Lossy Compression for Visualization of Atmospheric Data

Leigh Orf leigh.orf@ssec.wisc.edu and Dave Semeraro semeraro@tacc.utexas.edu

Texas Advanced Computing Center, University of Texas at Austin - tacc.utexas.edu

Abstract

- We utilize lossy compression as part of a strategy to reduce the size of visualization data for a thunderstorm simulation.
- A high resolution isotropic mesh was used in order to resolve the physics of the anvil region of the storm where the phenomenon of interest was located.
- High temporal resolution was required to resolve the transient phenomenon. This combined with higher spacial resolution greatly increased the amount of data used for analysis.

Data Reduction Strategy

The volume of data produced by the simulation was managed using lossy compression. The data reduction followed a three stage process outlined below.

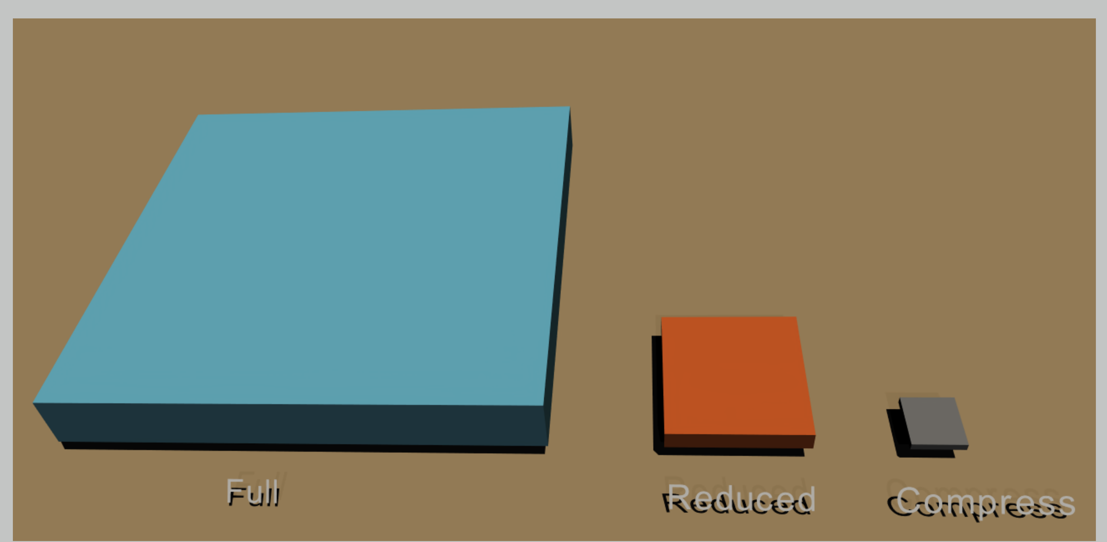
- Focus domain on area of interest. The region of the anvil of the storm downwind from the over shooting top.
  - 50 m cell size
  - 243 km x 241 km x 30 km ⇒ 68.2 km x 75 km x 10 km
  - 14 Billion Zones ⇒ 400 Million Zones
- Reduce number of 3D output variables Over a dozen ⇒ six

Vertical Wind	Horizontal Wind
Cloud Water	Cloud Ice
Temperature	Vorticity

- Lossy Compression. Compression ratio of approximately 20:1

The figure below illustrates the effect of the data reduction strategy. The full domain is represented by the block on the left. The second block represents the focused domain. The third block shows the amount by which the focused domain would have to be shrunk to achieve the reduction provided by lossy compression.

Figure: Relative Data sizes



Lossy Compression

- Lossless compression achieves reduced data size without loss of accuracy of the data. Lossy compression achieves higher compression ratios by allowing some loss of floating point accuracy.
- ZFP[1] is an open source C/C++ floating point compression library. Floating point precision is lost in the compression process. The algorithm is, usually, capable of far greater compression ratios than lossless methods.
- ZFP allows the user to specify the maximum amount of deviation the compressed data will have from the original floating point data. Specifying an accuracy parameter α for a variable insures that compressed values of that variable will differ from the original uncompressed 32 bit floating point value by no more than α. The values of α used for the variables in this work are shown in the table below.

Variable	α
Cloud ice	0.05 g/kg
Cloud water	0.003 g/kg
Temperature	0.1 $^{\circ}C$
Vorticity	0.01 sec^{-1}
Horizontal Wind	0.1 m/s
Vertical Component	0.1 m/s

- It has been determined by experiment [2] that accuracy parameters as high as 0.01 g/kg have no visible impact on the quality of isosurface visualization of cloud water. This value was used as an upper bound in this work. Compression ratios of 20:1 were achieved with no discernible degradation of the images. Research to determine more rigorous methods for choosing accuracy is ongoing.

Conclusion

The use of lossy compression allowed the investigation of the physics of the Above Anvil Cirrus Plume in high temporal an spatial resolution. Loss of floating point accuracy did not degrade the accuracy of the visualizations.

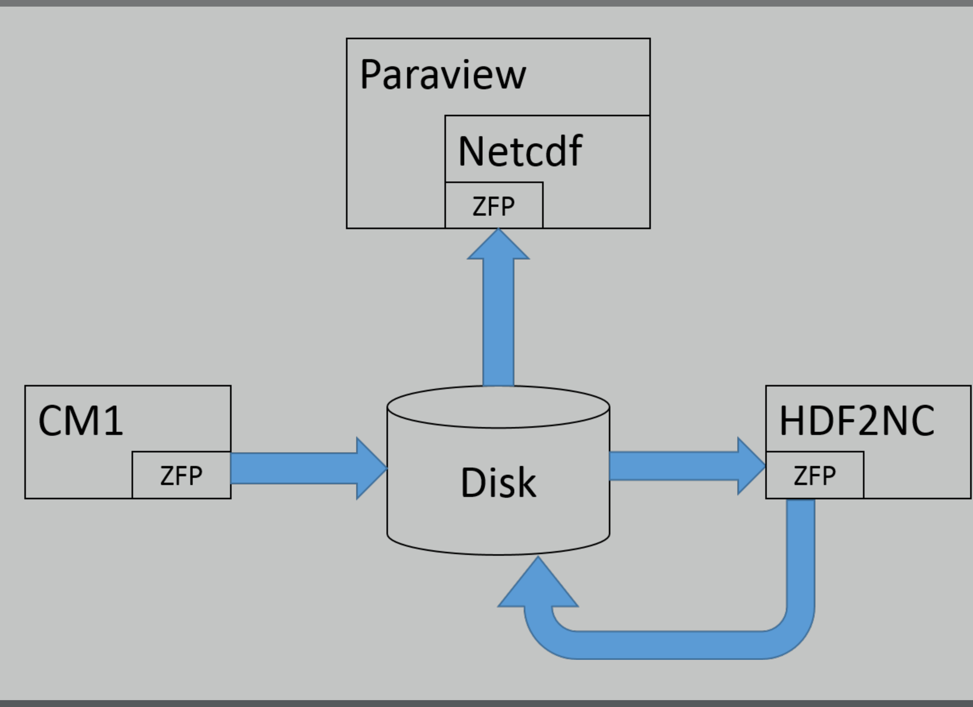
References

[1] Lindstrom, P., 2014: Fixed-Rate Compressed Floating-Point Arrays. IEEE Trans. Vis. Comput. Graph., 20, 2674–2683.

[2] Leigh Orf, 2017: The use of ZFP lossy compression in tornado-resolving thunderstorm simulations. AGU Fall Meeting, New Orleans, 11 Dec 2017. Invited poster IN11B-0039

Analysis Dataflow

- CM1 was used to simulate 1.5 hours of storm evolution on a 50 meter grid at $\frac{1}{3}$ second resolution.
- CM1 was modified to output data in compressed format using the ZFP library. This data is output as compressed HDF5 data. A utility was used to convert the ZFP compressed HDF5 data to compressed NetCDF format for input to the visualization software.
- A NetCDF ZFP plugin was used to allow the Paraview NetCDF reader to read the ZFP compressed NetCDF files without modification.



ParaView Visualization

The feature of interest in this investigation is called an Above Anvil Cirrus Plume. Analysis revealed the driving physics behind the formation of the plume is very similar to the hydraulic jump. The plume itself forms as a wave as high speed flow in the anvil moves into lower velocity air forcing the wave formation and the upward flow. The breaking wave formation was observed in animations of the cloud structure on top of the anvil. The images below, taken from the animation, show the wave represented in several ways. The wave structure appears in the center of each image.The bottom two images show cut away sectional views of the anvil.

Figure: Volume render of cloud ice

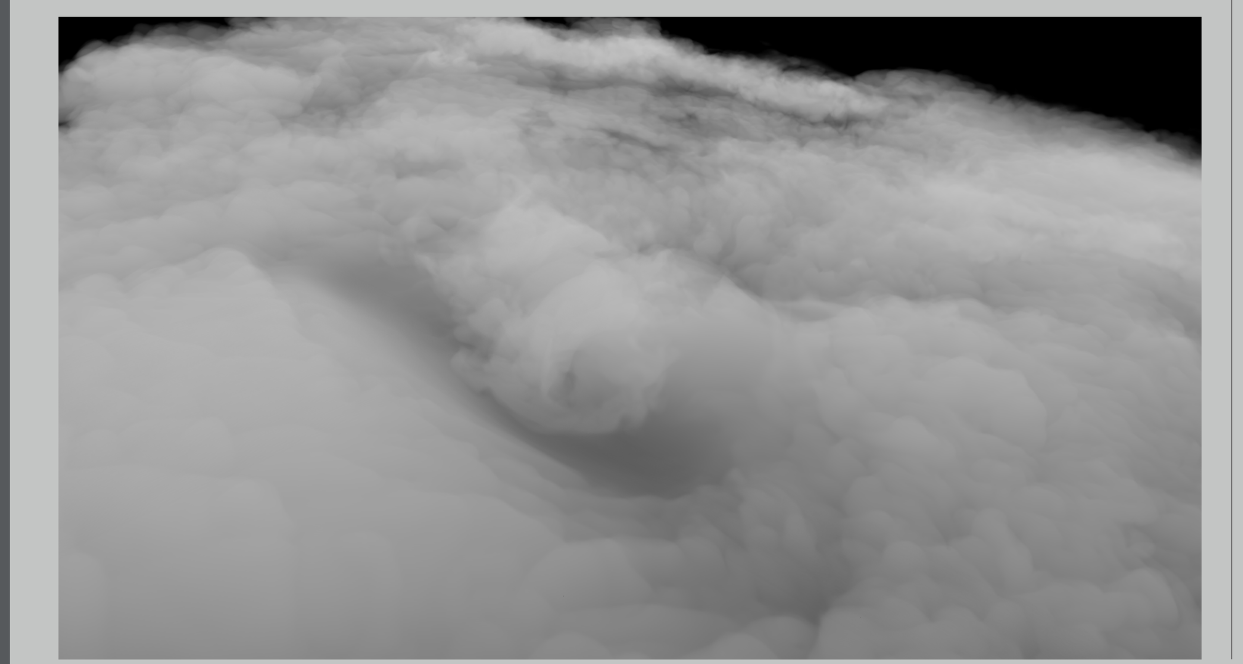


Figure: Isosurface Cloud ice. Value =0.01

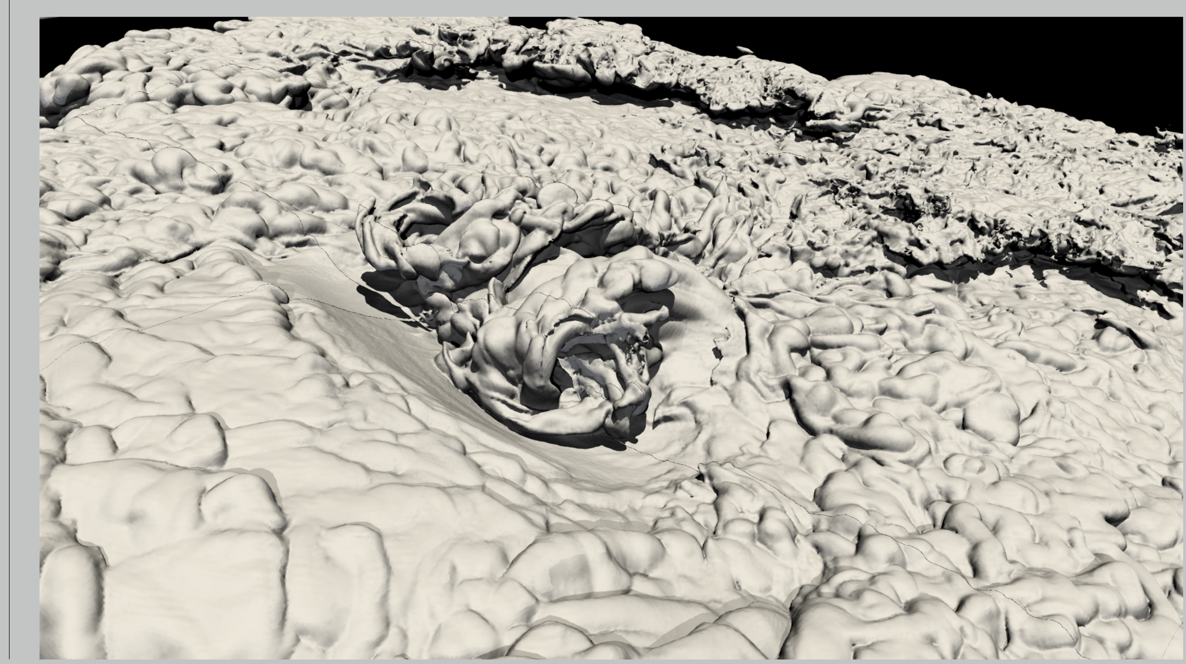


Figure: Ten Cloud ice contours

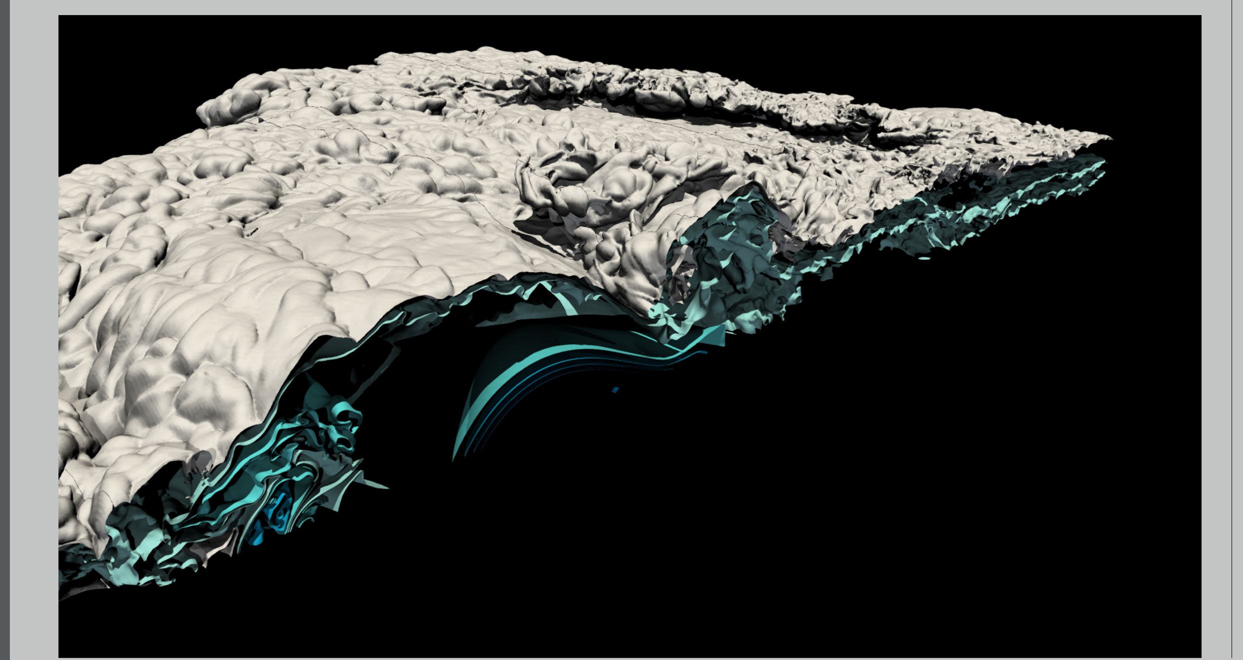


Figure: Cloud Ice and Horizontal Wind contours