Antarctic Water Masses, Sculpted Visualizations

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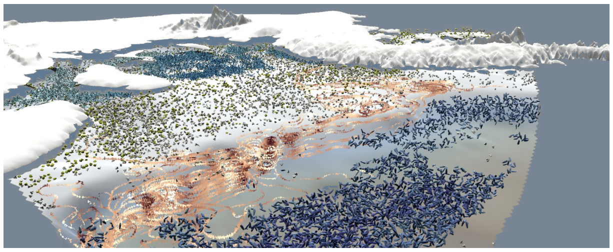

Figure 1: Employing Artifact-Based Rendering, visualization system enabling the application of hand-crafted and custom encodings renders five types of ocean water masses under teh Filchner-Ronne Ice Shelf. Data - E3SM climate model, LANL, U.S. DOE [1].

Abstract

The high-resolution simulating of climate physics enable scientists to study how differing scenarios may affect the climate over time. Visualizing the results of such models involves transforming the raw model output to imagery using domain-specific paradigms that convey information to the scientist. Ocean scientists classify sea water into *water masses* - bodies of water that share ranges of physical properties - as a means to understand the dynamics of the ocean. In this work we demonstrate sampling to represent the amorphous shapes of multiple water masses and use Artifact-Based Rendering to render these samples using hand-crafted natural forms.

1 Representing Water Masses

Understanding the physics of seawater and ice sheet interactions is vital to understand the effects that various scenarios may have on the Antarctic ice sheets. The Energy Exascale Earth Systems Model(E3SM) is a coupled ocean, sea-ice, land-ice and atmospheric model that enables climate scientists to study the physical evolution of the climate over varying scenarios. In this work we address a specific scientific problem: how the interaction between sea water and ice sheets affect ice-sheet melting rates. To help ocean scientists to understand these interactions, we transform the raw data using a domain-specific paradigm - the classification of sea water into multiple water masses based on common ranges of salinity and temperature properties. Figure 1 shows a frame from the visualization; figure 2 shows this classification in a temperature vs. salinity plot.

These water masses form amorphous shapes in the ocean. Fine detail of water-mass boundaries is less important to the scientist than understanding the relative motion of the water masses as affected by ocean currents. Traditional methods of visualizing these shapes - notably translucent boundary representations and volumetric renderings - to confusing interplay of colors as the water mass bodies overlap. Instead, we chose *sampling* - the positioning of randomly located points inside grid cells proportionate to the ratio of the volume of the cell and the total volume of the corresponding water mass. This reveals the water masses in a very natural way - as particles identified by color and shape and carried by ocean currents.

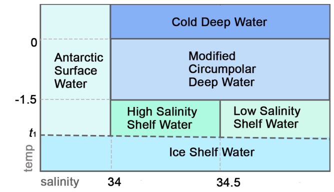

Figure 2: The classification of ocean water masses based on a salinity and temperature scale.

Artifact Based-Rendering ((ABR)) was created to enable intuitive associations and clear visual distinction of multiple variable data sets. Prior research identified three visual characteristics that enable distinguishable forms with in a crowded field. These are: the aspect ratio of the profile; the density of the texture; and angular verses curvilinear forms. Figure 1 demonstrates these concepts.

2 Process

The overall visualization work is divided into two asynchronous tasks: the input of raw simulation data and its transformation to renderable imagery and rendering. The first step is relatively slow, and depends on the time necessary to load the data from disk or, if running *in-situ*, from the simulation itself. Rendering is performed much more quickly, responding to input from the user either though mouse interaction or, if in VR, head motion.

We perform the first of these two tasks using Paraview, a well-known scientific visualization application. Paraview loads the data (or receives it directly from the simulation), transforms it *geometrically* using custom sampling code to produce samples of the water masses and pathlines representing current flow. Particle density and pathline seed points are user-definable parameters to this process.

Paraview then transmits this geometry to an instance of Artifact-Based Rendering (ABR) using a custom socket-based interface. ABR is a Unity application running on an external host with advanced graphics capability. ABR provides an interface enabling the user to associate geometry with visual properties, such as glyph type for samples and line type for particle traces. By using instancing for glyph shapes, ABR is capable of rendering many thousands of complex glyph shapes at sufficient interactive speeds to support virtual reality.

3 Conclusion

The visualization techniques and system described were developed by members of the visualization group at the University of Texas at Austin's Texas Advanced Computing Center working in close collaboration with ocean modelers and climate scientists at the Los Alamos National Laboratory.

Acknowledgments

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References

[1] G. Abram, F. Samsel, X. Petersen, M. R.and Asay-Davis, D. Comeau, and S. Price, "Antarctic water masses and ice shelves: Visualizing the physics," vol. 41, no. 1, p. 35–41, 2021.