SCIENTIFIC VISUALIZATION: ENRICHING VOCABULARY VIA THE HUMAN HAND

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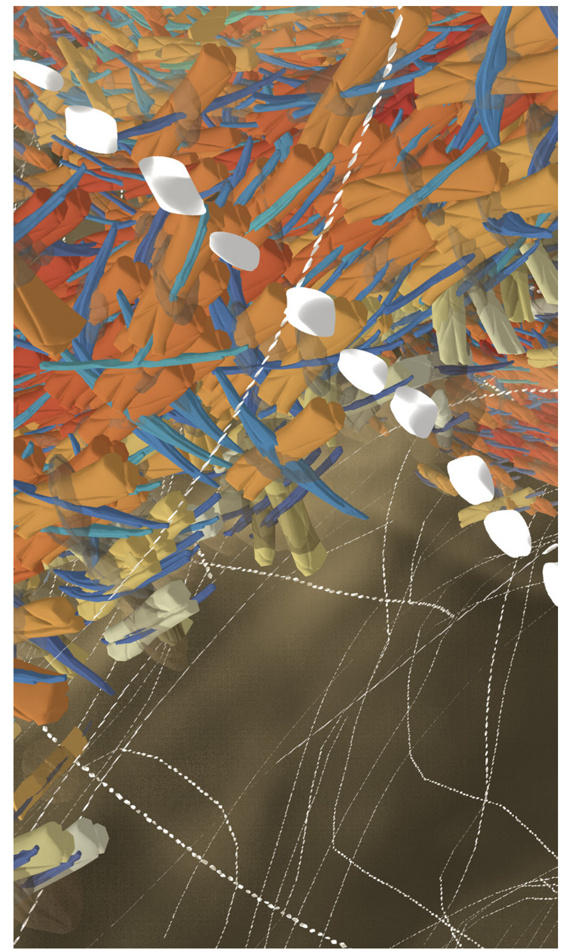
Abstract
As scientific data grow larger and more complex, an equally rich visual vocabulary is needed to fully articulate its insights. We present a series of images that are made possible by a recent technical development "Artifact-Based Rendering," a component of our broader effort to create a methodology for scientific visualization that draws on principles of art and design .

Authors Keywords
Scientific visualization; glyphs; visual art; collaboration.

Introduction
This annotated portfolio contributes a visual digest of the preliminary results and processes produced thus far by Sculpting Vis, our research team's multi-year effort to develop new computer tools and processes to bridge the disciplines of art and computer science in order to better support artists' involvement in scientific visualization. Sculpting Vis also encompasses an ethos that centers on hands-on, physical, creative, artist-driven approaches to visualization. Here we present the design theory underlying the glyphs of "Artifact-Based Rendering: Harnessing Natural and Traditional Visual Media for More Expressive and Engaging 3D Visualizations" [1], a new framework of tools and processes to create 3D/VR data-driven visualizations employing artist-made artifacts.

The theory is, in part, to leverage the richness and control over visual expression that is possible when artists work with traditional media. The ease of iteration and experimentation simply cannot (yet) be matched in the digital world. We therefore look to leverage the physical world as a way to design more visually rich and expressive digital visualizations. By starting in the physical world and moving to the digital, our approach seeks to effectively convey data while increasing sustained engagement and connect with our humanity.

Sculpting Vis employs a wide range of techniques to encode color, texture, and other visual properties. Here we introduces an overview of the process involved in the conception and physical production of hand sculpted glyphs, our library of glyphs, as well as reflections on artistic design theory and practice that informed the work.



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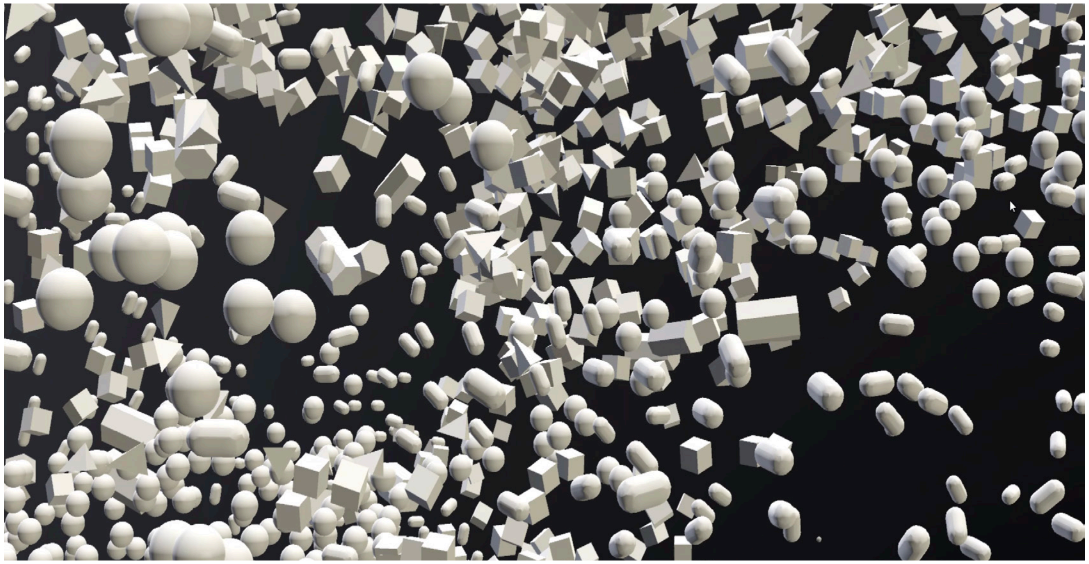
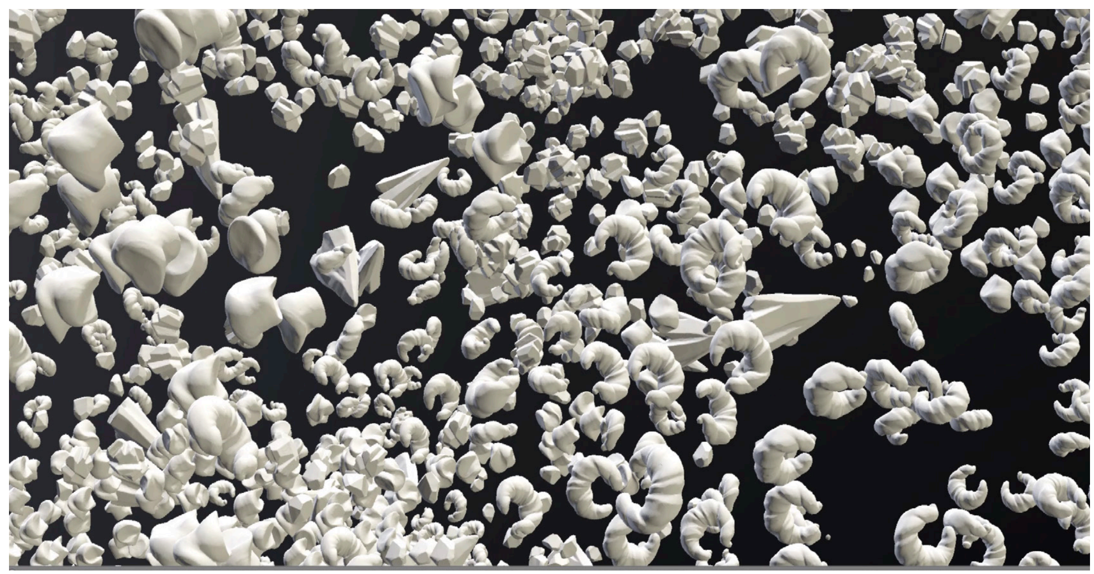


To the left is a detaiI of a supernova simulation visualization [3, 4] using commonly available glyphs to represent the stages of water and heavy metals produced in the supernova explosion.

By comaprison the image below uses forms from the Sculpting Vis Glyph Library on page 3 [2]. Curvilinear forms represent stages of water and angular forms represent heavy metals that are formed in a

Motivation

Art, at its core, stems from our human desire for connection to others and to our world. Scientists, particularly those in the environmental community, struggle to connect and to communicate with their peers and with the public. Widely used 3D visualization software packages, such as Paraview, include small sets of 3D glyphs, typically based on standard geometric primitives. By incorporating hand crafted glyphs, enabled by Artifact Based Rendering [1], our work enriches the visual language available for multivariate 3D visualization. In turn, it allows for a wider variety of glyphs that create more intuitive and effective connections between variables and associations between variables and the natural, physical properties they represent.



The Glyph Library

The Glyph Library is a free-to-download library of directionally-sensitive, 3D glyphs created as a part of our research. Each symbol can be imported into major vis applications, such as Paraview, mapped onto a data set, and colored depending on the needs of the scientist and the focus of the data vis.

Organization

The foundation of artistic design theory is built on the premise that all imagery is comprised of points, lines, shapes and forms [4].
We have organized our Glyph Library on this premise, creating "glyphs families" for each category. We added direction as it is an important element in visualization.

The "glyph families" were developed with three goals in mind:

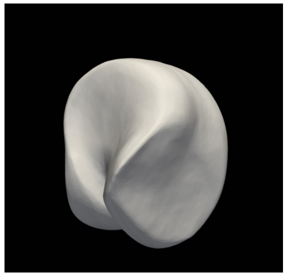
1. Making a series of forms that are easy to distinguish when they are applied to multivariate data .

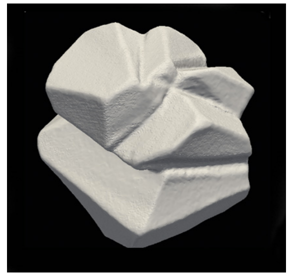
2. Creating forms that could be intuitively associated visually with properties of scientific variables.

3. Employing art and design theories in order to create a visualization that is both engaging and decipherable to a general audience. Families share "visual DNA," which are properties that include organic composition, geometric composition, and densely textured surfaces. [5].

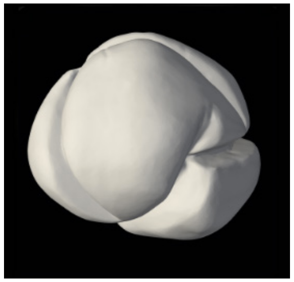
Contrast types:

curvilinear
verses
geometric

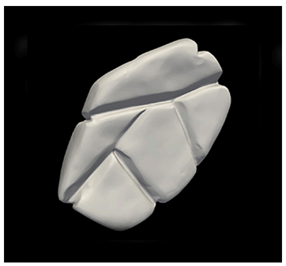


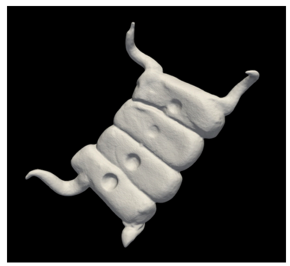


sparcely textured
verses
densely textured



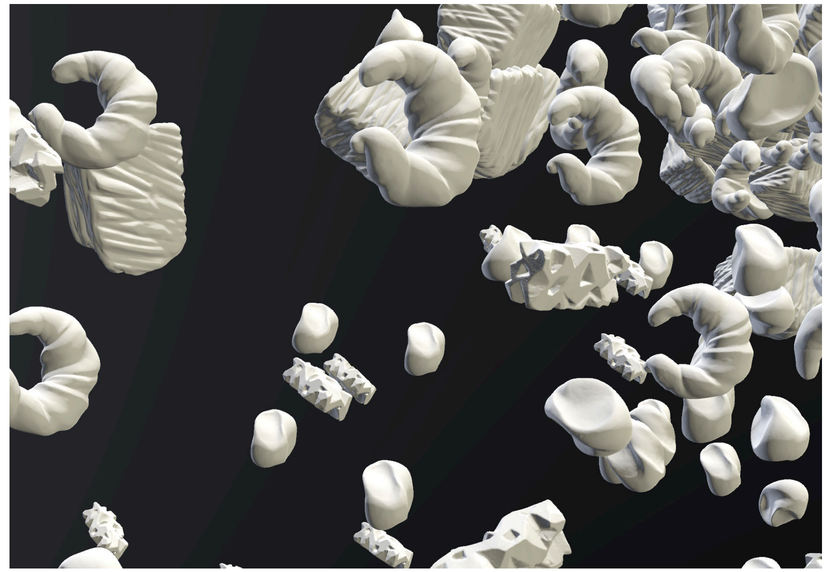
abstract
verses
representative





Creating Contrast

Visual contrast is a key tool that artists use to represent relationships between different aspects of composition. Color, texture, and form can all be used to create contrast in organizing information, directing attention, and establishing hierarchies between information. We apply this concept when developing glyphs categories in the Library.

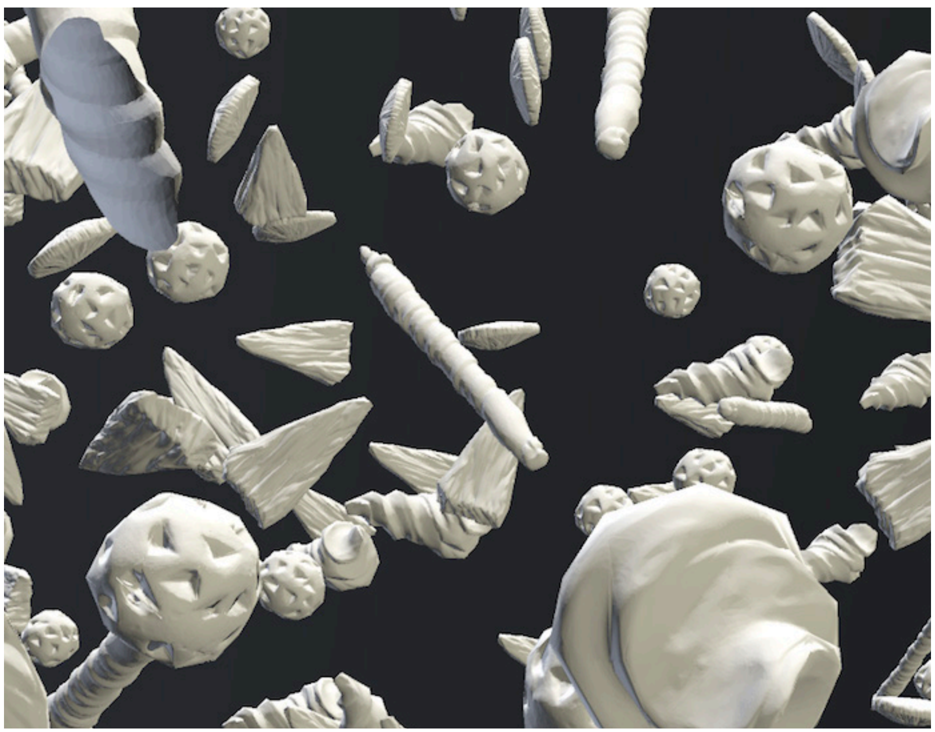


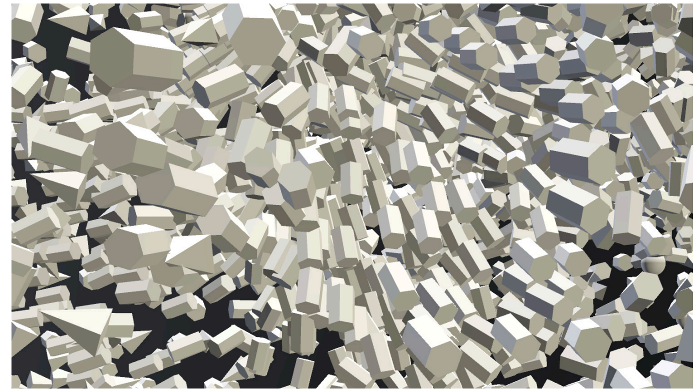
We created over two hundred clay thumbnail sculptures of potential glyphs, exploring how contrast could create relationships between them. A key finding during this part of the process, given the same amount of time, we created many more variations of potentially useful glyphs using physical sculpting thatn we could in a graphics program. The time consuming nature of creating different glyphs in graphics programs is a hurdle to variation; we found that sculpting by hand allowed us to sketch out many different ideas, from which we could distill the best.

The left image is a glyph family. These glyphs are grouped based on the aforementioned qualities that scientists can use to create a vis that clearly distinguishes between categories of similar variables.

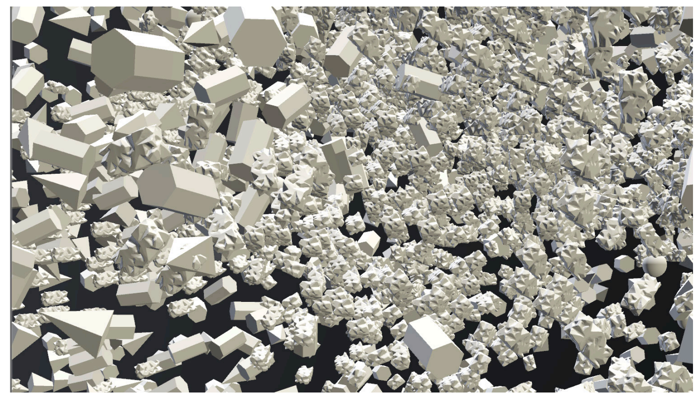
Deploying Contrast

After organizing and narrowing down the first version of the Library, we experimented with how to best deploy visual contrast. A key challenge in visualizing large, complex scientific data is the difficulty of creating glyphs to represent numerous variables that are easily distinguishable from one another. In order to test the impact of different textures, we experimented with different combinations of white glyphs on a supernova simulation. We sought to determine which families are visually distinguishable when applied to data with many small points. The figures shown here demonstrate the first tests of this iterative experiment.

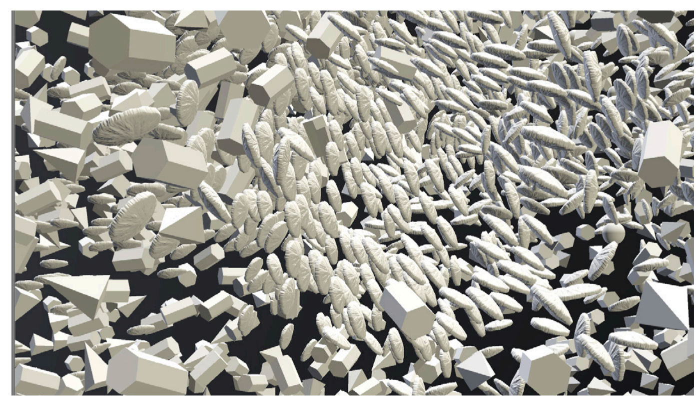


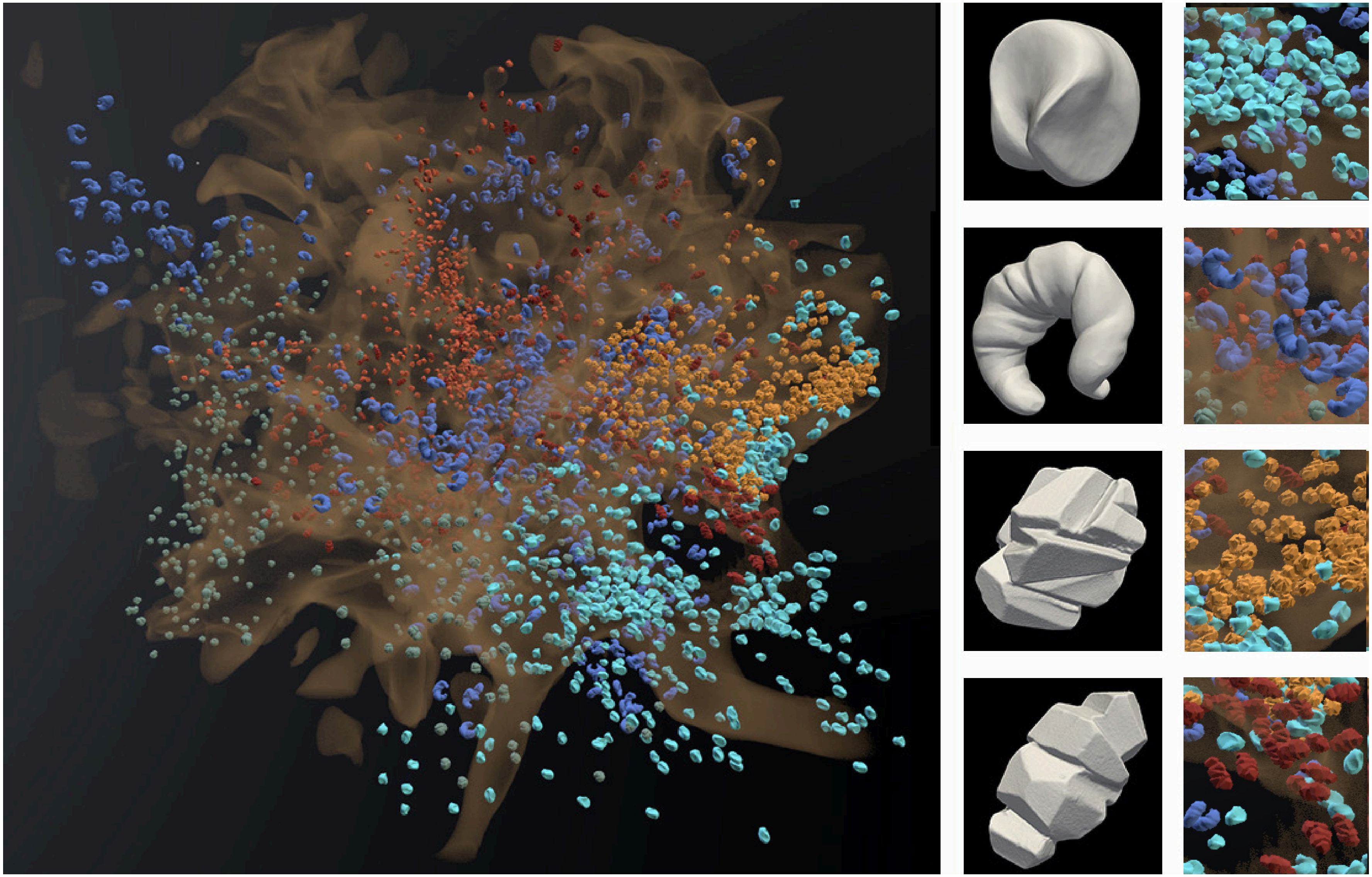


geometric forms only



Above: substitution with a highly textured glyph
Below: substitution with a disk profile glyphs



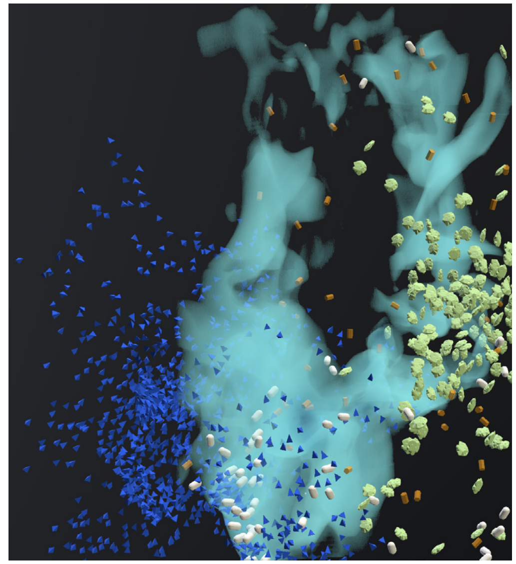


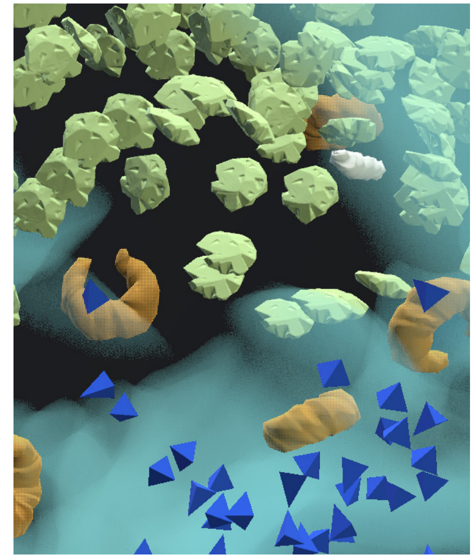
Our next step was the introduction of color, well known as the most potent encoding channel [6]. In the visualizaion above of a supernova simulation, scientists are interested in the categorical distintion between heavy metals, temperature, gas density, and the stages of water formation. We found that in a crowded large field, we were most easily able to differentiate variables that differ in profile, texture charcteristics and texture density.

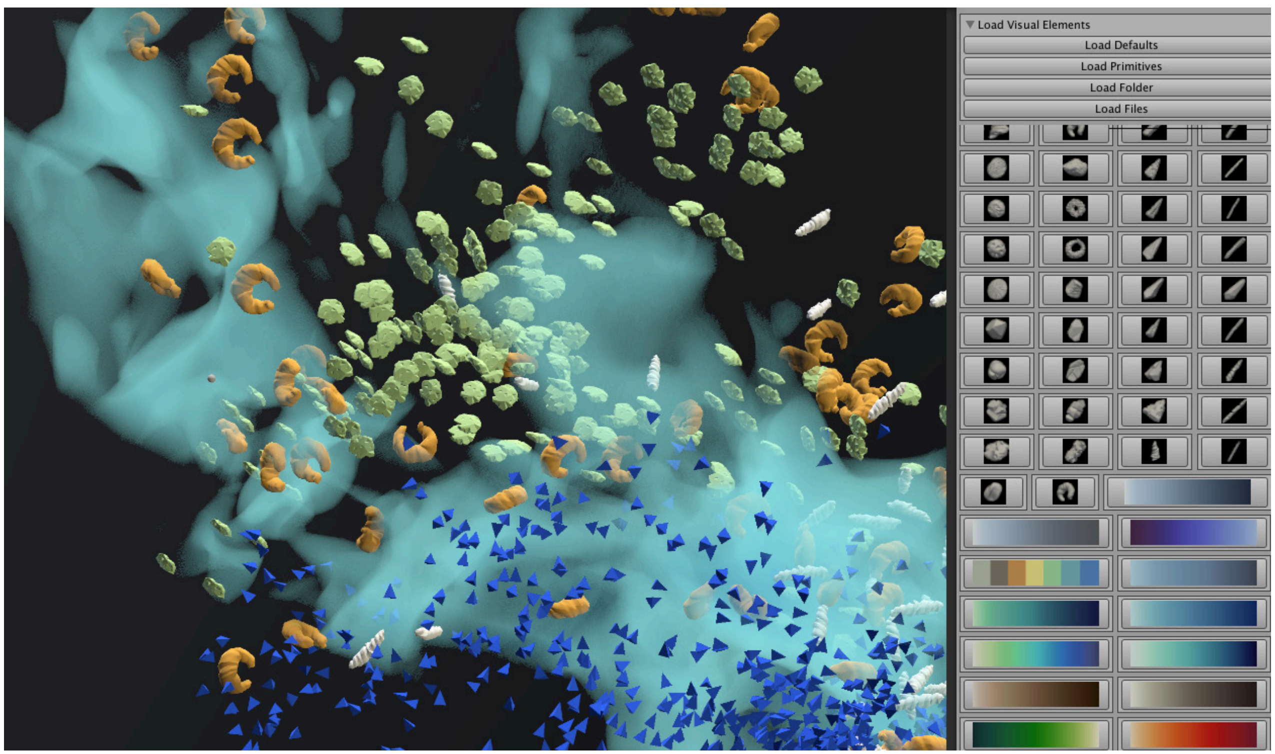
Curved forms represent different stages of water formation and angular forms represent heavy metals formed during the supernova. The volume rendering represents gas density of the exploding supernova.

Constructing the Visualizations

Iteration is fundamental to the artistic process. When balancing the enormous range of choices within the Artifact Based Rendering [1] system (interface below), several stages of experimentation and iteration are required to balance the interaction between variables. The Artifact-Based Rendering user interface, design by our multidisciplinary team, enables one to quickly and easily experiment with the wide range of options. Here we see a glyph sets as well as a wide selection of colormaps. On page 15 you can see the application of other types of encodings including line and texture.

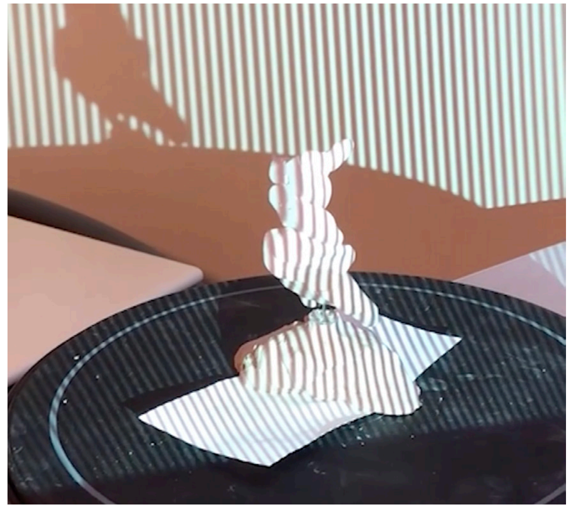






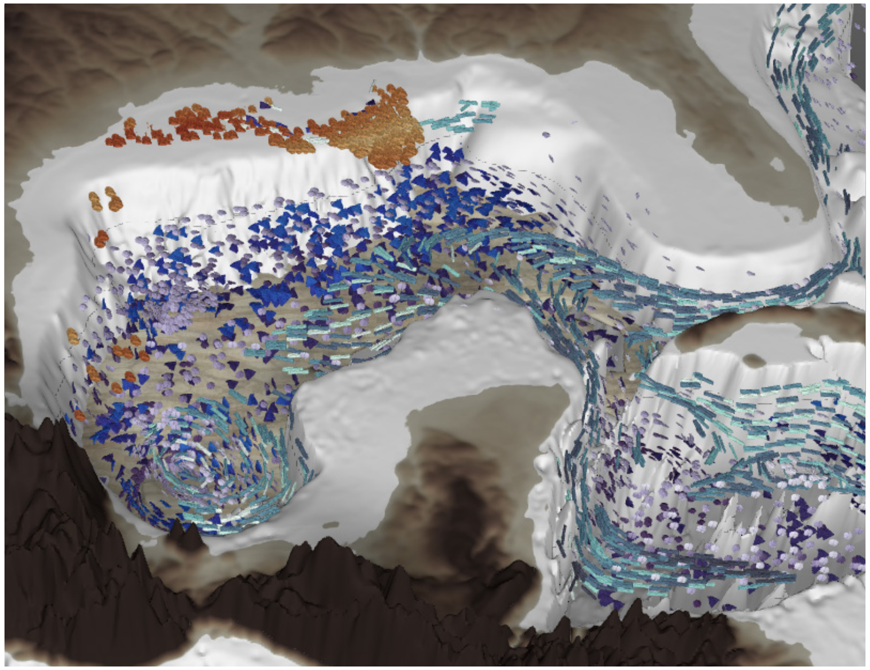
Combining the hand crafted glyphs with standard geometric form provides another clearly identifiable type of contrast.

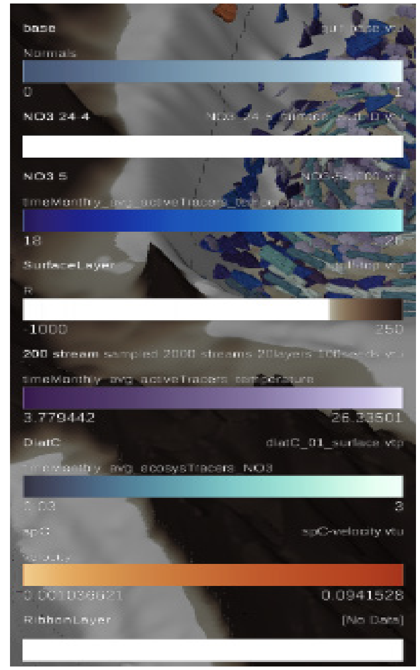
Creation and Capture

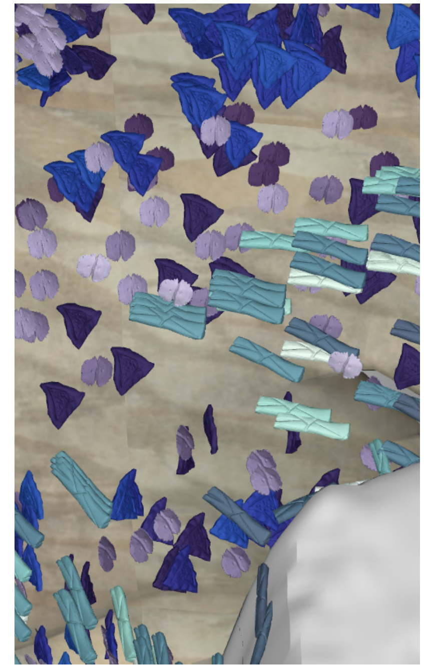


The glyps are constructed using tradtional clay and catured with an EinScan-SE structured light 3D scanner. Each scan produces a high-resolution mesh of roughly 100,000 vertices with corresponding photographic texture data. These resulting .obj files are reduced to enable the data rendering.

Painted glyphs were captured with a 2D scanner. Below the paint glyph is being framed in black to accentuate the edges facilitates identification.

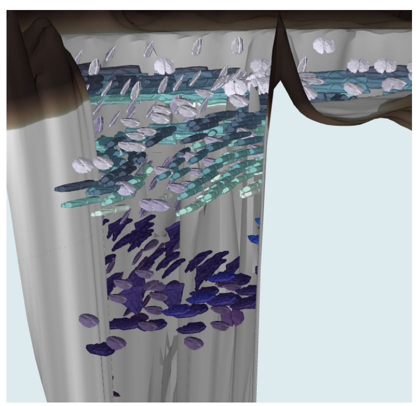


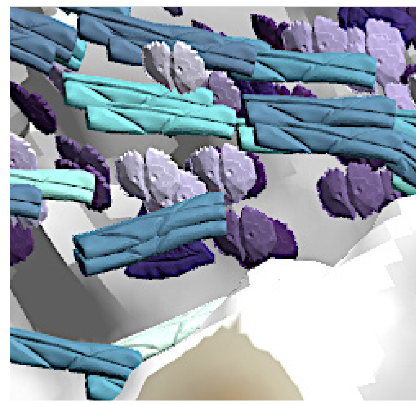


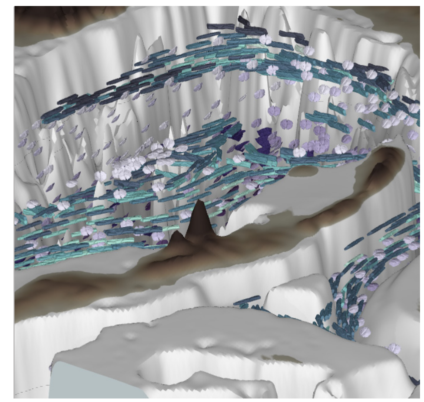


These visualizations, depicting the biogeochemistry in the Gulf of Mexico, encode multiple variables within one image thus enabling scientists to identify how the ocean conditions impact the plankton. There are over 30 variables, encompassing both physical conditions such as temperature and velocity as well as physical elements such as plankton, carbon and nitrates. Understanding the impacts and dependenciues is critical to answering their science questions.

This detail exposes the depth of the variables enabling scientists to track the vertical mixing over time.

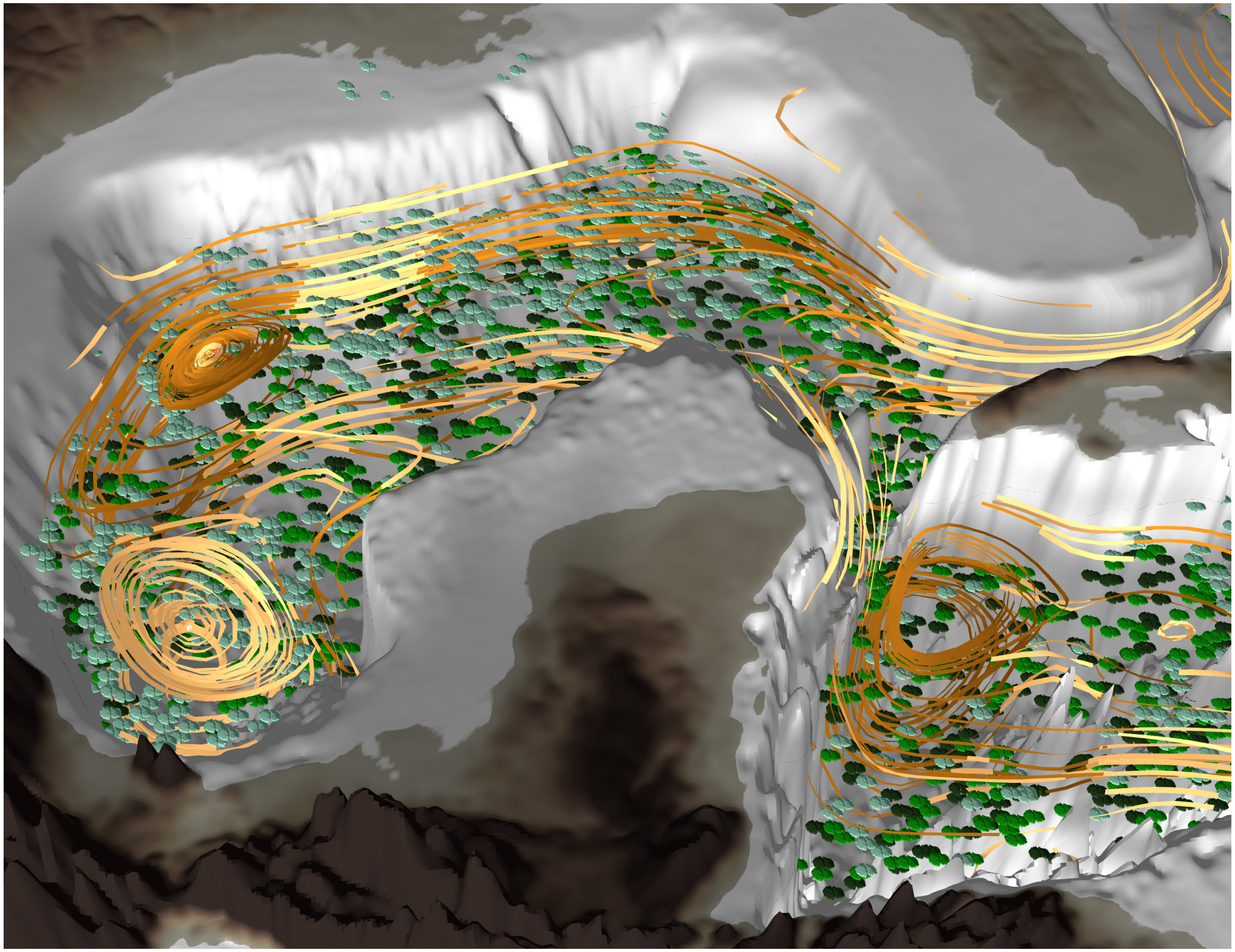




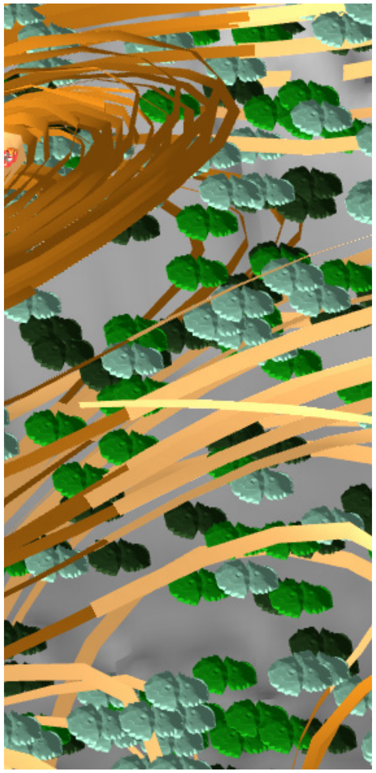


E3SM Ocean simulation of the biogeochemistry in the Gulf of Mexico, is being developed by the Climate, Ocean, Sea-Ice Modeling group at Los Alamos National Laboratory.

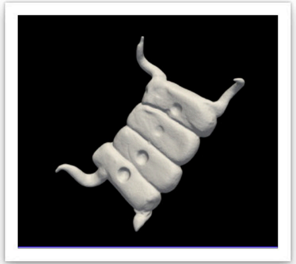
VISAP'19, Pictorials and annotated portfolios.

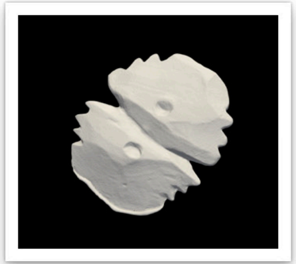


The streamlines show velocity and are colored by eddy direction. The plankton shaped glyphs are colored by levels of nitrates which promote plankton growth.

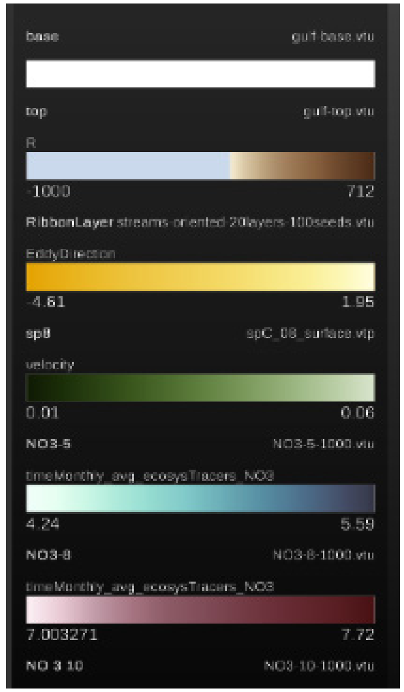


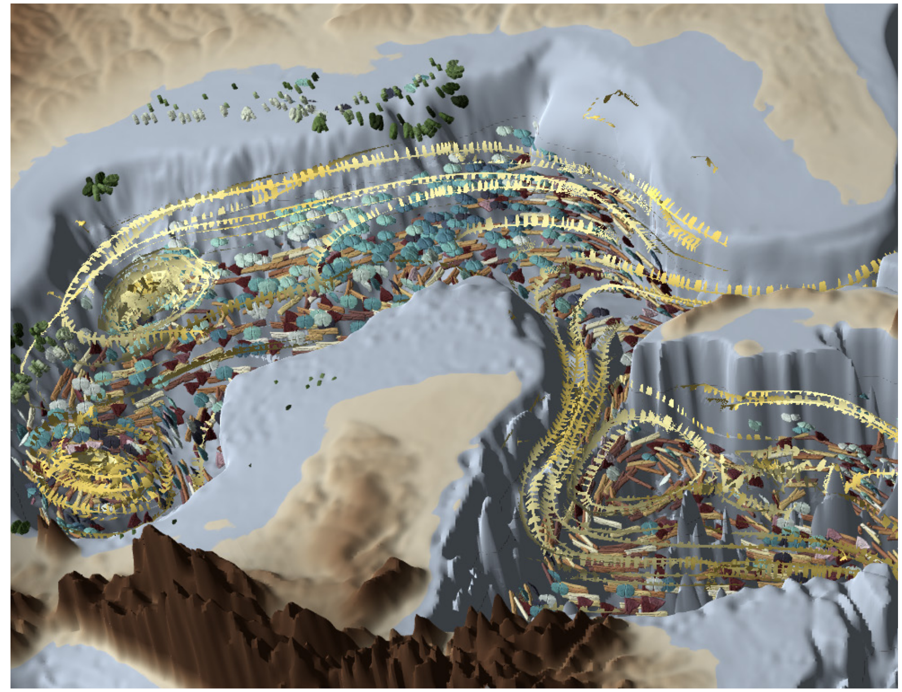
Plankton-shape representative glyphs.



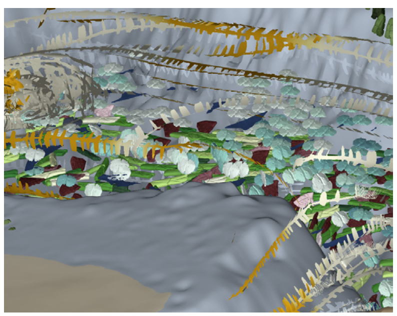


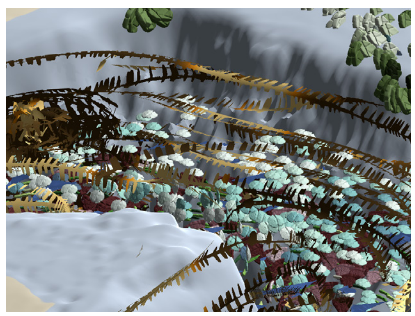
Artists are trained to organize and balance the visual components of images in order to create clarity from complexity.
Artists iteratively hone the shapes, hues and densities to create balanced clear communication.

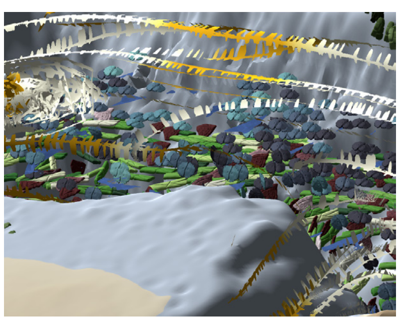


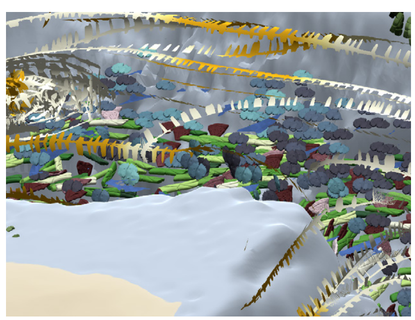


Biogeochemistry in the Gulf of Mexico, P. Wolfram, LANL

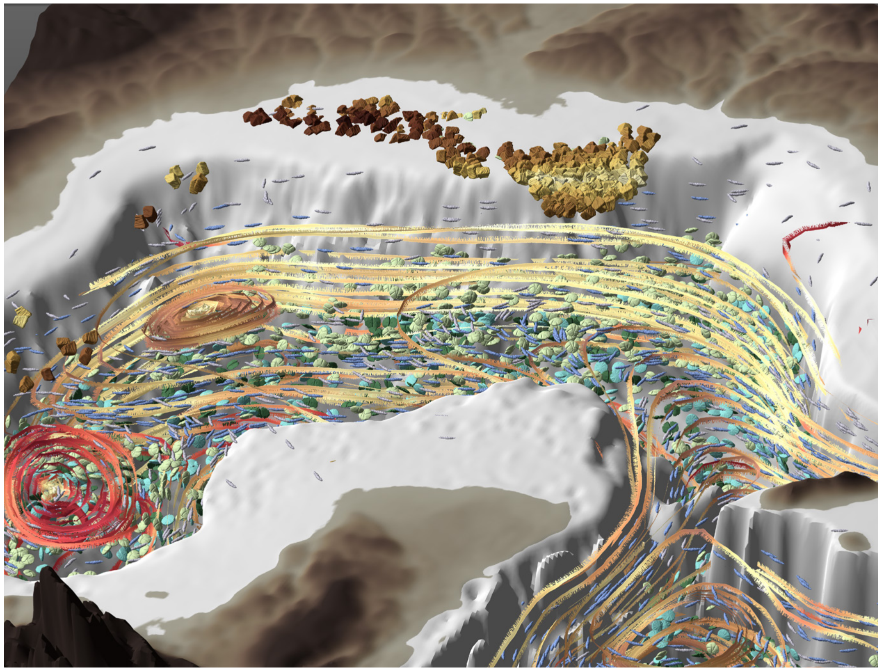




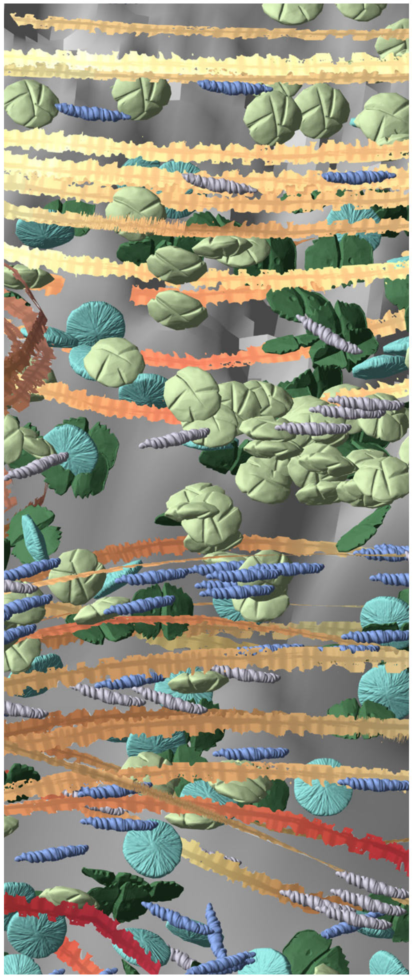


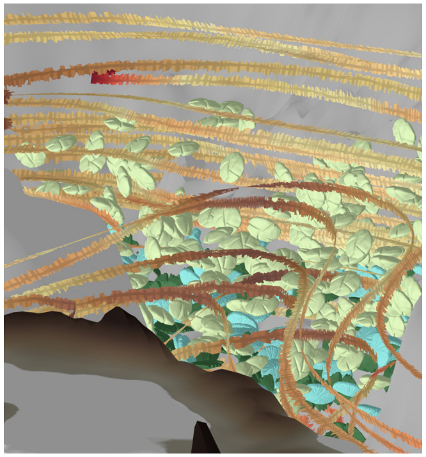


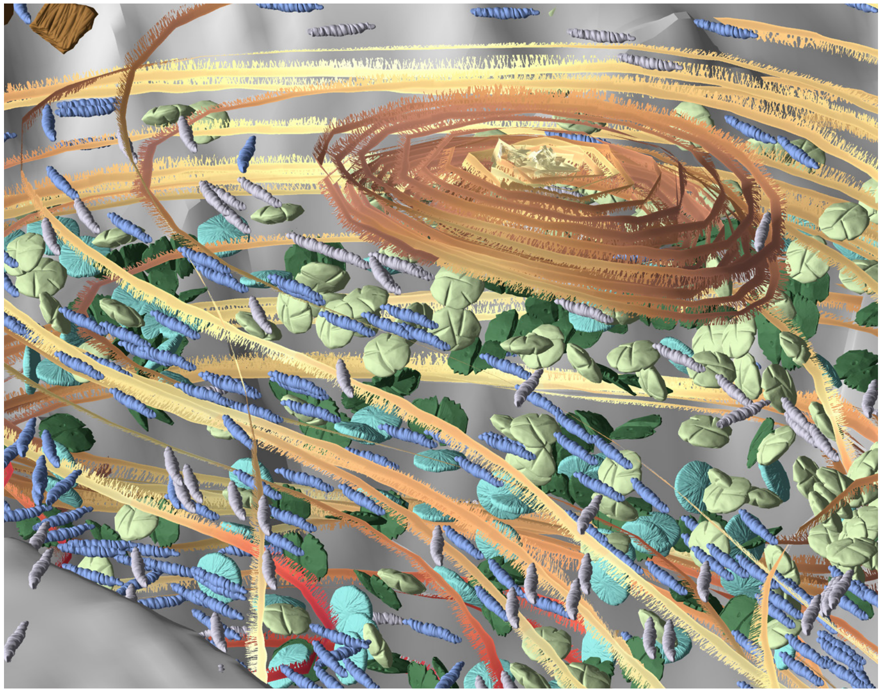
On the top left, the 3D surface of the Gulf seafloor is muddy and the variables are difficult to distinguish due to a lack of lighting variance.
The four images to the left demonstratethe iterative ajustments made to the above visualization, in order to reveal the components and relationships within the visualization. In the set, on the upper right, more variation in luminance has been added, but there is now too much contrast in the ribbon representative of eddy direction to distinguish it from its surroundings or to decipher the minutiae of color gradation, which in this case represents velocity. At bottom left, the color of the ribbon has improved and is now identifiable. However, its surrounding variables are still in too much shadow. Finally, on the bottom right, the desired result has been achieved: a clear, well-lit visualization with appropriate contrast, color usage, and luminance implementation.

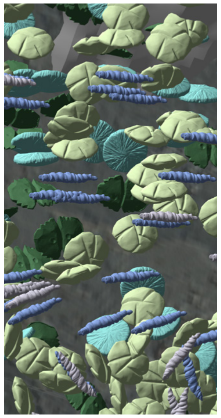


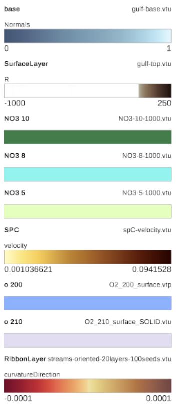
The ability to track the relationships between variables over time is crucial in understanding the nature of changing ecosystems.
The surrounding images show seven different variables, including temperature, nitrate concentration, vorticity, velocity, plankton concentration, and plankton type, three of which are also encoded with a scalar field of another variable.
Here, the fringed ribbon represents eddy direction, while the gradient change in color shows velocity.

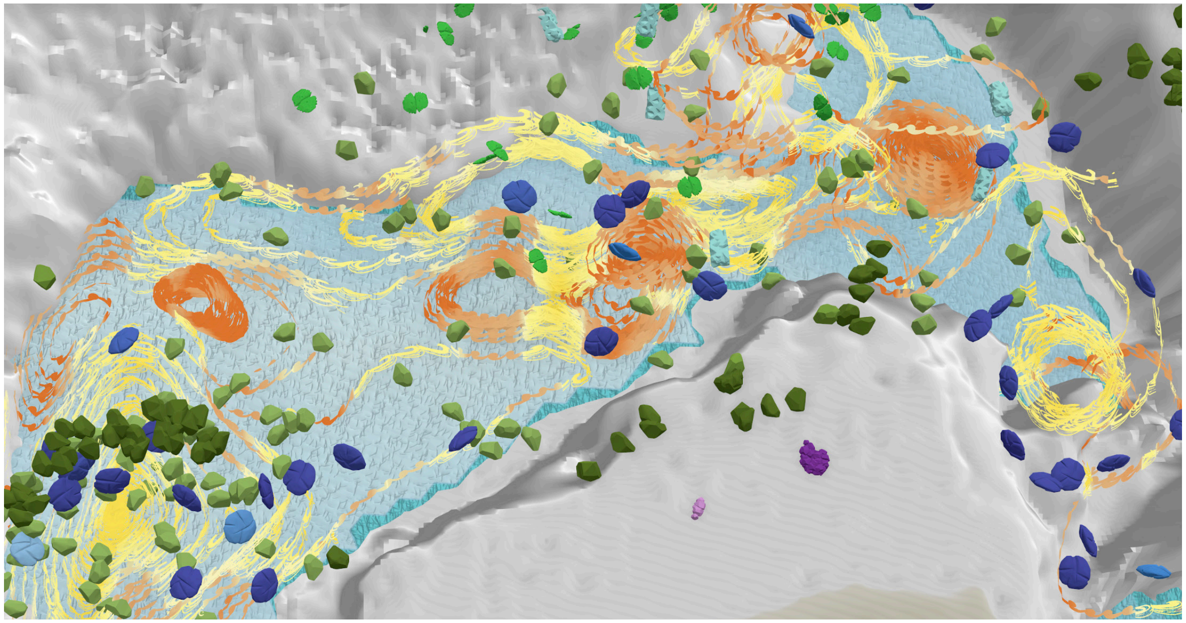








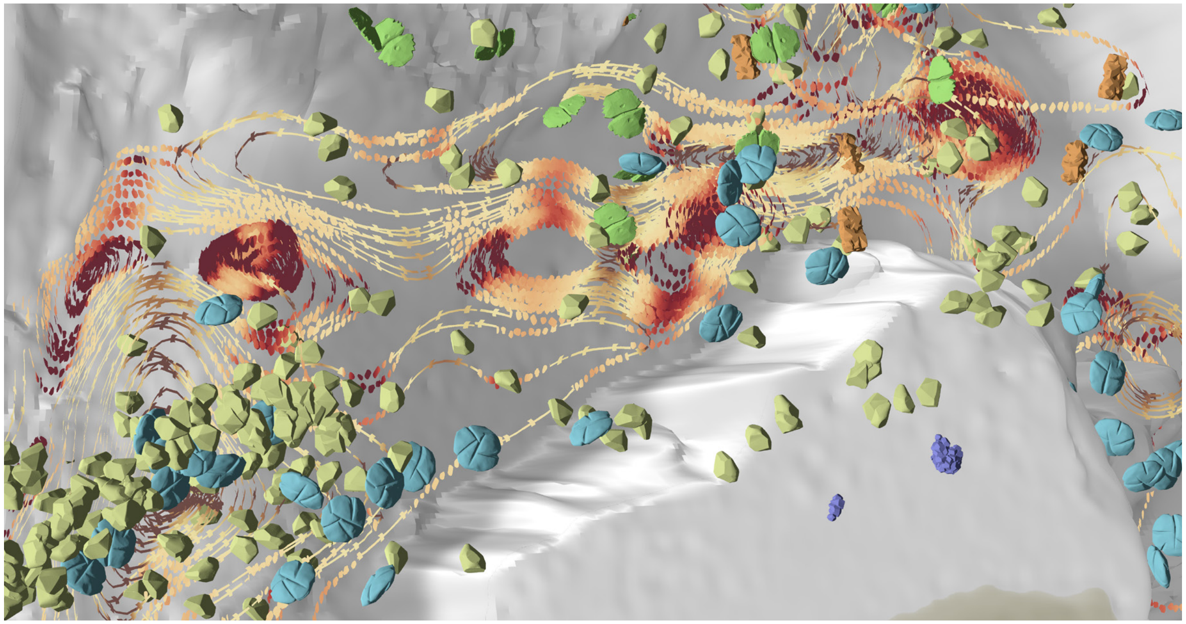


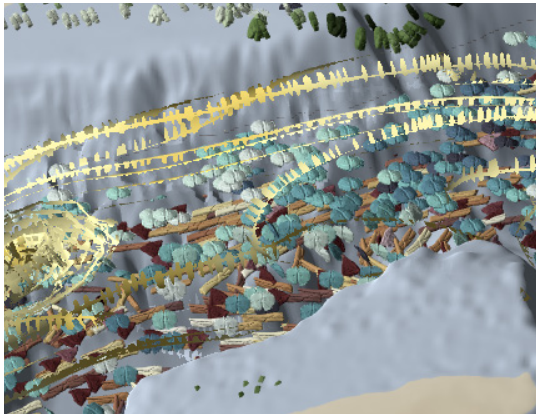


Affective Visualizations

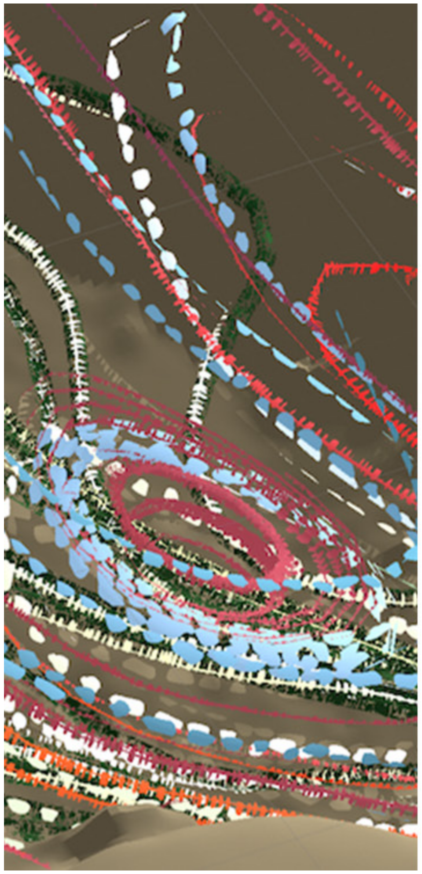
Sculpting Vis is predicated on the idea that scientific visualizations are more effective when they are engaging. Humans are drawn to beauty—drawn to engage with it, interact with it, and ponder it for longer periods of time.

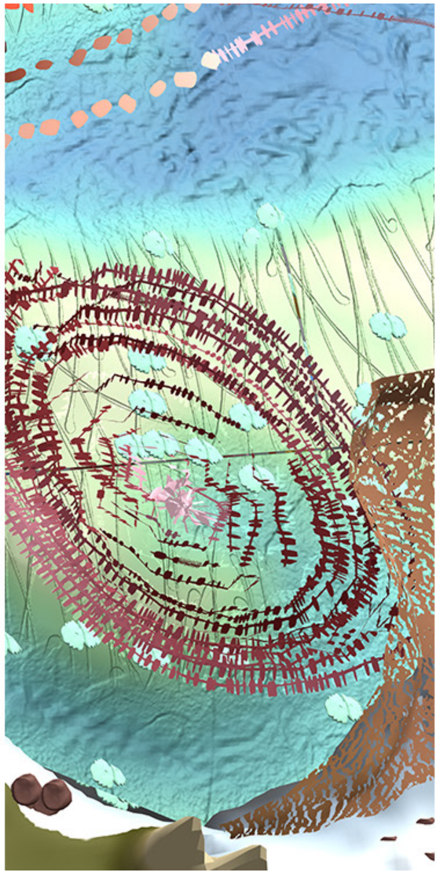
On the left we see a comparison of subtley differenty palettes on the same data. While they both are colorful palettes, the mood of the visualization on the top is a more playful palette while the visualization on the bottom, also colorful and engaging provides a more neutral affect. The palette below draws from somber hues [11].

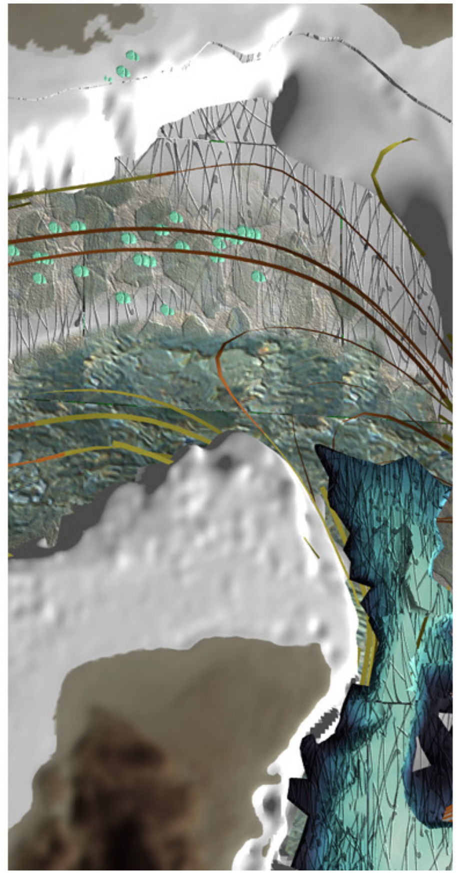


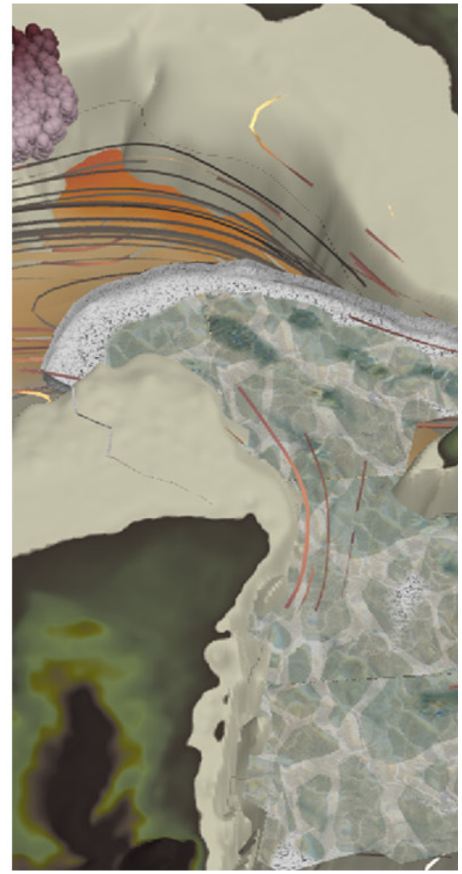


Sculpting Vis is being developed by an intradisciplinary research team dedicated to the need for a human connection to big data during an era when it is needed in order to address pressing societal issues.

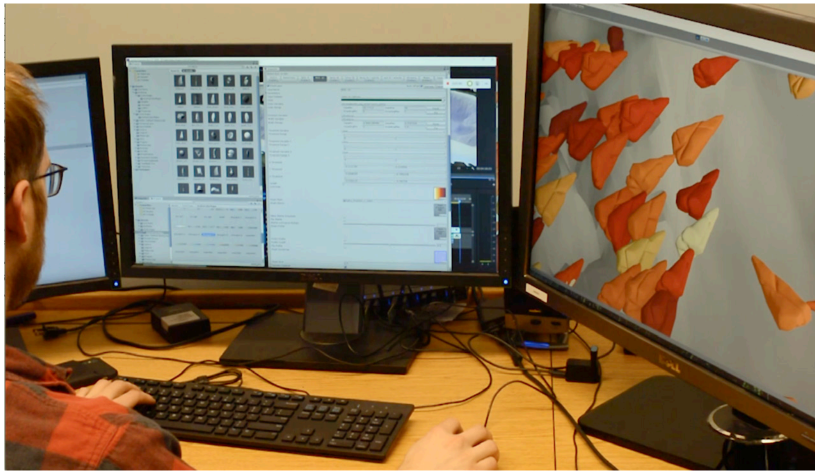








Future work includes extending the vocabulary of line, texture and pattern palettes and integrating them into the ABR system. Above are a few examples of the possibilities employing the full range of visual elements in Artifact-Based rending.



The work presenented here is one aspect of a broader effort to bring artistic language to scientific visualization. Sculpting Vis and Artifact-Based Rendering are part of an ongoing research effort currently being undertaken at the Interactive Visualization Lab, University of Minnesota and the Texas Advanced Computing Center, University of Texas at Austin.

The Sculpting Vis Glyph Library contains open-access downloadable glyphs. All resources are available and freefor download at www.sculpting-vis.org.

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