15.13 A Hierarchical Volume Renderer Tool for the Atmospheric Sciences

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1. INTRODUCTION

Computational power continues to grow and subsequently modelers are carrying out simulations with increased temporal and spatial resolution. This in turn has resulted in increasingly larger volumes of data that need to be analyzed. Three dimensional visualization of this data is cumbersome because most software products were not designed to handle 10's of millions of grid zones per field. For example, Vis5D is a commonly used rendering tool in meteorology. While an excellent tool, the interactive surface rendering performance markedly degrades with larger data sets and thus the researcher often turns to two-dimensional visualization tools for interactive analysis. The Hierarchical Volume Renderer (HVR) is an alternative to surface rendering software and has been used to view three dimensional turbulence simulations with grids in excess of a billion zones. This interactive tool for creating single frames or animations has the potential to be valuable to both geoscience researchers and operational forecasters.

Collaborating with the Laboratory of Computational Science and Engineering at the University of Minnesota, we are developing an interface to couple HVR to atmospheric data sets, such as those from MM5 and the WRF model. HVR runs on ordinary Windows PCs using Open GL software rendering. The hierarchical nature of the software enables display of subjects closer to the viewer's location at high resolution, whereas subjects farther away are shown at lower resolution. This feature greatly reduces the computer resource requirements and permits truly interactive behavior for even billion zone volumes.

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2. TOOL DESCRIPTION

The HVR tool gains its efficiency through the use of hierarchical data files. The tool is not designed to read in model history files directly; so preliminary conversions are required to regrid and translate the data into a special hierarchical format. This process is repeated for each desired variable to visualize. The grid spacing within the HVR tool is uniform in all spatial dimensions, and vertical stretching, if desired, must be completed within the conversion process. The output from this process is the hierarchical volume file format, which is subsequently further described.

This hierarchical volume data format provides a single byte integer representation of the variable's data value for each uniform three-dimensional grid volume. Metadata then provides the scale reference for interpretation of this compressed data value to the original. With the one-byte limitation, volumes must be assigned a single value within the 256 bin range. A certain degree of finesse may be required to transform this limited range to highlight the desired features. This then marks the finest resolution representation of the variable within the grid. Next, the entire data set is again represented in a lower resolution set of bricks, averaging across 2x2x2 grid volume values from the finest representation. This coarser level of data is then even further reduced through subsequent similar iterations until the entire grid can be represented within a single eight brick chunk. These additional representations of the data set add minimal size (~20%) to the hierarchical volume data file relative to the byte representation alone. This block-tree hierarchy can then be utilized to efficiently render the variable.

Using the hierarchical volume data file, the HVR tool can be used to generate a representation of the variable in the grid volume. Using the hierarchical structure in the data file, variables in the grid which are close to the eye view point and within the pixel resolution of the display are displayed at peak resolution. Regions of the volume far from the view perspective, however, are represented at a coarser brick, allowing for the entire volume to be represented with an economical utilization of memory. Specific thresholds for display quality and size are fully adjustable, with better interactive performance as the display size and image quality are reduced. Similarly, the tool can directly render output at adjustable data quality and dimensions, such as for the generation of high quality animation sequences.

A number of different view perspectives and interactive exploration options are available. The entire data set can be viewed, or sub-regions within the data set can be isolated for exclusive examination. Interactive exploration can be achieved through several mouse controlled functional modes, such as track ball, spherical and translation. A near and far clipping plane can be used to further manipulate the view depth and perspective. The appearance of the displayed variable is adjustable through user defined colors and opacities across the full range of values using a graphical look up table.

Sophisticated animation series can also be constructed using the HVR tool. A series of key frames are specified, which can vary in view perspective and/or time, with a user specified number of interpolated frames in between. The tool will smoothly transition between multiple view perspectives and/or times based on user specified animation criteria. A viewing tool is also included with the package to view the raw movie output, which follows a continuous string of rgb file format frames.

There are several additional features available with the HVR tool in addition to the functions previously mentioned. One such example is the capability to generate stereo images for passive stereo displays. Additionally, some statistical analysis tools are readily available. Graphical probability density functions can be created for any variable, as can cross correlation representations between two different variables or times within a single variable. Given the hierarchical structure of the data format, the tool is also well adapted to cluster applications where data is distributed across an array of hosts.

There are, however, some present limitations with the practical application of this tool for atmospheric data set analysis, given the tool in its present form. First, only a single variable can be displayed simultaneously, which is impractical for direct vector and tensor representation. This limitation can be overcome somewhat by developing more complex data set descriptors which combine several variables, such as using vorticity to describe multi-dimensioned flow patterns. Also, the range of data can sometimes cause extrema to dominate the available 256 bins of range, potentially limiting the desired resolution in the range of interest. This can be corrected for subsequently, but can pose a problem in an automated system where the range of interest for a particular variable may vary. Finally, the hierarchical volume data file format is most effective when the transformed data set is a size power of two in all dimensions (e.g. 128x256x256), which generally requires a grid transformation of the original data set.

3. SAMPLE APPLICATIONS

The convective modeling group has worked with LCSE to develop several conversion tools for meso- to storm-scale numerical model output commonly employed within our research. These tools regrid and translate the native model output format into the compressed dump format previously described. Similar tools could easily be developed to adapt to other data set formats. We have subsequently applied the HVR tool to several atmospheric models, which to date includes the MM5 community model, the experimental WRF model as well as the NCOMMAS cloud model.

Demonstrations of renderings generated with HVR are offered to suggest some possible applications of this tool for the atmospheric science community. Fig. 1a and 1b provide sample visualizations of native and derived fields from an MM5 simulation of Hurricane Opal (1995) by Romine and Wilhelmson (2002). The former is a top-down view rendering of the cloudwater field and the latter is enstrophy. Further, the tool is also demonstrated for a numerical simulation of a supercell using the NCOMMAS cloud model (model and data courtesy Lou Wicker of NSSL). Fig. 1c is a rendering of the virtual cloudwater field from a side perspective. Fig. 1d is a top-down perspective of the rainwater field where near field clipping is employed to restrict the viewed volume area to the near surface layer. The HVR tool has also been adapted to visualize WRF model output (not shown).

4. CONCLUSIONS

HVR software provides a unique new tool for interactive investigation of model output and for developing sophisticated animations of native and/or derived fields. While not meant to serve as a stand alone all-purpose tool, this product adds additional dimensionality to the presently available suite of visualization utilities employed in the atmospheric sciences. It appears particularly well suited to visualizing large and complex data sets for gaining a qualitative understanding of the distribution of a native or derived variable. The Laboratory of Computational Science and Engineering at the University of Minnesota is continuing development along with expanding the functionality of the already robust capabilities of this tool, including porting HVR to a LINUX platform in the near future. We will continue our collaborative efforts to explore new applications for this versatile and efficient rendering tool. Demonstrations of some of its interactive capabilities along with animation sequences constructed via the tool will be shown at the conference.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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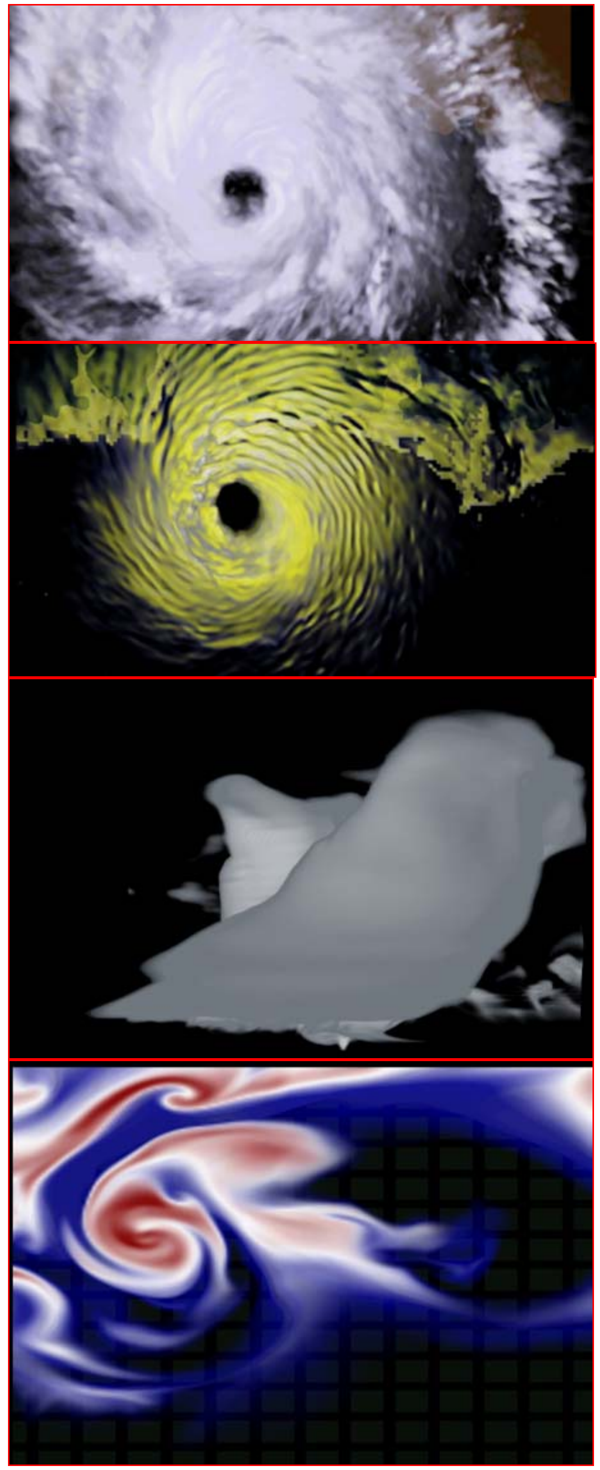

Fig.1. HVR renderings of (a) cloudwater (white) and (b) enstrophy (gray - weak to yellow - intense) hurricane simulation using MM5, and (c) virtual cloudwater (gray) and (d) rainwater (blue – light to red – intense) from a supercell simulation using the NCOMMAS cloud model.