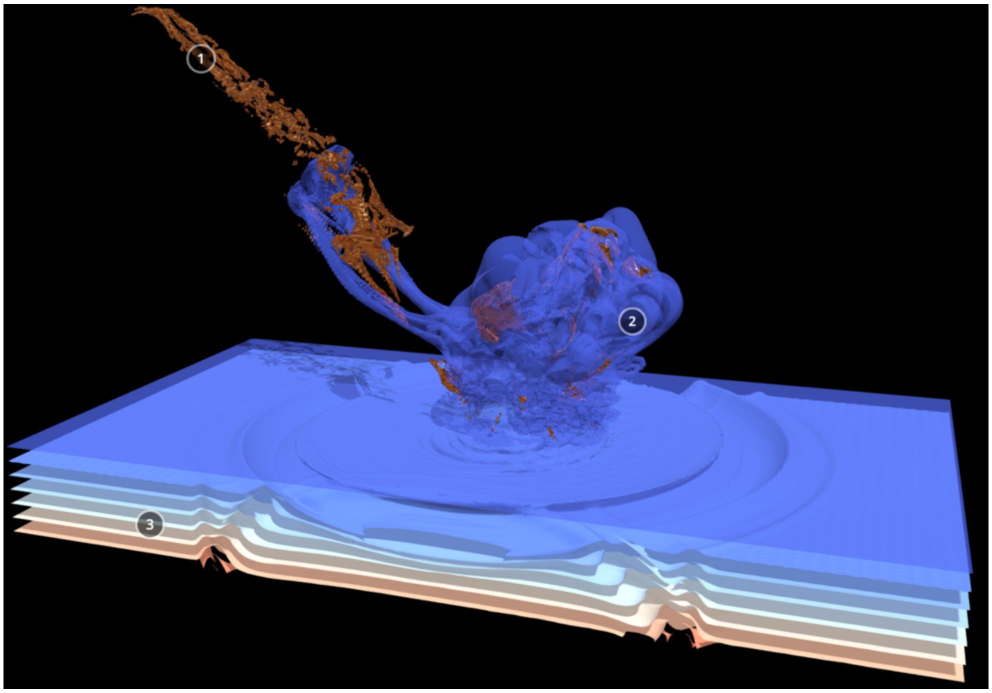
Deep Water Asteroid Impact

Final Project Report



SciVis (ENGR-E484/E584) – Fall 2022

TEAM 2

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General Instructions

- This final group report for the semester project is a moderate revision and extension of your group proposal from the Project 2 assignment.
- Please use complete sentences, section headers, and consistent formatting.
- Be sure to attribute all works of others through proper citations and endnotes. Be sure to properly quote any blocks of text written by others; likewise be sure to attribute images created by others.
- While this report may borrow your prior proposal and presentations, be sure that it is updated to reflect the final submitted work (rather than the originally planned project.)
- The highlighted text in each section indicates which parts are the same or updated, and those that are completely new. Please remove the highlighted text before submitting this report.

1. Topic Summary

On February 15, 2013, a small asteroid entered Earth's atmosphere. As it entered the atmosphere, the asteroid exploded at a height of around 29.7 km over Chelyabinsk in Russia. Three years after this incident, NASA founded the Planetary Defense Coordination Office to track and document Near Earth Objects which are potentially hazardous. This field of science is important since it could prepare us to deal with the catastrophic consequences of an asteroid's impact. 71% of the Earth's surface is covered by water, and any asteroid entering the Earth's atmosphere is likely to impact a water body, resulting in a Tsunami. Additionally, majority of the population lives near the coast, so it is important to model how large an impact must be to produce a hazardous tsunami. If impacts can create tsunami waves that can propagate efficiently over long distances, they could pose a significant risk.

2. Visualization Tasks

2a. Scientific Tasks

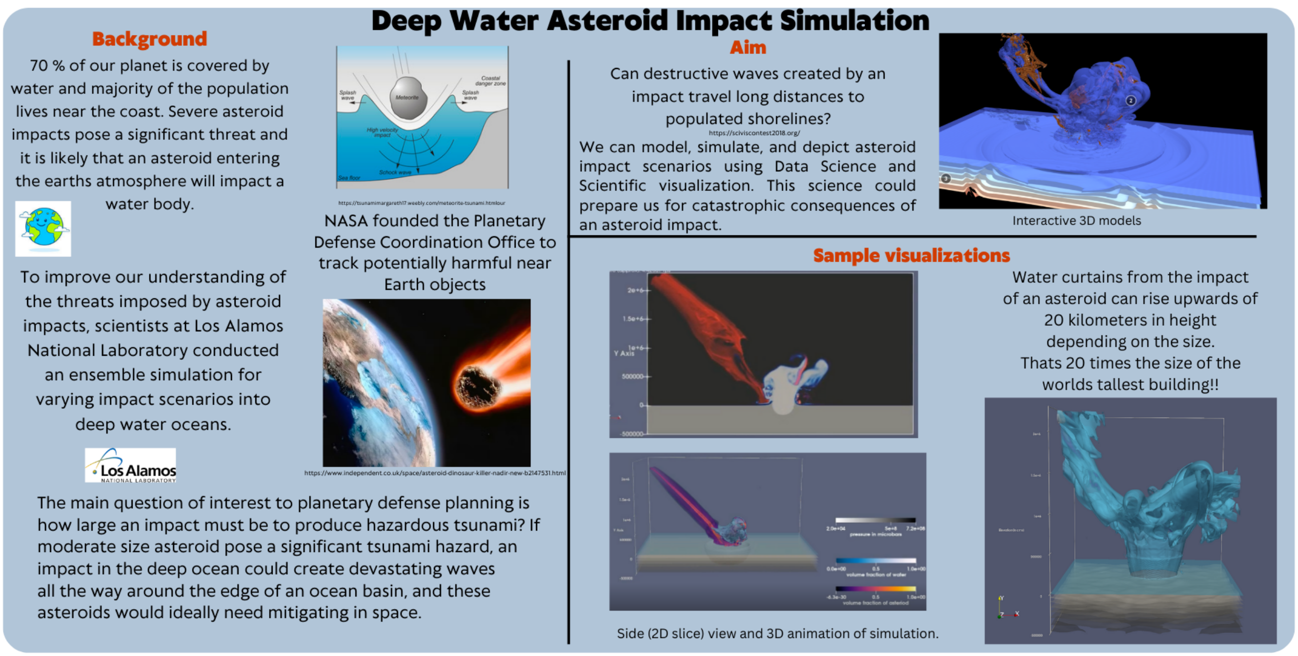
The goal of this contest is to develop visualizations to communicate new insights of an asteroid ocean impact. The specific scientific tasks the contest requires to address for research/technical audience are:

1. Describe/summarize the dataset (could be done at the level of individual simulations, or discrete time steps). As part of this task, graphic representations of information (such as images, videos, narratives, charts, maps, and numerical values) could be included to enhance the summary.
2. To examine and respond to the following inquiries resulting from the study of asteroid-generated tsunamis:
    a. Are tsunamis generated by an asteroid impact?
    b. If generated, what are the near and far field effects of the impact
    c. The major events of simulation, their time of occurrence and how can we decide about the events
    d. The effect of the size of the airburst on waves generated

e. The effect of angle of impact on the crater, tsunamis, near and far fields
f. Any unexpected things and discontinuities about the data

2b. Outreach/Communication Tasks

We created an infographic containing sample visualizations and short write-ups of the background, aim, motivation, and importance of visualizing deep water asteroid impacts. Additionally, we also created 3D Sketchfab models with annotations to enhance the experience and facilitate interactive learning.

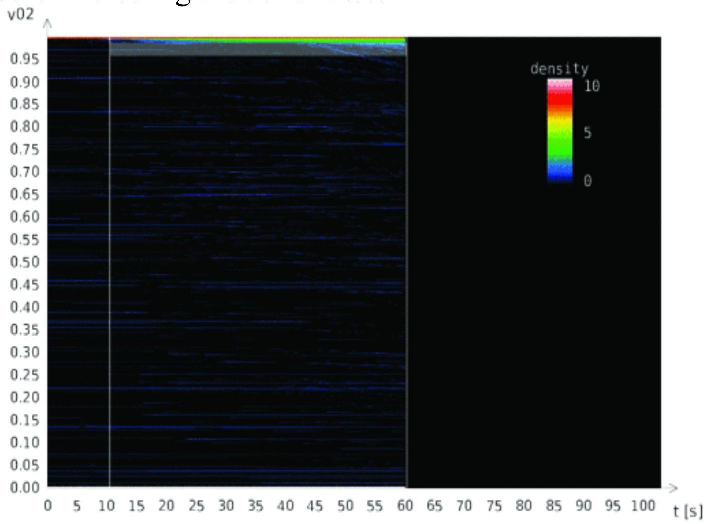


[Link to Sketchfab model](#) (yB31)
[Link to Sketchfab model](#) (yA31)

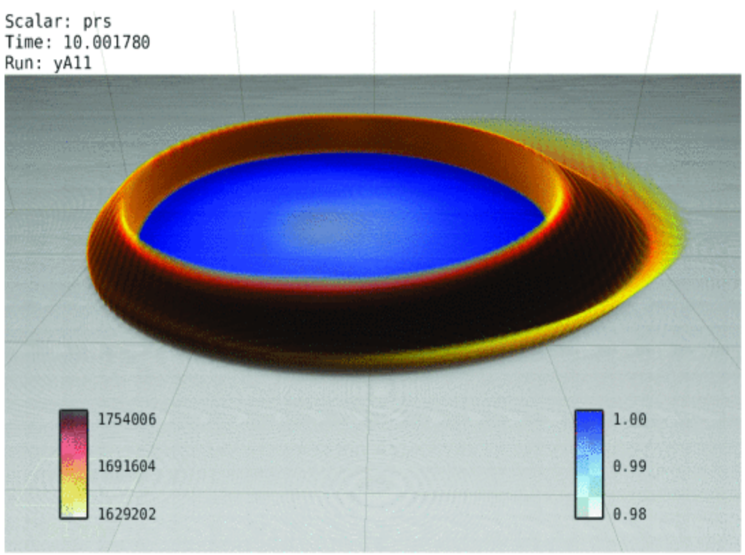
3. Prior Work

3a. Prior visualization submissions

There are many research publications based on this study, but the handful that we thought were interesting are as follows:



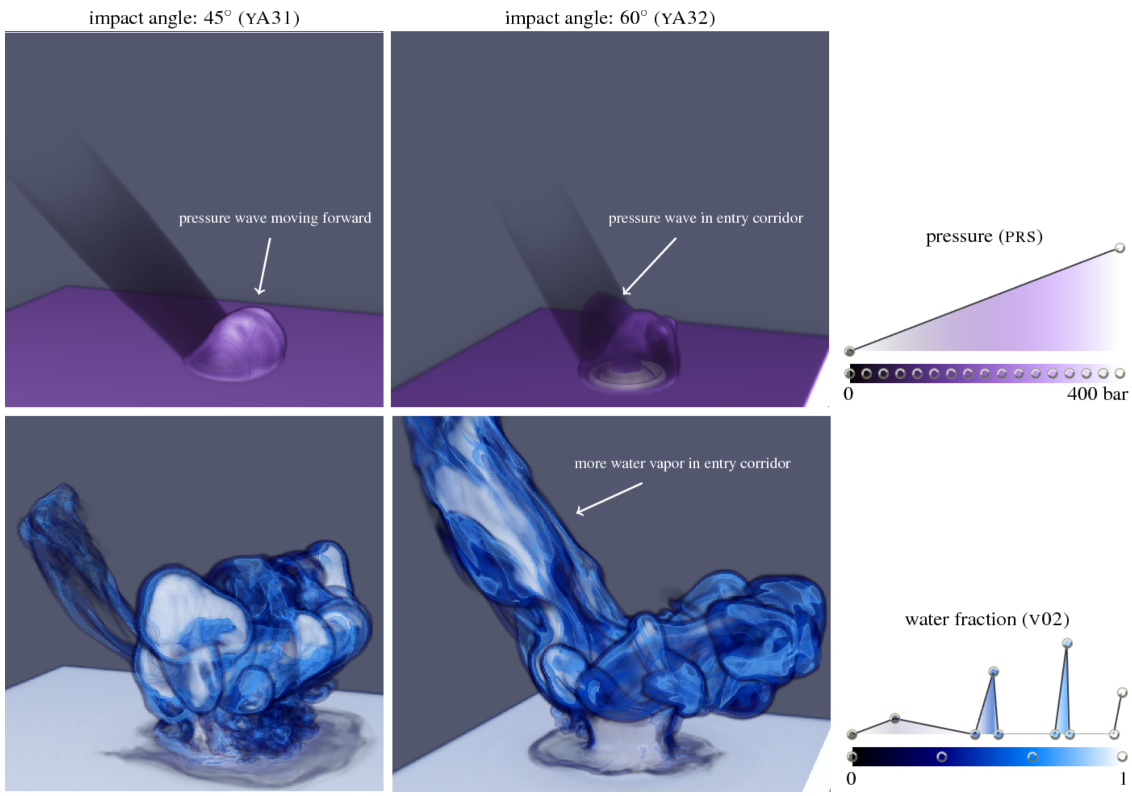
(a) Function plot of water fraction (v02) field of simulation run yA11. The top of the plot shows a pattern which has been selected interactively using a rectangle. The values at the upper and lower bound of the selected area clip the transfer function of the corresponding volume rendering below.



(b) Multi-volume rendering of water fraction (v02) and pressure (prs) fields of simulation run yA11. The transfer function of water fraction (v02) field (using colors as in the legend in the lower right) is derived from the selection made in the function plot above. The pressure (prs) field's transfer function (using colors as in the legend in the lower left) has been chosen such that the pressure wave above the water surface becomes visible.

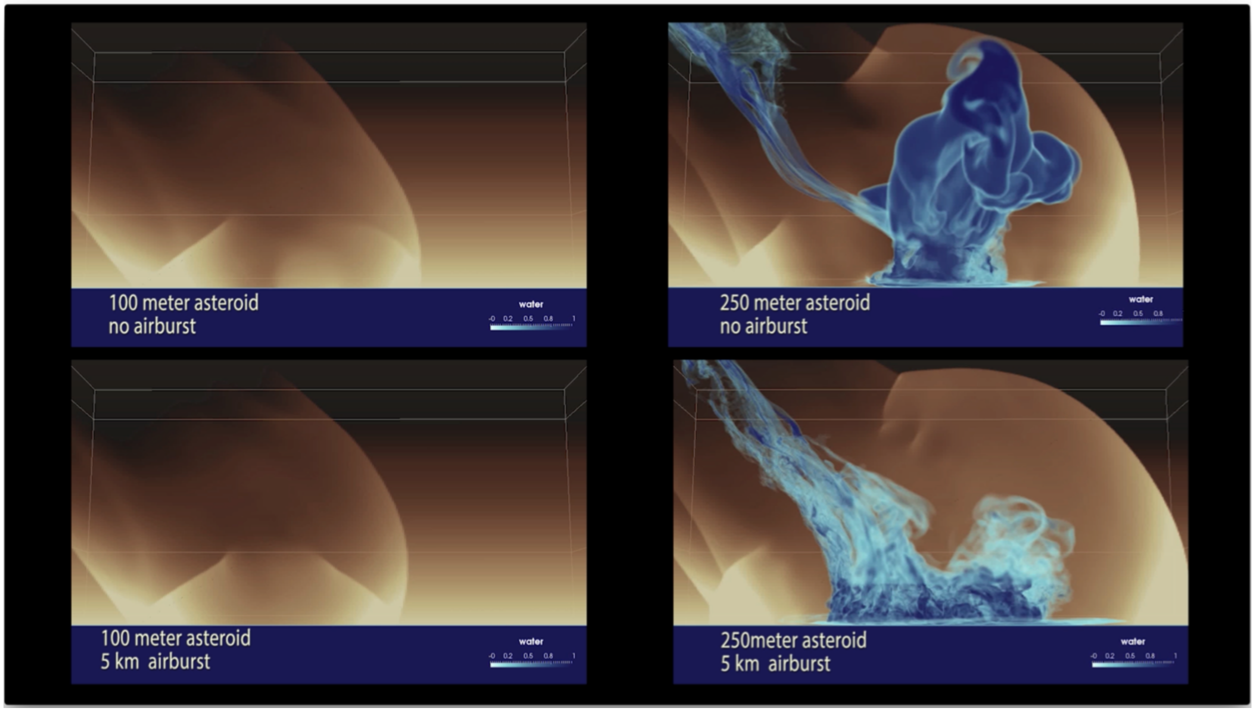
In "Visualizing Deep Water Asteroid Impacts: Interactive Visual Analysis of Multi-run Spatio-temporal Simulations," ***2018 IEEE Scientific Visualization Conference (SciVis)*****, 2018 by S. Leistikow, K. Huesmann, A. Fofonov and L. Linsen**

The visualization above shows that there is a connection between the pattern that is seen on the water's surface and the pressure wave. Around the center of the impact, the patterns of both fields are very similar to one another. Therefore, we will be able to deduce the pattern of the water jet and the impact it has just by seeing the pressure wave. [1]



In "Visualization and Analysis of Deep-Water Asteroid Impacts," ***2018 IEEE Scientific Visualization Conference (SciVis)*****, 2018 by R. Imahorn, I. B. Rojo and T. Günther**
The figure above shows a comparison of impact angles for an asteroid with a diameter of 250 meters and no airburst shows changes in the pressure wave (top) and the entry of water into the atmosphere (bottom). Top: The pressure wave is larger and more symmetrical at the 45° angle. During the 60° angle impact, the pressure wave encounters bumps, one of which ascends the asteroid entrance corridor. Bottom: As the water vapor plume of the 60° impact travels higher upwards along the asteroid entrance corridor, which was denoted by the pressure wave above, more debris is pushed into the stratosphere. We conclude that a steeper impact angle may have a stronger influence on the climate because more greenhouse gasses (water vapor) will enter the stratosphere. [3]

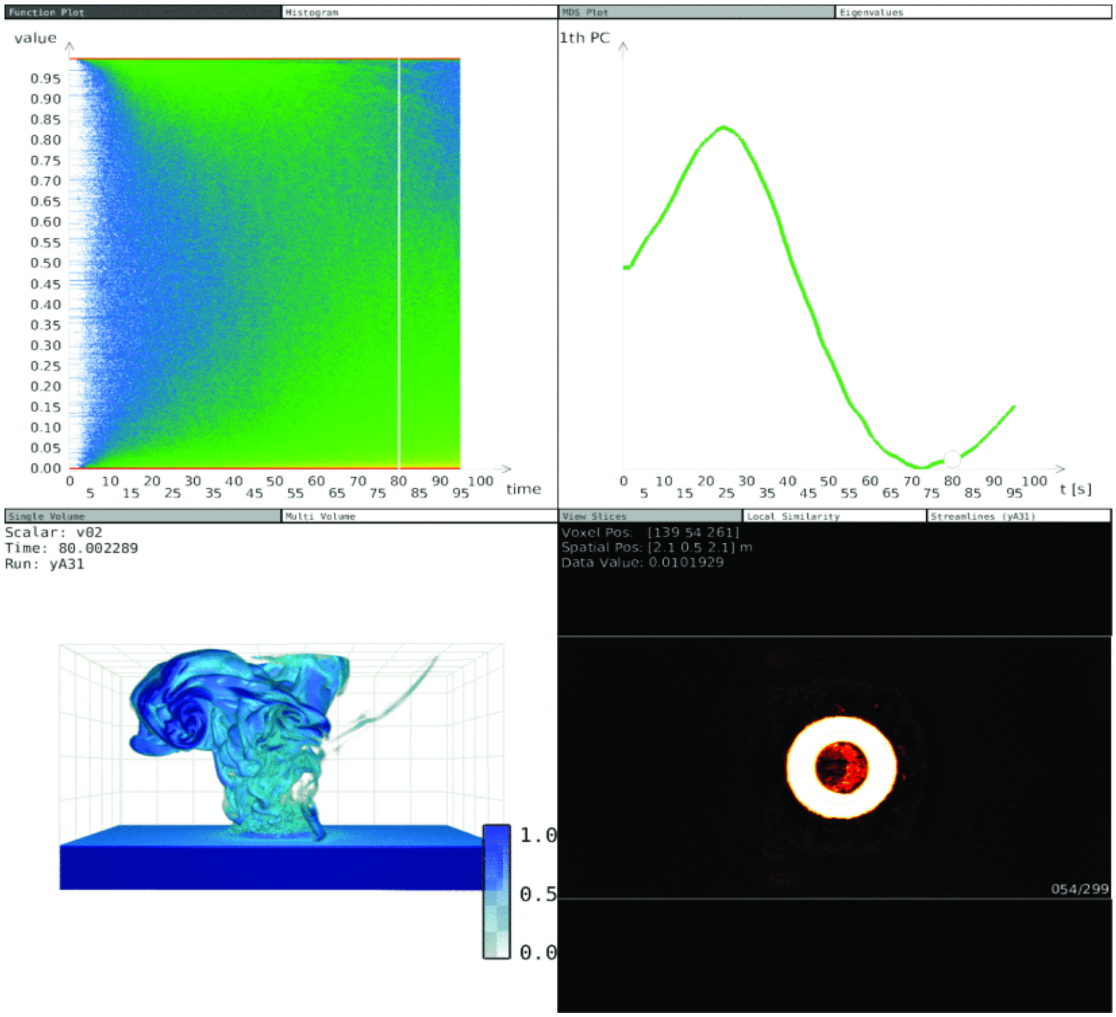
3b. Visualization from related publications



In "Deep Water Impact Ensemble Data Set", 2017 Los Alamos National Laboratory by Patchett, John M. Gisler, Galen Ross

Without an airburst, a 250-meter-wide asteroidal object strikes deep water at a 45-degree angle. Asteroid concentrations are shown in reddish tones, while water and temperature are shown in blue and yellow, respectively. The simulation makes use of 5 km of ocean depth and 23 km of the atmosphere. The simulation is 46 km by 24 km in size, with a total vertical dimension of 28 km. This is a straightforward depiction that provides a basic understanding of the investigation into asteroids' collisions. The fact that this visualization broke down the entire process into 3 easy steps makes it clear for both researchers and the general public, which is what we enjoyed most about it. [2]

3c. Charts, graphs, statistical analyses, etc.

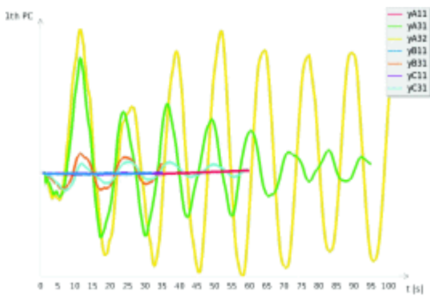


In "Visualizing Deep Water Asteroid Impacts: Interactive Visual Analysis of Multi-run Spatio-temporal Simulations," ***2018 IEEE Scientific Visualization Conference (SciVis)*****, 2018 by S. Leistikow, K. Huesmann, A. Fofonov and L. Linsen**

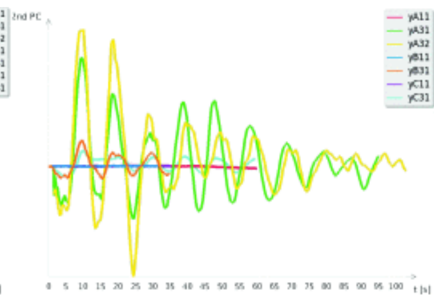
Because all views are linked, the user can select from function plots (upper left), multi-run similarity plots (upper right), and corresponding eigenvalue bar charts, as well as volume visualizations such as single and multi-volume rendering (lower left), slice or slab view (lower right), local similarity visualizations, and/or streamlines.

This graphic, provides detailed 1-D, 2-D, and 3-D renderings of the components that contribute to the outcome of the asteroid impact, piqued our interest.
This graphic can be used to identify time periods or functional intervals of interest, which can then be investigated further. The interplay of several fields can also be investigated. Individual runs must then be contrasted with one another in order to compare several simulations runs over time and understand how simulation settings affect the outcome. We present a method that is based on multidimensional scaling and field/isosurface similarity. Specific time steps of various simulation runs can be selected in these charts. To investigate the spatial distributions

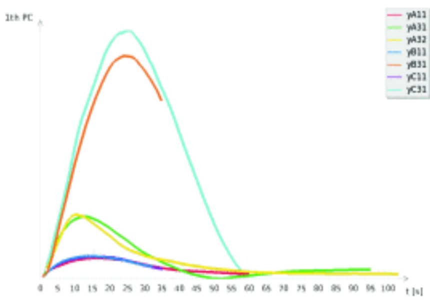
of patterns inside a single time step, employ volumetric visualizations with animation over time steps. We can compare spatial distributions between different runs or time steps using a different encoding. To properly employ all sights, it is necessary to combine queries from several perspectives, and interaction mechanisms in coordinated views facilitate this process. A researcher or student can easily engage with one point of view and get in-depth knowledge about the elements that are critical in determining the likelihood of an asteroid striking the water. [1]



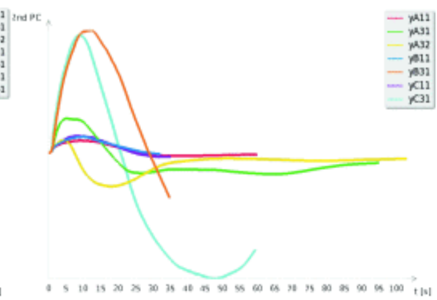
(a) First principle direction of pressure (prs) field.



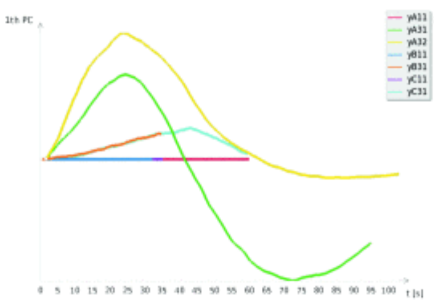
(b) Second principle direction of pressure (prs) field.



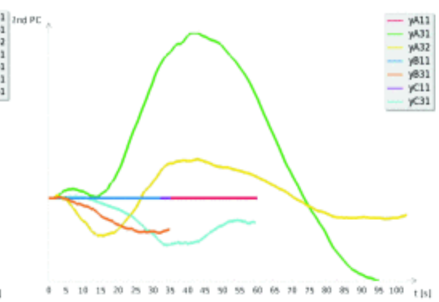
(c) First principle direction of temperature (tev) field.



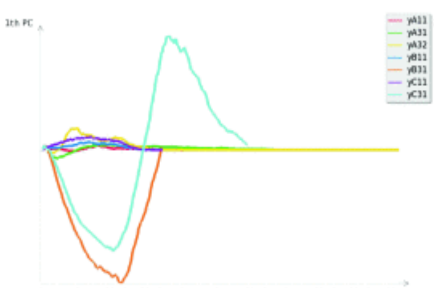
(d) Second principle direction of temperature (tev) field.



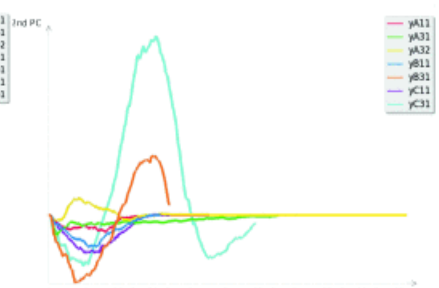
(e) First principle direction of water fraction (v02) field.



(f) Second principle direction of water fraction (v02) field.



(g) First principle direction of asteroid fraction (v03) field.



(h) Second principle direction of asteroid fraction (v03) field.

In "Visualizing Deep Water Asteroid Impacts: Interactive Visual Analysis of Multi-run Spatio-temporal Simulations," ***2018 IEEE Scientific Visualization Conference (SciVis)*****, 2018 by S. Leistikow, K. Huesmann, A. Fofonov and L. Linsen**
For each of the four scalar fields (pressure, temperature, water fraction, and asteroid fraction) the ensemble's 1D similarity plot over time for the first and second principal directions is shown. There are three distinct groupings of runs that behave similarly across all fields. Through this, we can see the change in behavior of the end result based on these factors taken into consideration. Asteroids' relative sizes appear to have the biggest impact on simulation outcomes, and the presence or absence of an airburst in scenarios involving large asteroids appears to be significant. Since the asteroid's oncoming angle was constant in all but one simulation run, this situation calls for additional study.[1]

4. Data Description

- What is the source of the data? (i.e., computational simulation, scientific instrument, etc.) - Computational simulation
- What is the specific file format of the data? (.vts, .vti, etc.)
  - Collection of .vti files, each representing a frame of the simulation.
  - Few of them had .vtu files embedded in .tar files.
- What is the underlying structure of the data? (e.g. regular uniform grid, structured grid, point cloud, polygonal mesh, adaptive mesh, etc.)
  - Uniform Rectilinear grid with adaptive mesh refinement technique.
- List the variables that are encoded in the data's structure.
  - (rho) density in grams per cubic centimeter. (g/cm3)
  - (prs) pressure in microbars (μbar)
  - (tev) temperature in electronvolt (eV)
  - (xdt) x component vectors in centimeters per second (cm/sec)
  - (ydt) y component vectors in centimeters per second (cm/sec)
  - (zdt) z component vectors in centimeters per second (cm/sec)
  - (snd) sound speed in centimeters per second (cm/sec)
  - (grd) AMR grid refinement level
  - (mat) material number id
  - (v02) volume fraction water
  - (v03) volume fraction of asteroid
- Does the data have a temporal component? If so, how many timesteps?
  - Yes, the data consists of a temporal component. The number of time steps depends on the combination of parameters and the dataset. Details are provided in the table below.
- Is the data made up of multiple simulation runs or scans? If so, how many separate data sets are there, and how do they differ from each other?
  - Yes, the data comprises multiple runs with combinations of different parameters resulting in 7 datasets (with some containing different resolution options)
- What is the size of each timestep/simulation run? What is the aggregate size of all data?
  - Size of timesteps ranges from 0.01 GB to 0.29 GB. Aggregate size of all the data is 576.1 GB. Details are provided in the table below.

- What transformations/conversions will need to be made on the data?
  - To highlight important aspects of the dataset, we will need to use various filters available within Paraview. We plan to work on subsets of the data and then apply the same filters on the entire dataset to render final animations.

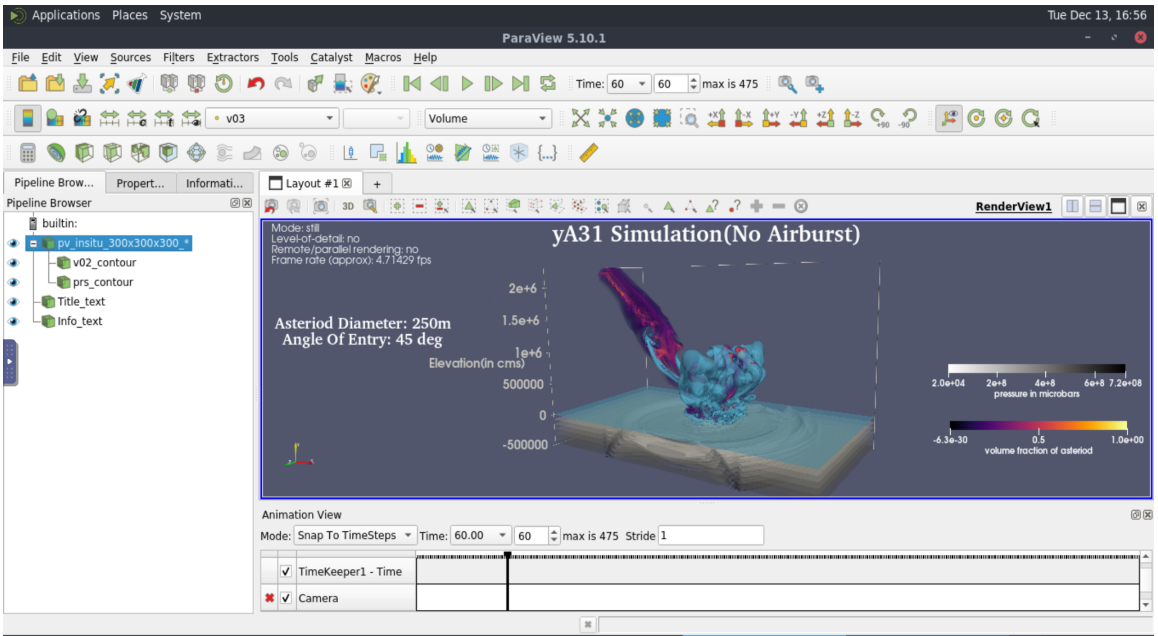
STRUCTURE AND FORMAT OF THE DATA

Simulation	Type	Time steps	Fields	Asteroid diameter	Asteroid angle	Airburst height	Size
yA11	Uniform Rectilinear Grid	209	Prs, tev, v02,v03	100m	45deg	No airburst	21.1 GB
yA31	Uniform Rectilinear Grid	473	All	250m	45deg	No airburst	193.8 GB
yA32	Uniform Rectilinear Grid	487	Prs, tev, v02,v03	250m	60deg	No airburst	114.4 GB
yB11	Uniform Rectilinear Grid	162	Prs, tev, v02,v03	100m	45deg	5km	126.6 GB
yB31	Uniform Rectilinear Grid	173	Prs, tev, v02,v03	250m	45deg	5km	57.3 GB
yC11	Uniform Rectilinear Grid	176	Prs, tev, v02,v03	100m	45deg	10km	13.3 GB
yC31	Uniform Rectilinear Grid	265	Prs, tev, v02,v03	250m	45deg	10km	49.6 GB

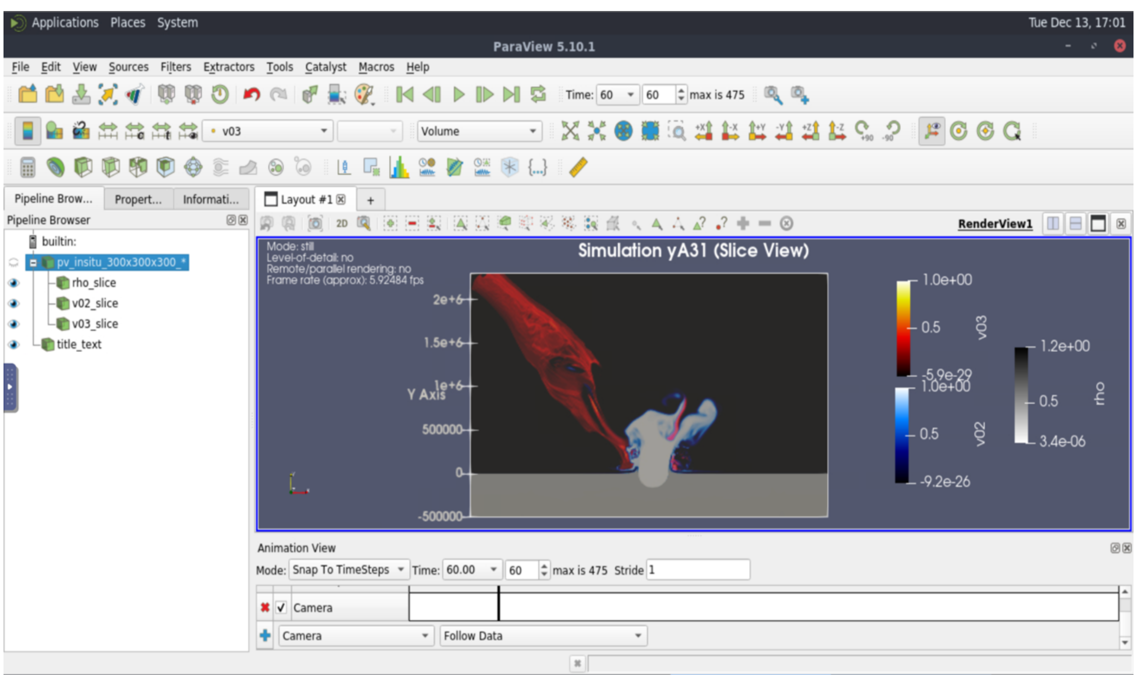
5. Final Visualization Workflow

- For each visualization style you implement, capture at least one screenshot of the entire ParaView window. Be sure to capture the Pipeline view along with the Render window and any other view windows that are important to the task being show. (e.g., Animation View.)

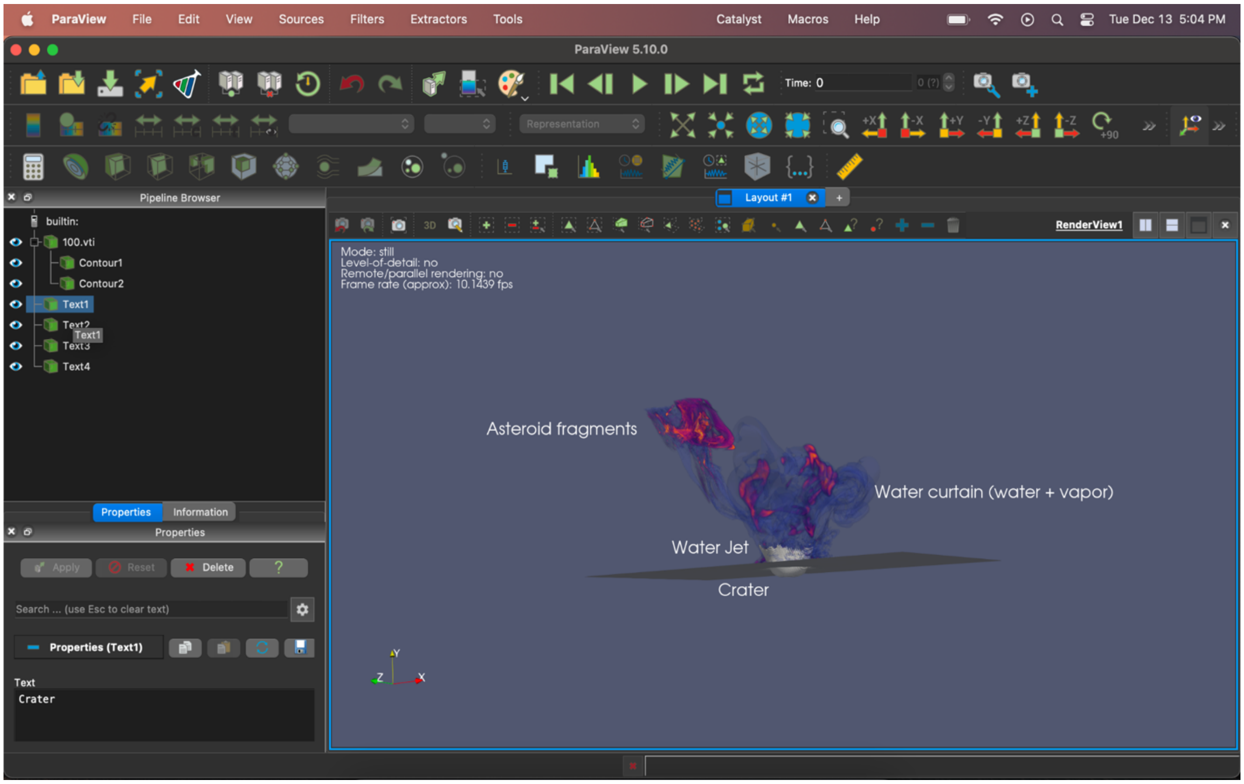
3D simulation



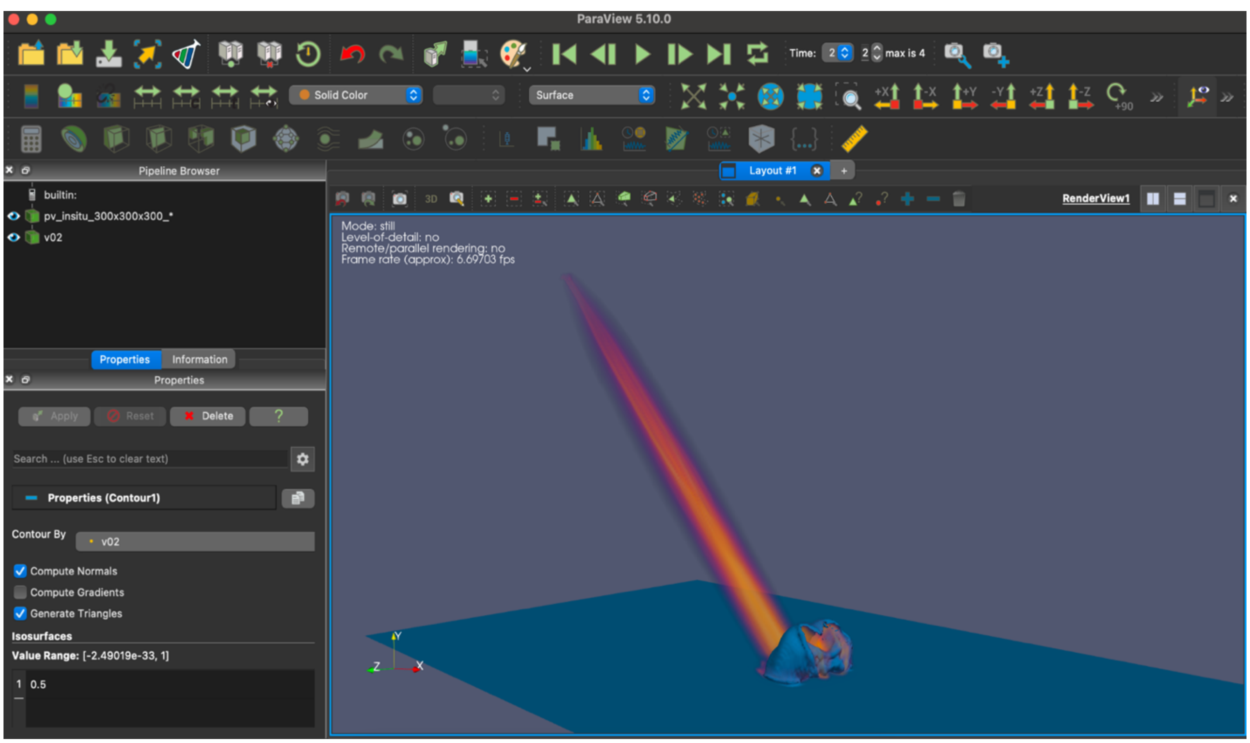
Slice View



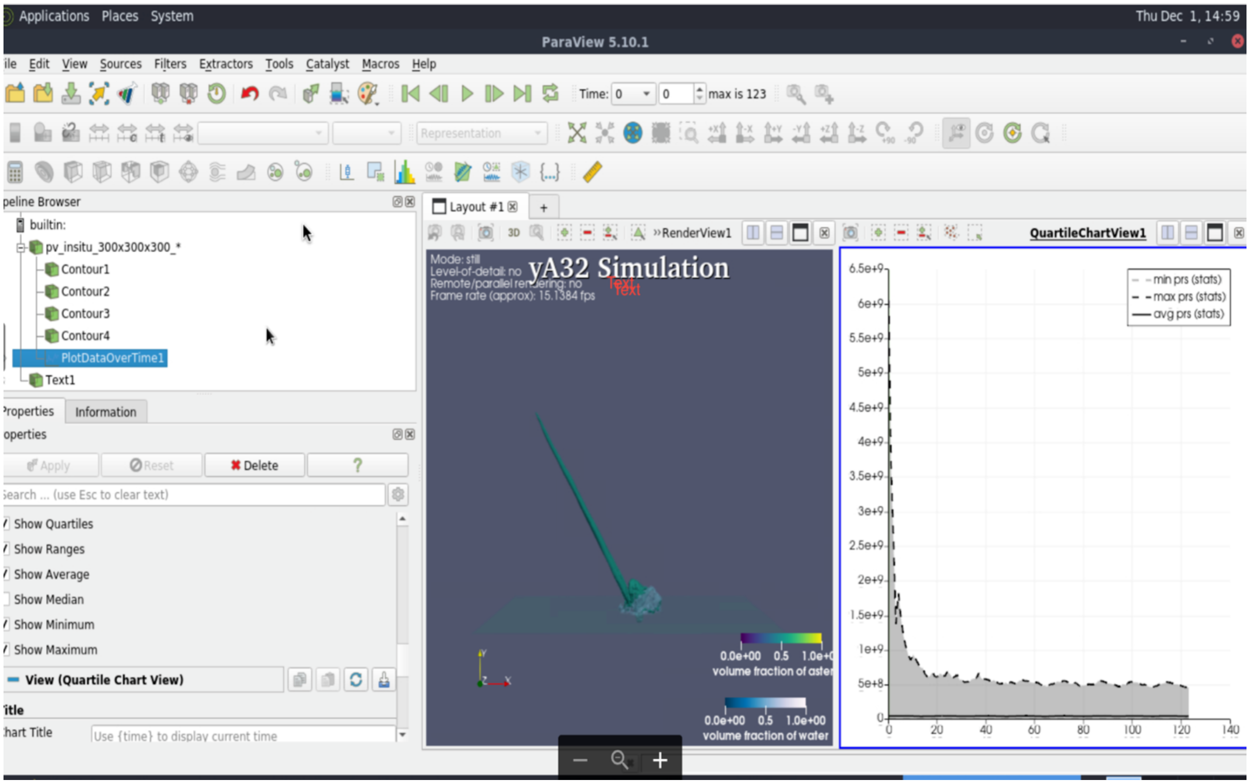
Labelled Diagram



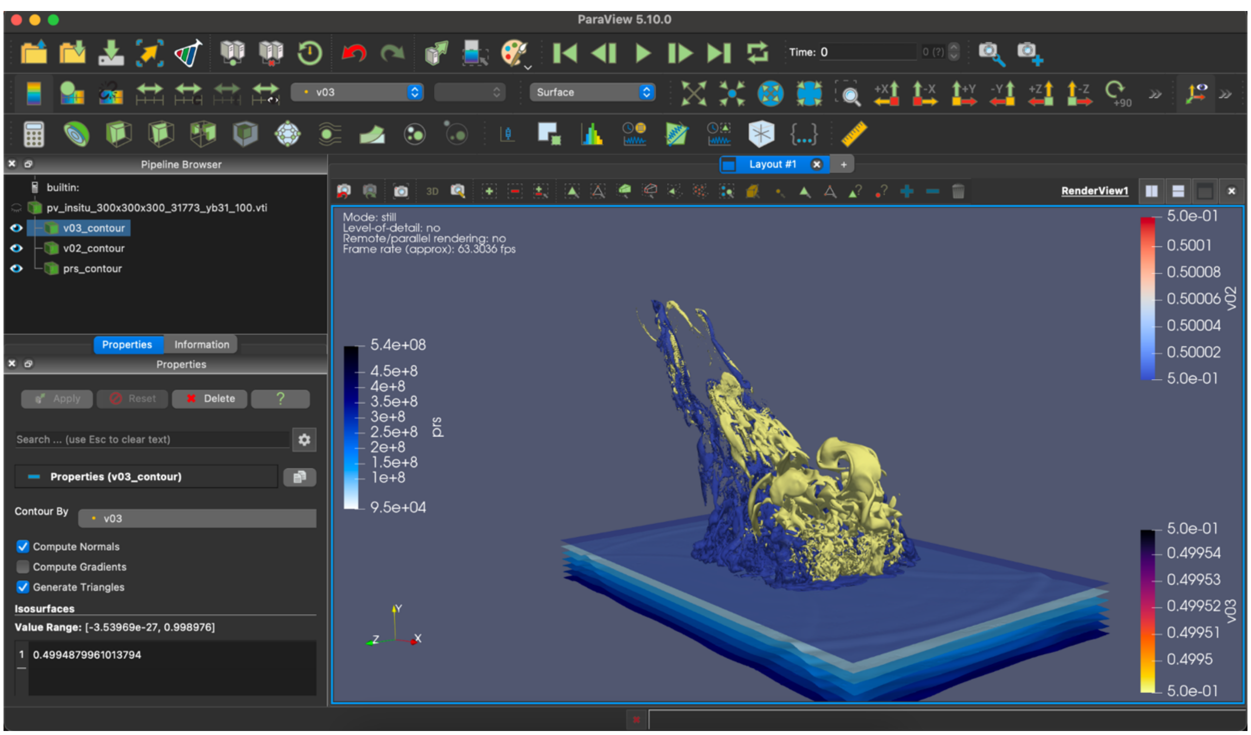
Pressure Wave



Plot data over time Filter

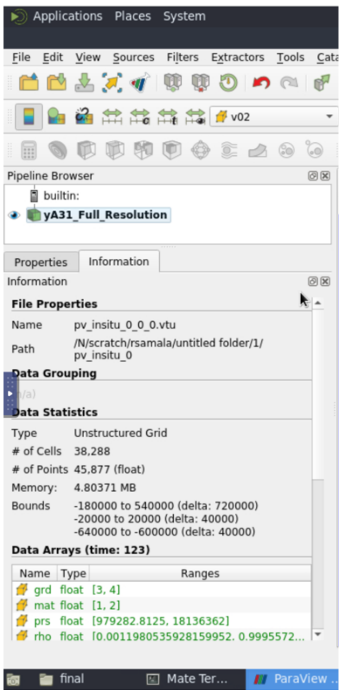


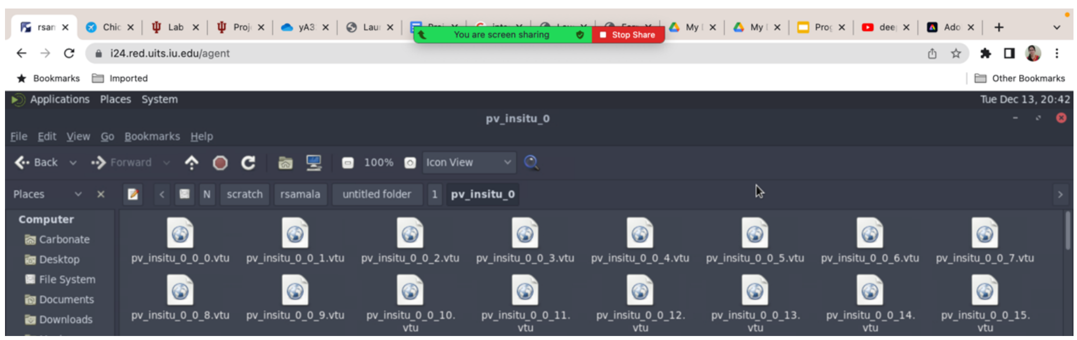
3D model – export in .gltf format to Sketchfab



NOTE: We tried visualizing the 500x500x500 resolution dataset for yA31 but could only generate a short video due to the size of the dataset and frequent shut down of the Paraview instance. ([Link to video]())

With the full resolution dataset, we managed to download the entire dataset, but realized that all of the time steps are compressed in tar folders. For this task we need to write a script to un-tar all folders first before attempting to load it into Paraview. Upon extracting one of the tar folders, we noticed that the data is in the form of an unstructured grid and the folder consists of multiple .vtu files.

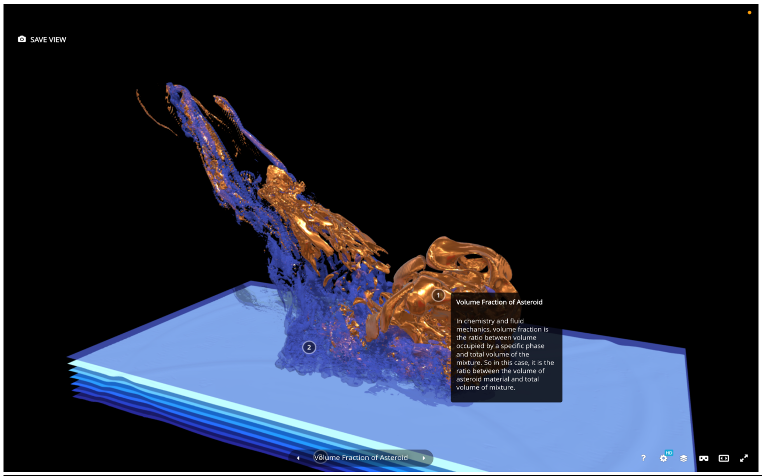




6. Final Visualization Results

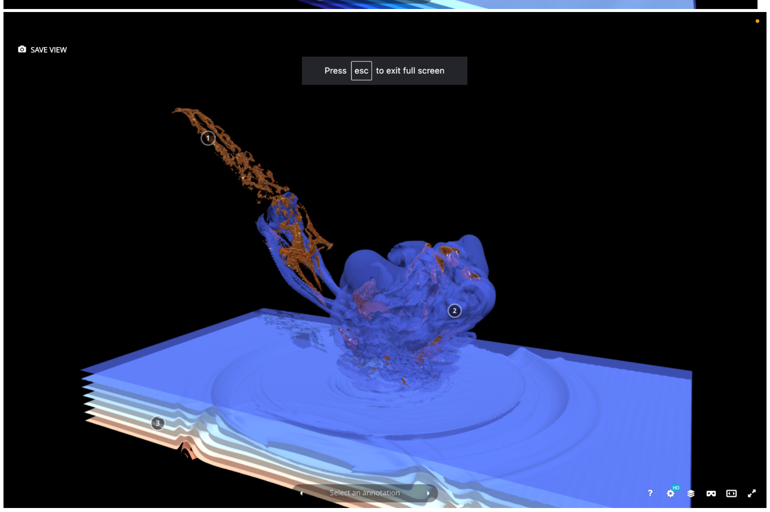
- In an organized fashion, present a representative sample of screenshots of your visualizations. These may be ParaView renders, a series of frames from your video(s), or screenshots of your Sketchfab model(s).

- Be sure to include URLs to online components in the report where appropriate.



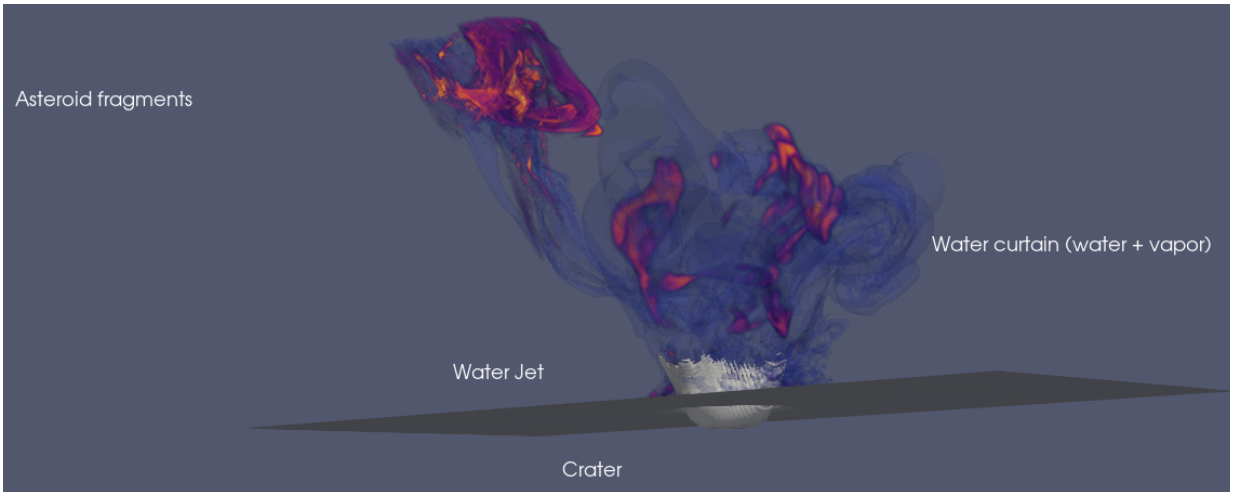
yB31 - Sketchfab Model

URL

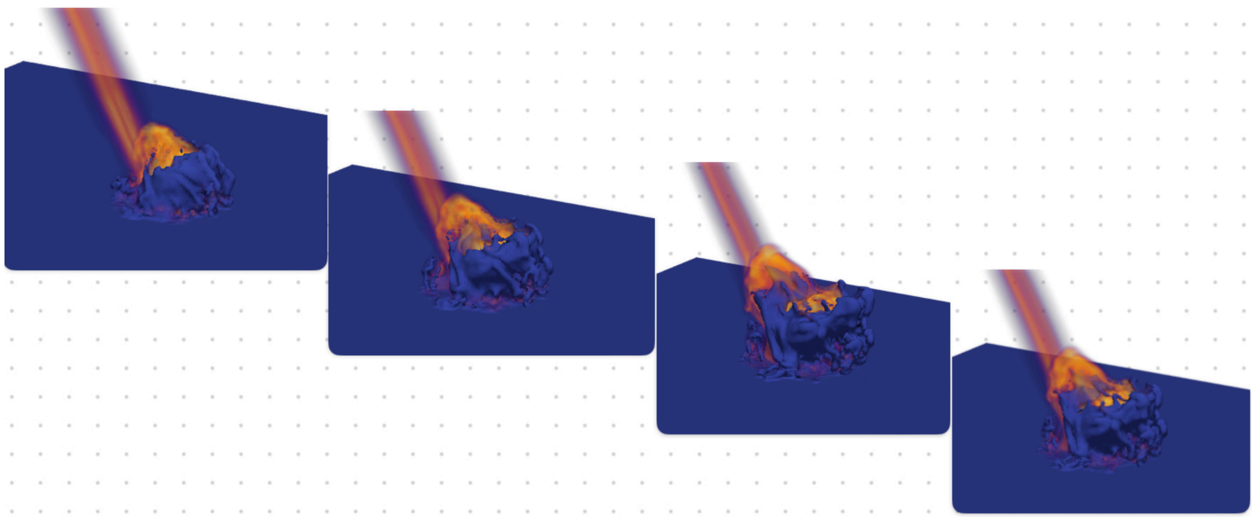


yA31 - Sketchfab Model

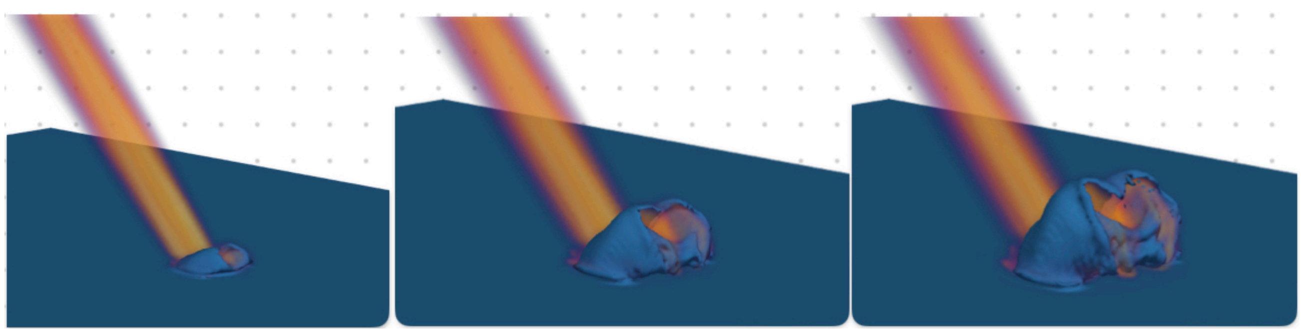
URL



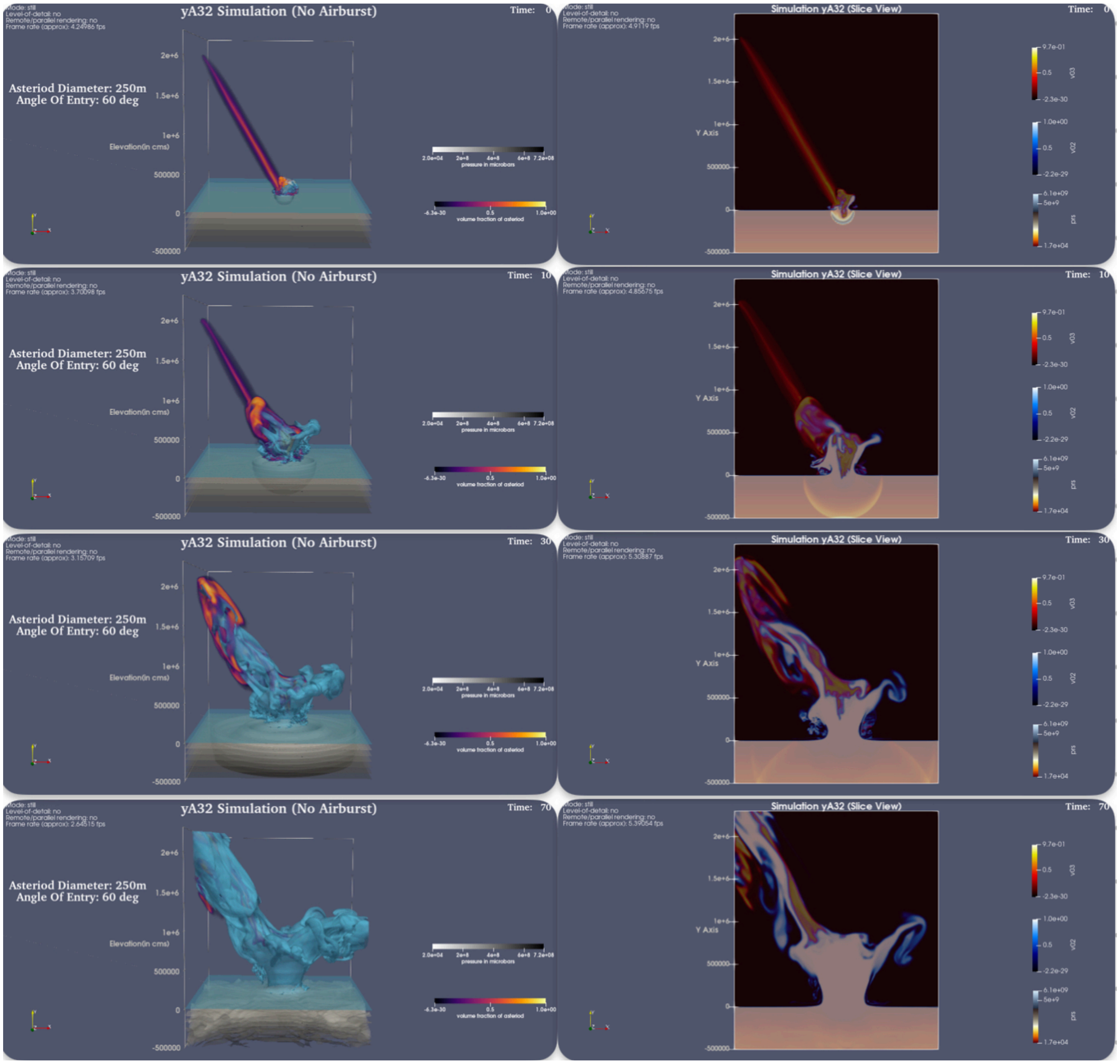
yA31 - Labeled Diagram



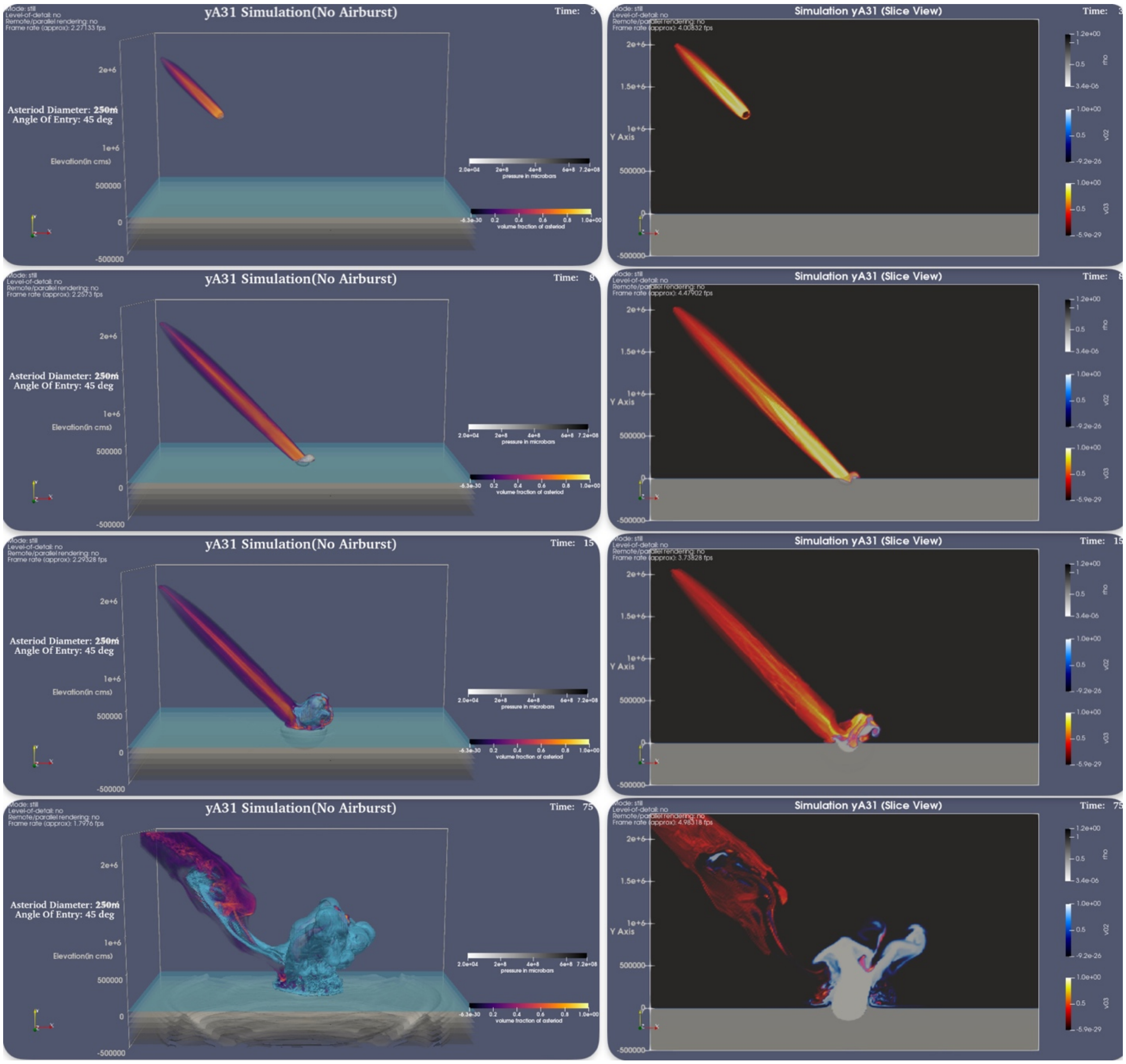
yA32 - Pressure wave formation.



yA31 - Pressure wave formation



yA32 animation (link)



yA31 animation (link)

7. Group Reflection

As a group, answer the following questions in <u>several complete sentences each</u>.

a) What project features ended up being different from your team's initial vision to the final implementation? Why did they change?

- Initially we thought of creating only 3D animation videos, since we were influenced by existing visualizations. But as the project progressed, we started to look at more ways to represent the same data and highlight the aspects of each of the ensembles and create easy to understand visualizations and came up with new solutions.

- We took inspiration from the existing visualizations and successfully created our own visualizations exploring different features like :
  - combination of isosurfaces
  - slice views
  - graphs
  - exploring colormaps and various filters
  - exploring sketch fab with color features
  - infographic improvisation with our created visualizations
- We also explored Sketchfab which was not part of the initial goal. We explored and experimented with a lot of different options and features in Paraview and SketchFab during the course of this project progress which made us aim higher compared to the initial plan.

b) What tasks end up being easier than anticipated? Which were harder than anticipated?

1. We expected the sketchfab task to be easy. But it was slightly tedious since we experimented with a lot of different materials and lighting options to get to the final stage.
2. We also never expected the colormaps would be so hard to tune, which was choosing a different colormap for each variable without overlapping.
3. The experimentation process was time consuming, but it was fun to weigh the advantages vs disadvantages of the different visualizations and realize that few experiments were dead ends. It was a great learning experience, nevertheless.
4. Contouring was easy, creating videos was time consuming.
5. We had planned to generate and analyze graphs initially. This proved to be a time-consuming task since paraview would crash very often. We eventually ended up generating graphs for a subset.

c) If your team had the project to do over again, and knowing what you do now, how would you change your technical approach?

- With the knowledge we now possess, if we were to start over the project, we would begin by forming questions about what we actually want to show through our visualizations and answering the specific scientific tasks first. Our next step would be to enhance the visuals to respond to each scientific task with additional technical components.
- To complete our scientific tasks, we would also like to understand the values of various variables at major events in the process. With the aid of such knowledge, we would be able to clearly concentrate on the relationship between many variables and a variety of disasters, such as tsunamis, green house effects, and sound effects on the environment.

d) If your team had the project to do over again, how would you change your task prioritization and time management?

- If we were to redo the project, we would prefer to use the same task prioritization. We were able to simultaneously learn and fully comprehend the many components of the visualization process because of this workflow,
- We began our research on the very first day of the project and continued it right up until the very end. We were able to achieve the greatest results possible in the period allotted because we regularly engaged in experiential learning. If we had more time, one of our priorities would be to look into the possibility of animating Sketchfab models.
- For time management, it would have been really helpful if we would have found a way to run the simulations of all the datasets simultaneously rather than doing it one after the other (linearly).

8. References

[1] S. Leistikow, K. Huesmann, A. Fofonov and L. Linsen, "Visualizing Deep Water Asteroid Impacts: Interactive Visual Analysis of Multi-run Spatio-temporal Simulations," 2018 IEEE Scientific Visualization Conference (SciVis), 2018, pp. 97-118, doi: 10.1109/SciVis.2018.8823612.

[2] Patchett, John M. Gisler, Galen Ross, "Deep Water Impact Ensemble Data Set", 2017 Los Alamos National Laboratory

[3] R. Imahorn, I. B. Rojo and T. Günther, "Visualization and Analysis of Deep Water Asteroid Impacts," 2018 IEEE Scientific Visualization Conference (SciVis), 2018, pp. 85-96, doi: 10.1109/SciVis.2018.8823609

[4] NASA, "Planetary defense." www.nasa.gov/planetarydefense.

[5] Visualization of the Deep Water Impact Ensemble Data Set

[6] Aggregated Ensemble Views for Deep Water Asteroid Impact Simulations

What to submit

Upload this document to Canvas. You only need to submit this once per group.