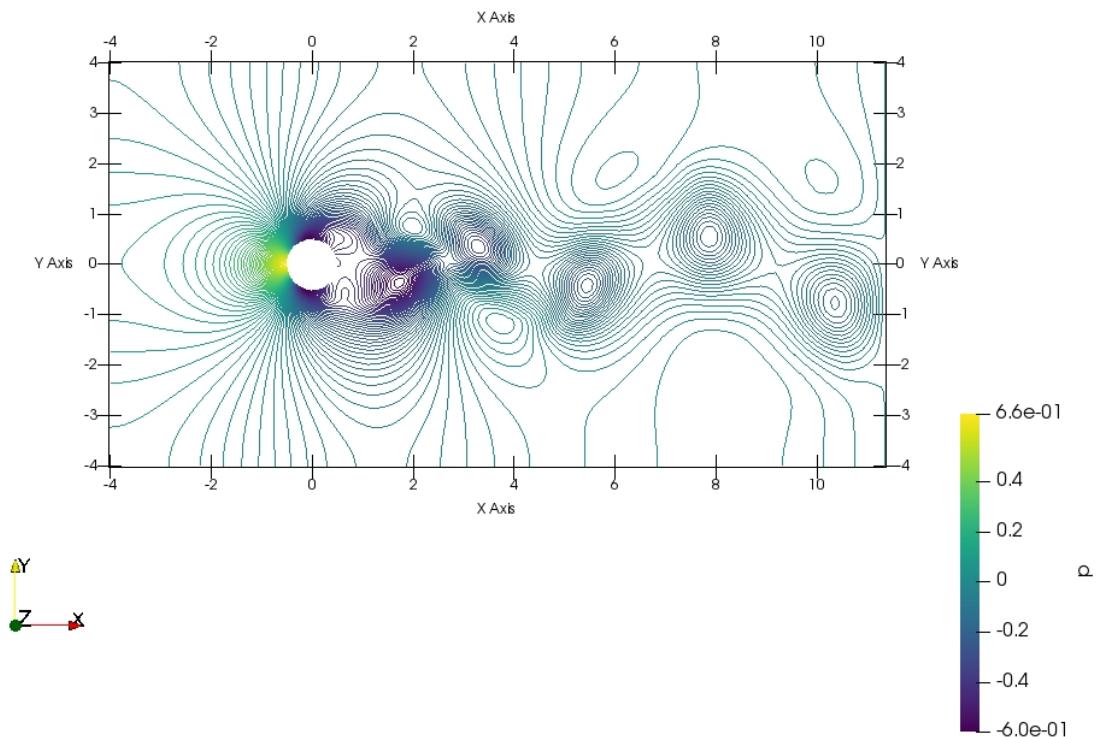


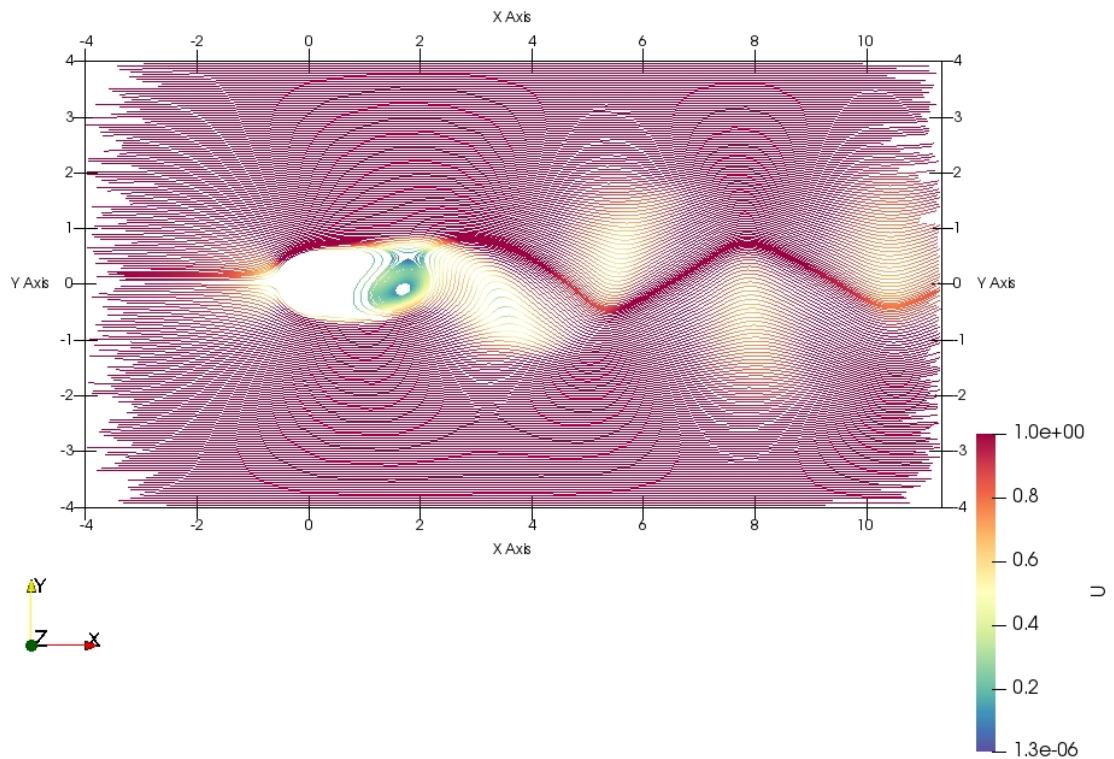


- `run_110_1:`

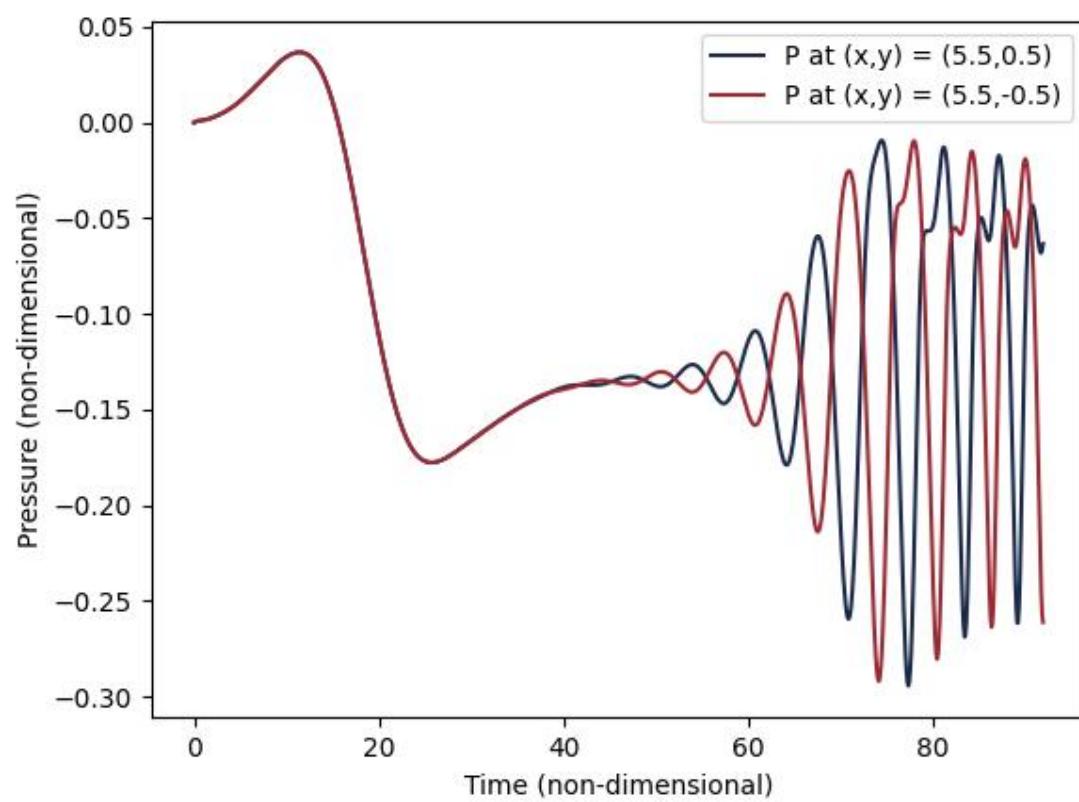
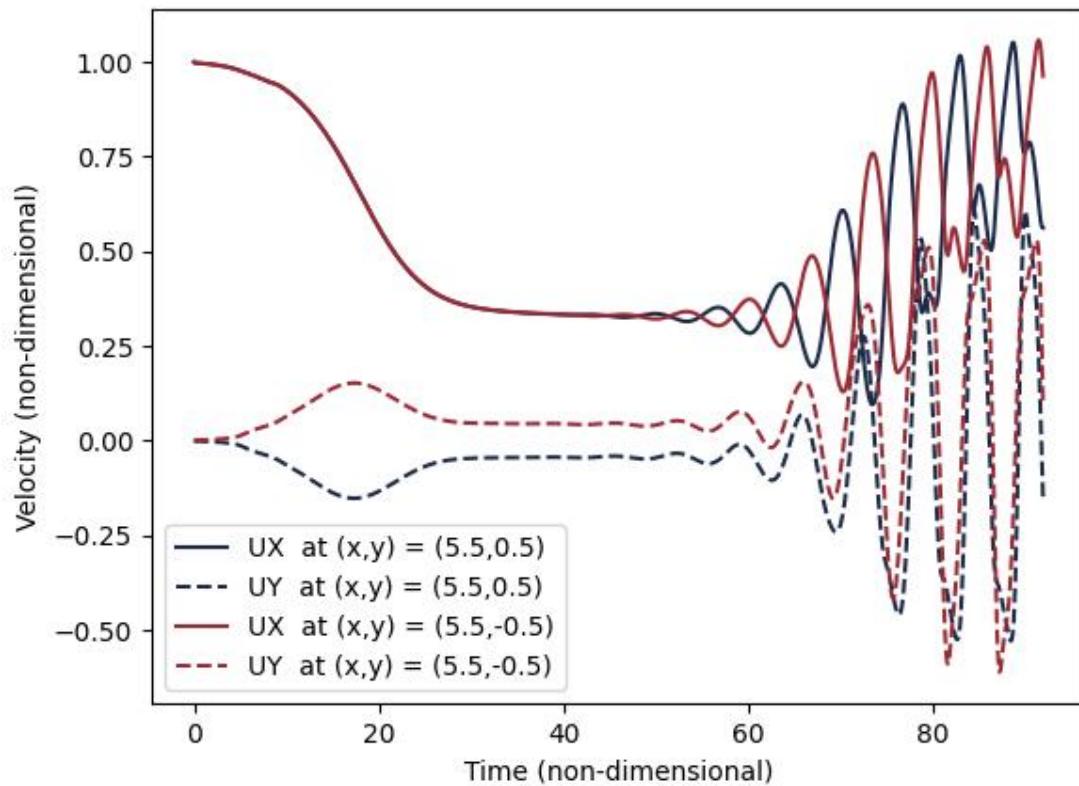








Time History plots for `run_110_1`:



5. Mesh Improvement

We can see that the mesh extent is fairly adequate, except possibly the height (H) for Re=110. All boundary flow is not perturbed, with the exception of the aforementioned region. We can also see vortices for the Re=110 case, and the inner block does not cause any boundary issues, so we will make only the following minor changes to each mesh.

For the mesh `run_20_1`, we will increase the `blockMeshFactor` from 10 to 15 (so a block increase of ~2.25). This mesh will be called `run_20_2`.

For the mesh `run_110_1`, we will increase the `blockMeshFactor` from 36 to 45 (so a block increase of ~1.5625), and increase height (H) from 4 to 6. This mesh will be called `run_110_2`.

5.4. Mesh Files

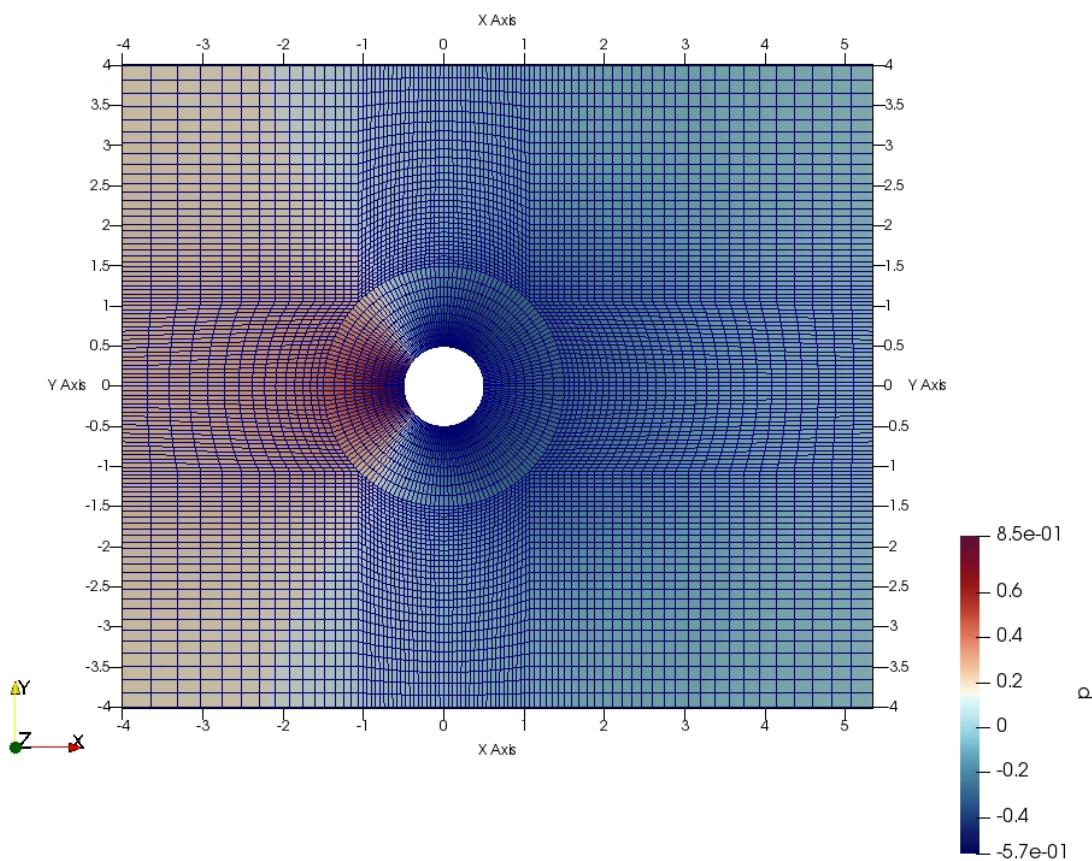
Files for the new meshes are listed below.

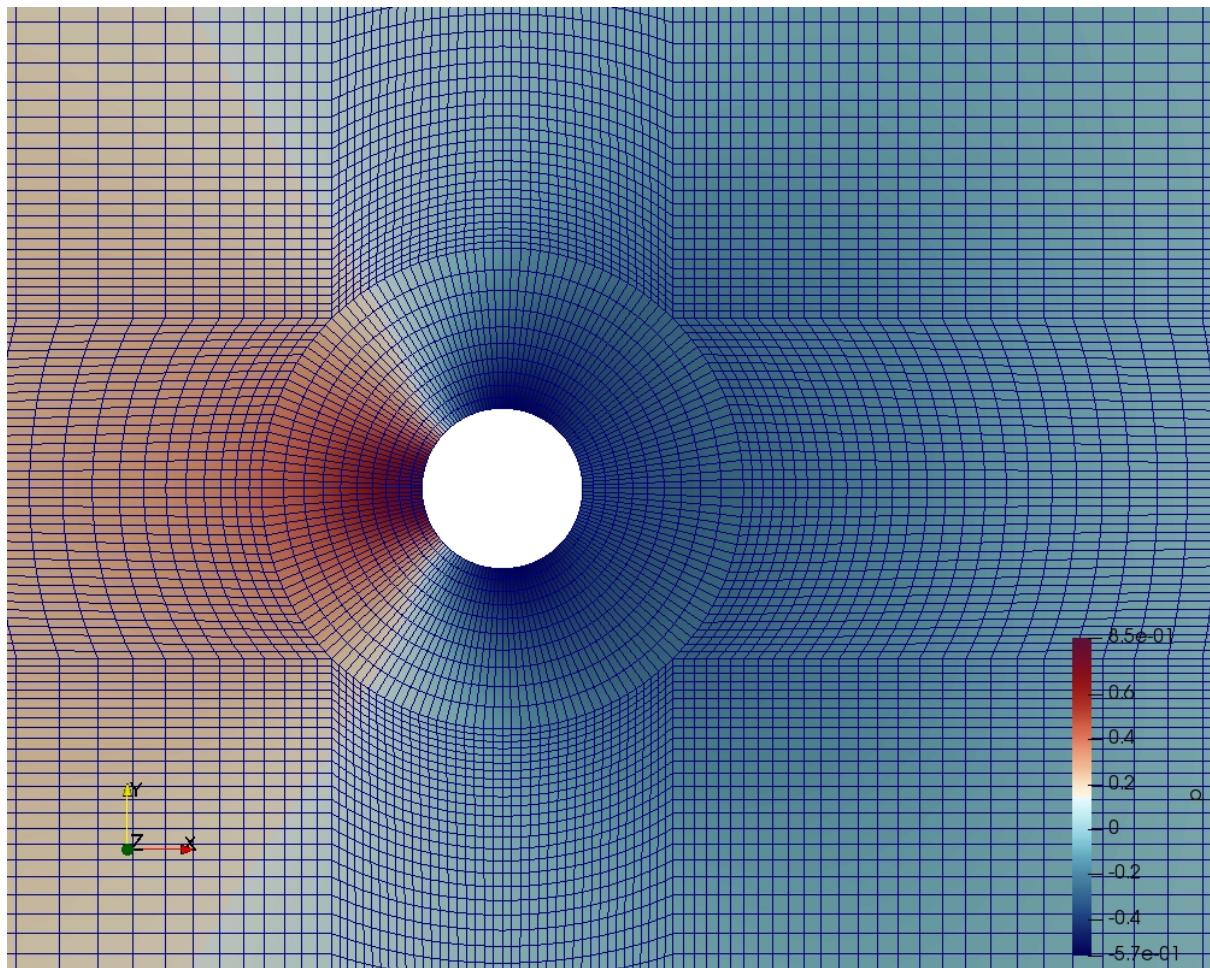
BlockMeshDict files are available here: [run_20_2](#) and [run_110_2](#), blockMesh logs are available here: [run_20_2](#) and [run_110_2](#),
checkMesh logs are available here: [run_20_2](#) and [run_110_2](#).

5.5. Mesh Figures

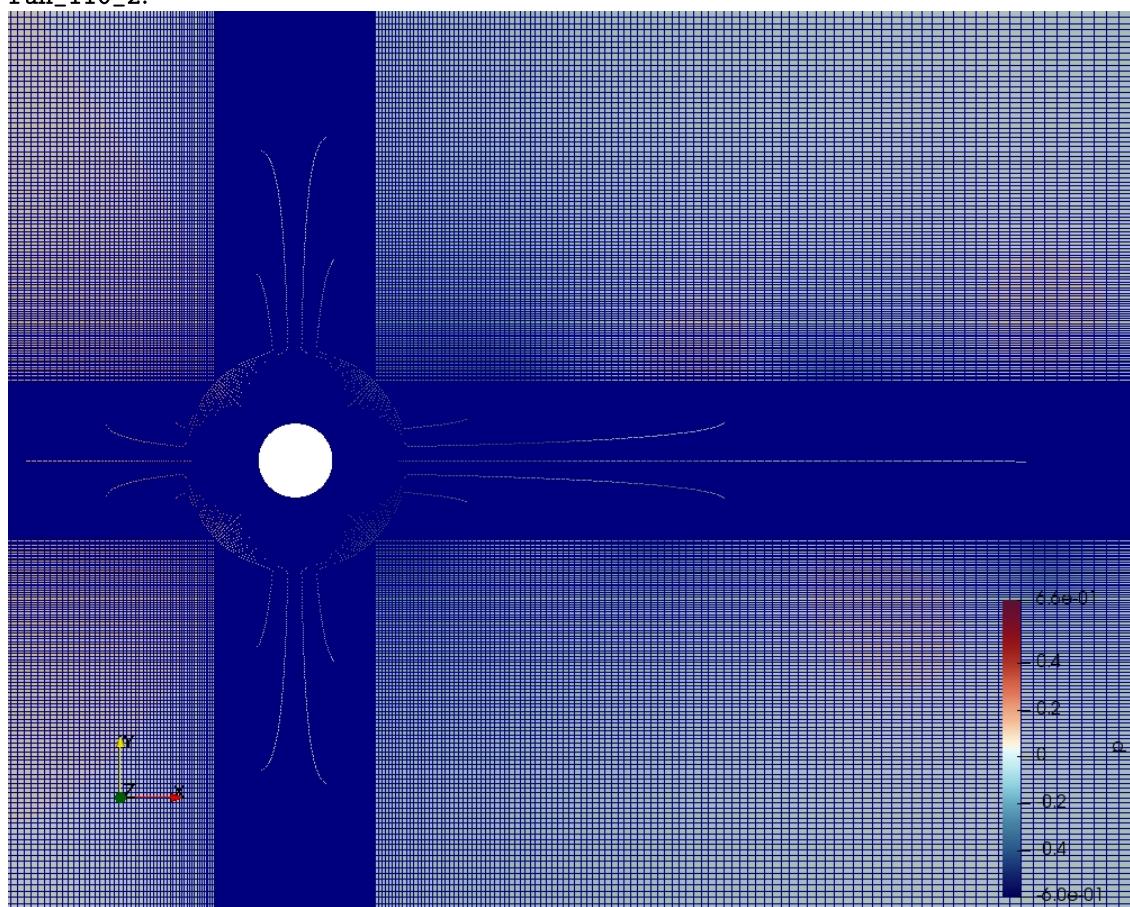
Mesh images are shown here, for detail comparision. We will show the `run_20_1` mesh first and then the `run_110_1` mesh.

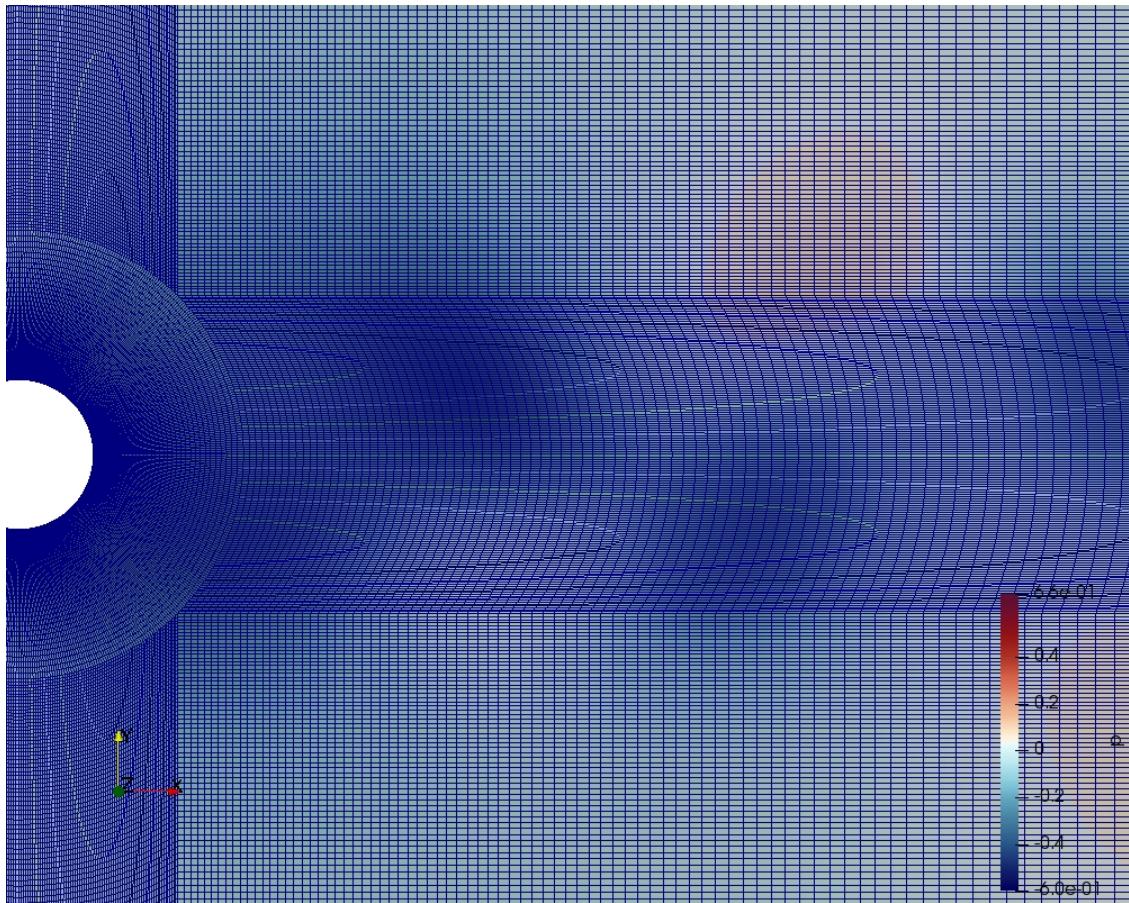
- `run_20_2`:





- run_110_2:





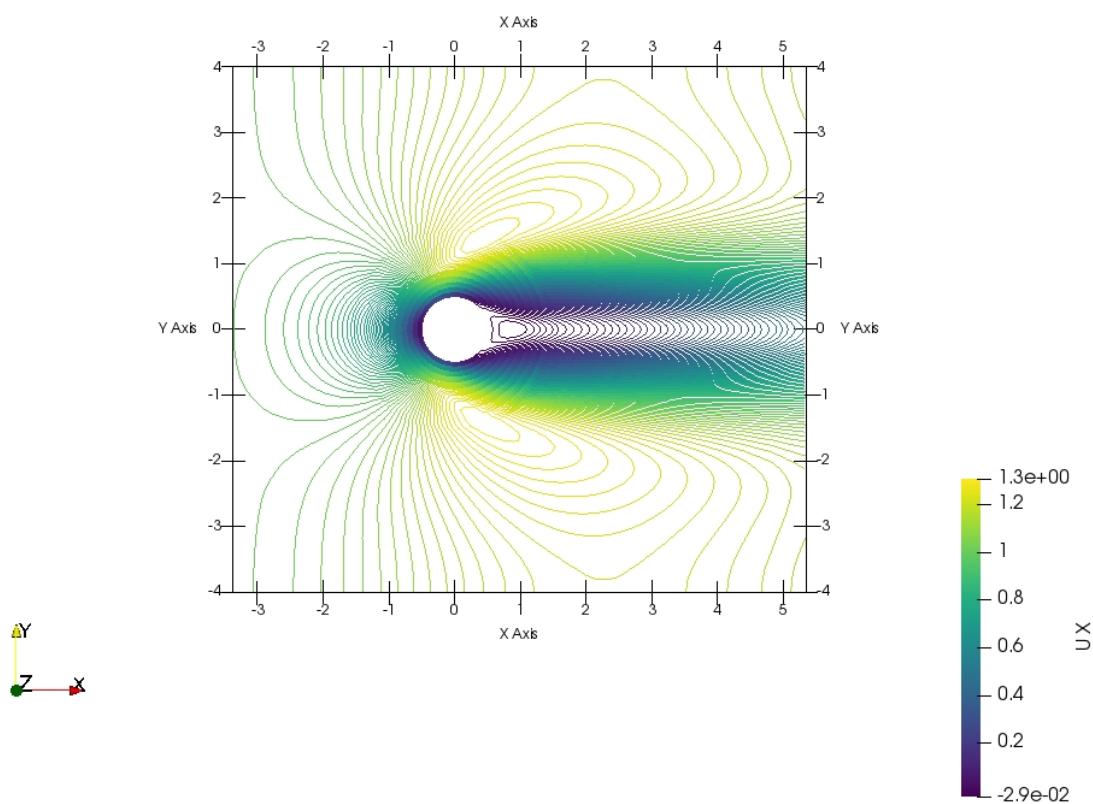
5.6. Solutions

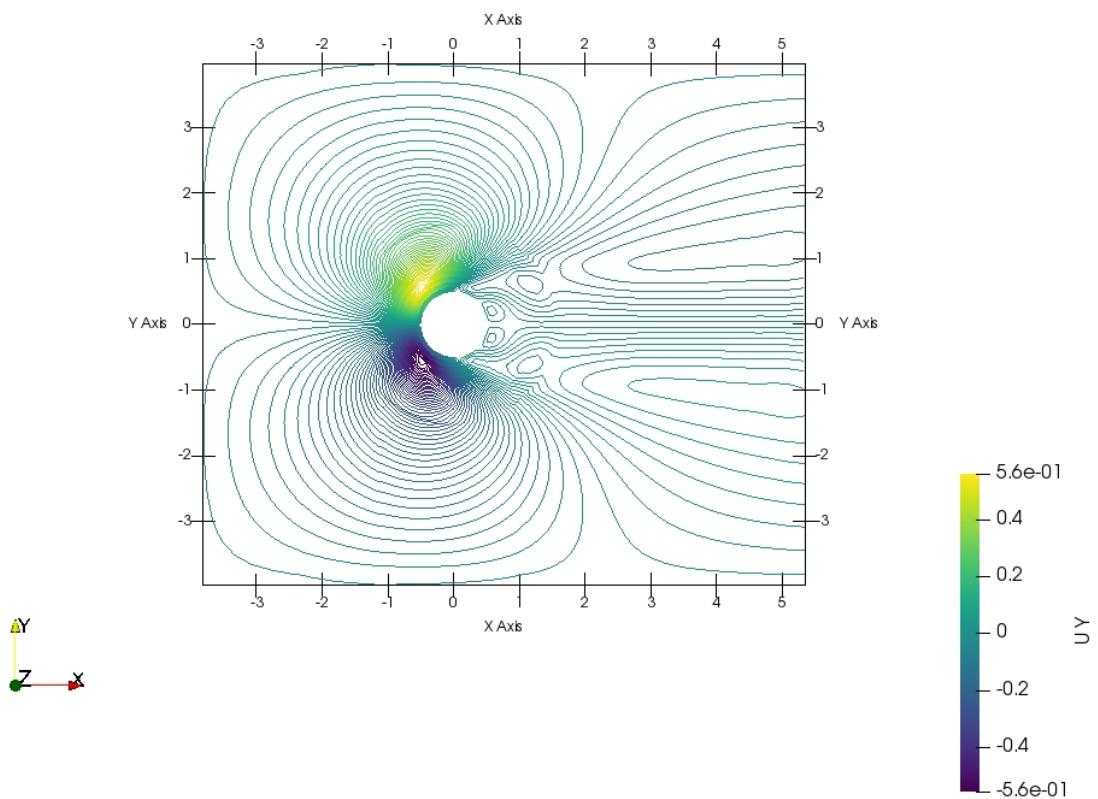
The Re=20 mesh will be shown first.

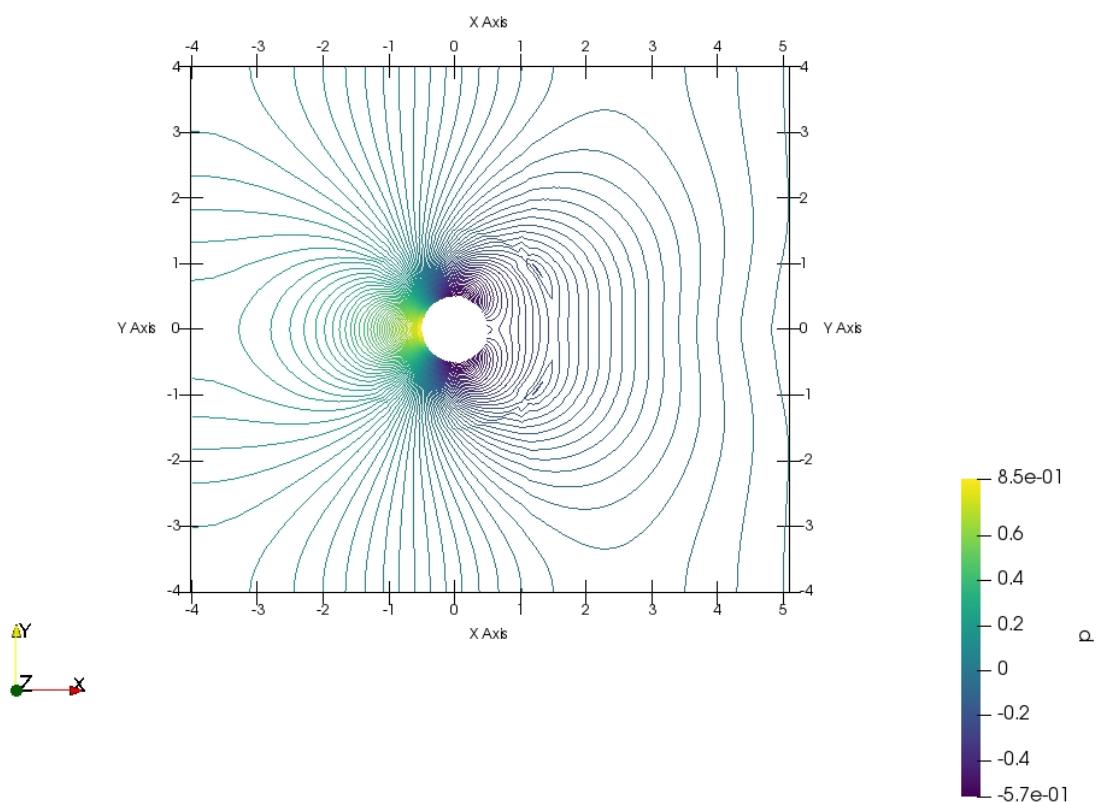
The same three contour plots will be shown: $\frac{u}{U}$, $\frac{v}{U}$, $\frac{p}{\rho U^2}$, along with a streamline plot.

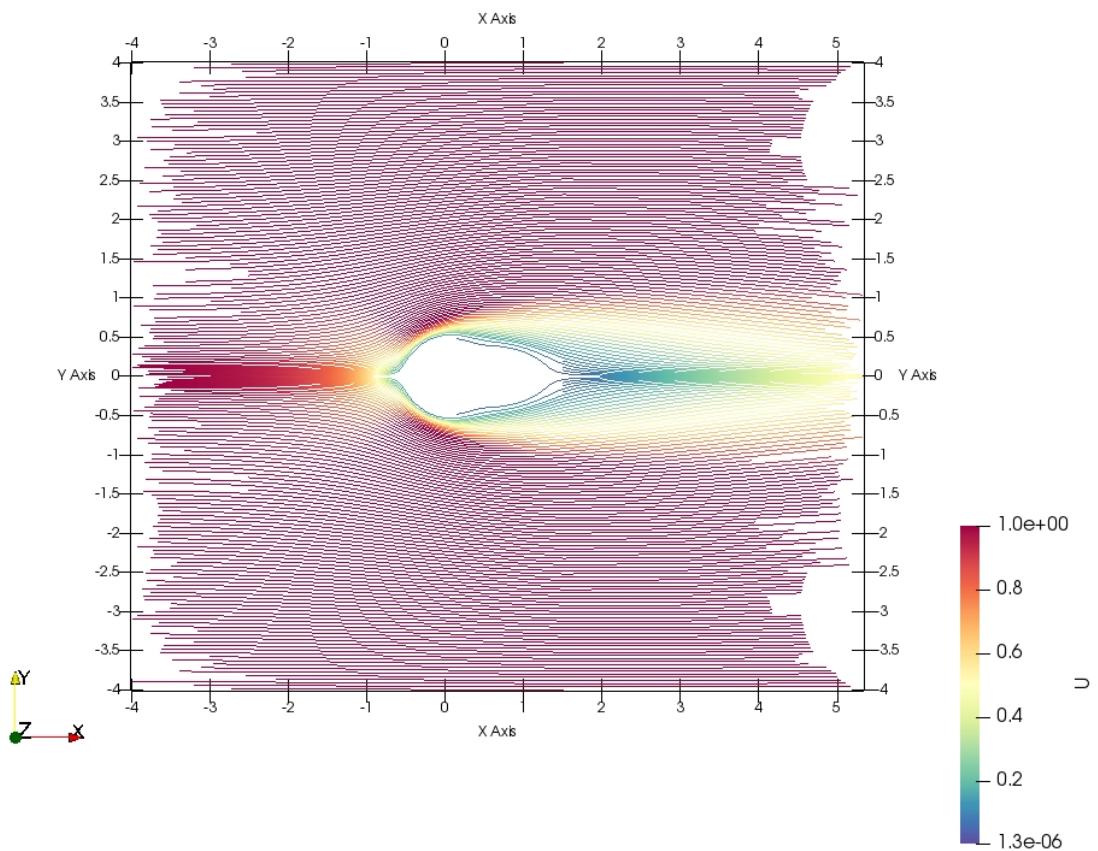
For Re=110 (the unsteady case), a time history of $\frac{u}{U}$, $\frac{v}{U}$, $\frac{p}{\rho U^2}$ at $(x, y) = (5.5, \pm 0.5)$ versus normalized time $\frac{t}{D/U}$.

- `run_20_2`:

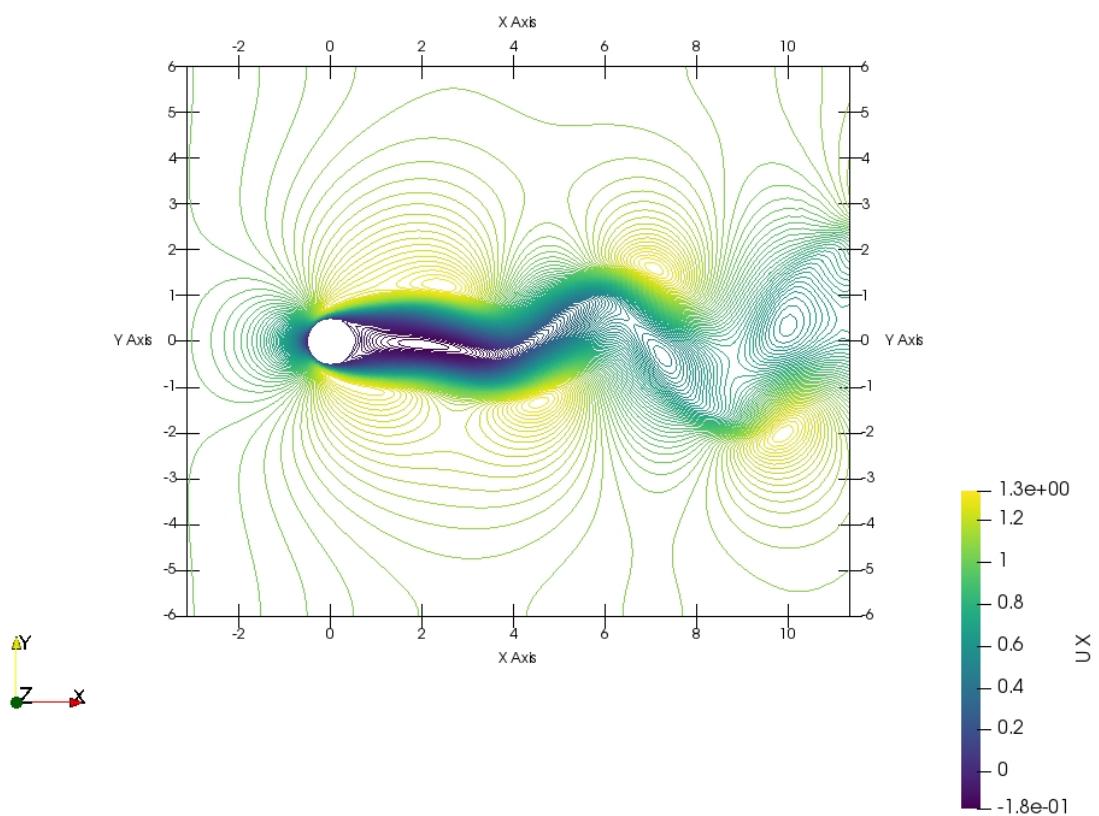


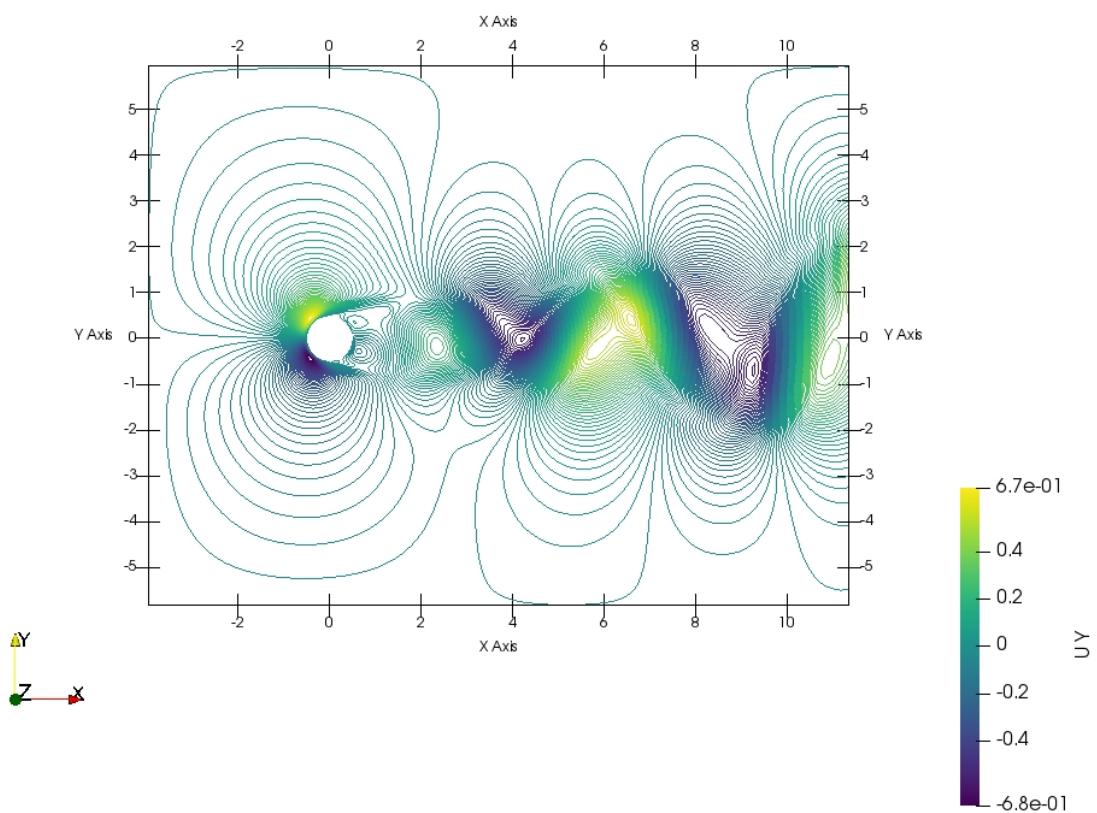


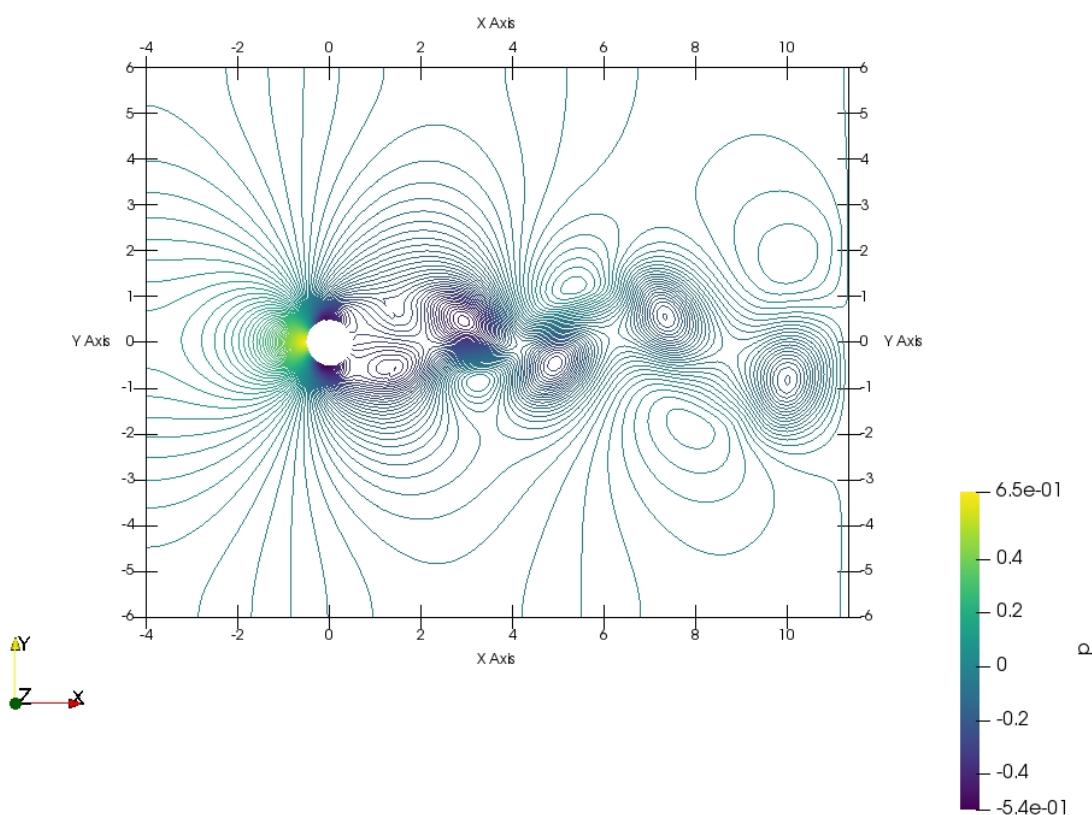


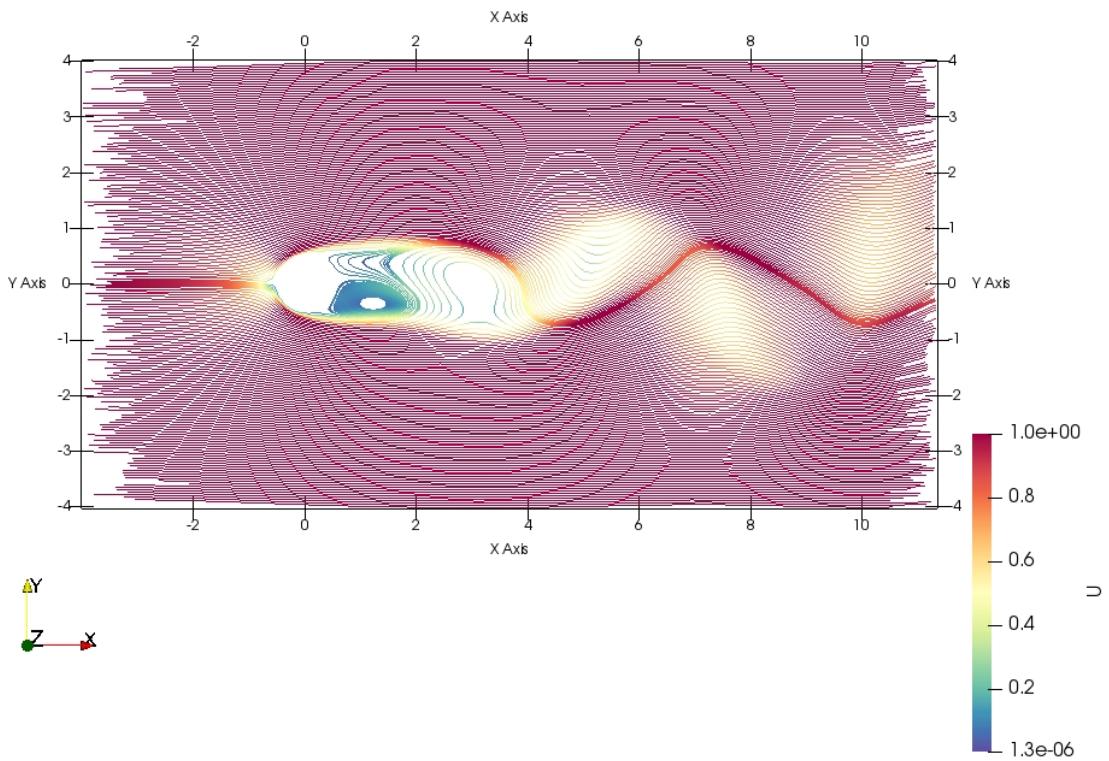


- `run_110_2:`

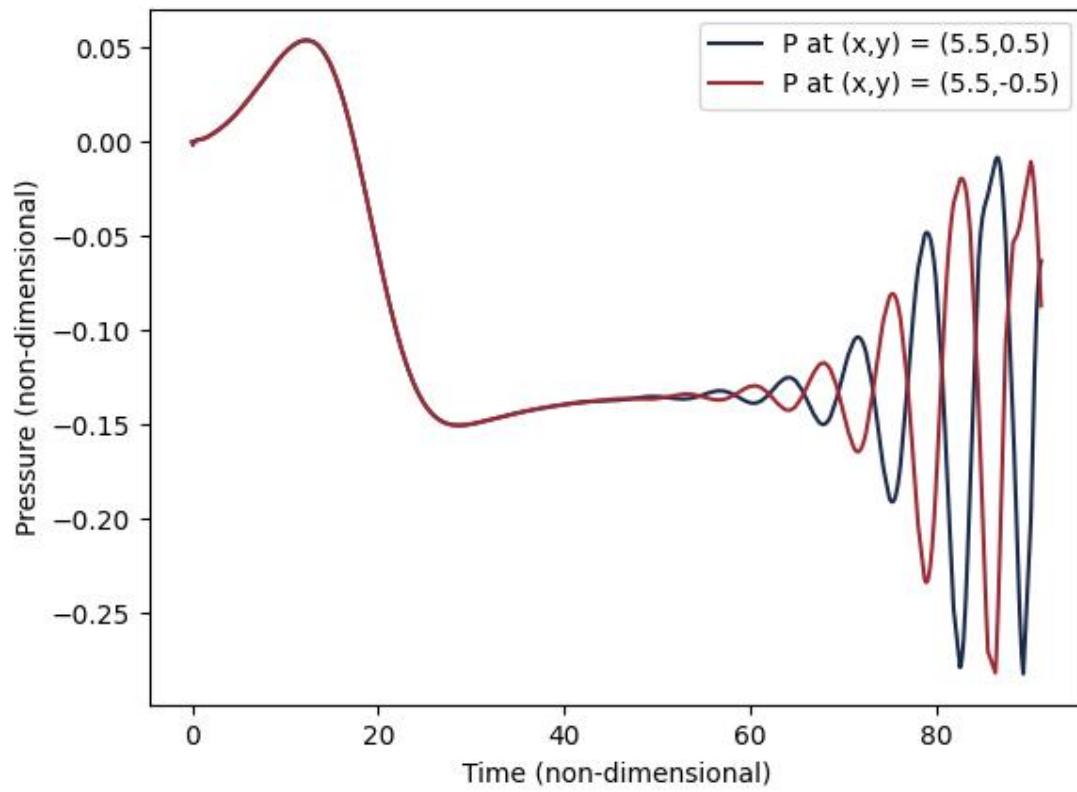
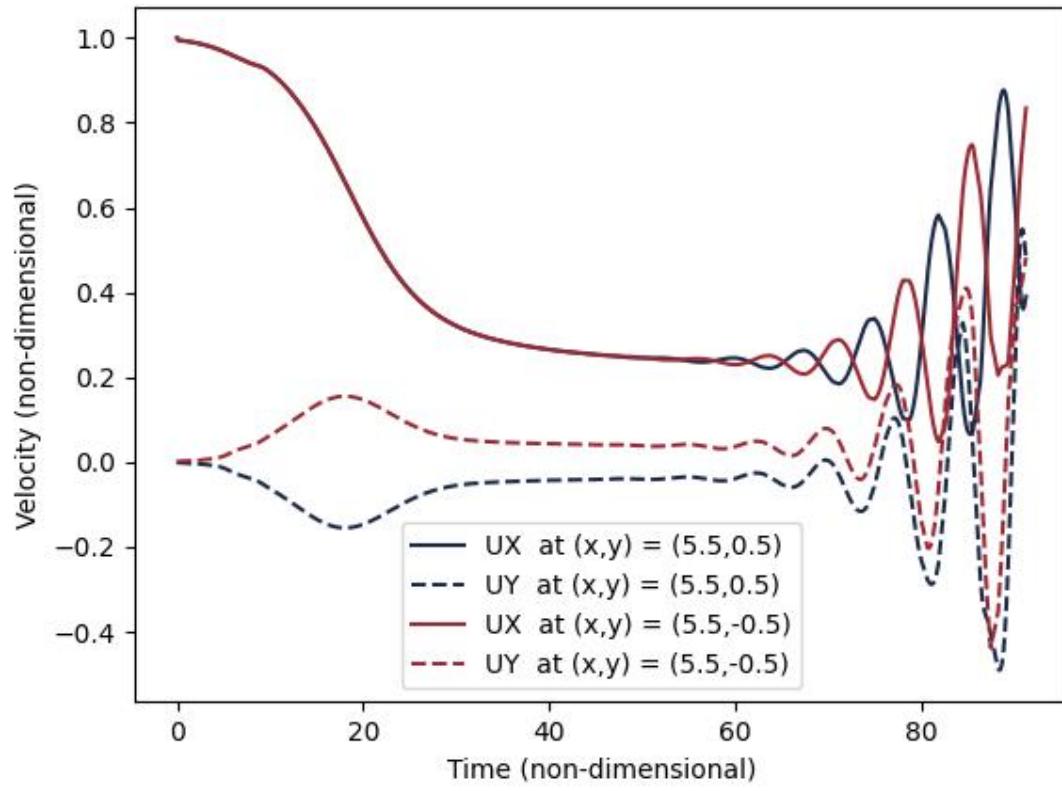








Time History plots for `run_110_2`:



6. References

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7. Appendix

Thank you so much for reading this work!

Affiliation:

Justin Campbell
Aerospace Department, University of Texas at Austin
E-mail: Campbelljustin989@gmail.com - jsc4348

Affiliation:

Amanda Hiett
Aerospace Department, University of Texas at Austin
E-mail: hiett.mandy@utexas.edu - amh7427

Affiliation:

Archithaa Mohan
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E-mail: archithaa.mohan@utexas.edu - am87807

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Akhil Sadam

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Aerospace Department, University of Texas at Austin
E-mail: akhil.sadam@utexas.edu - as97822