Towards Petascale Simulation and Visualization of Devastating Tornadic Supercell Thunderstorms

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Outline

Understanding the most devastating tornadoes

- The strongest, longest-lived tornadoes (long-track EF5) are the least common, but produce the most devastating damage and significant loss of life
- There is a lack of published research involving the simulation of such tornadoes embedded within their parent storm

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HDF5 output and interface to model data

- 3D floating point arrays written on a per-node basis using serial HDF5 and buffering to memory before writing to disk
  - C API created to interface with native CM1 HDF5 output, allows easy conversion to other formats (e.g., netCDF)
  - VisIt plugin flexible enough to operate on full domain or any subset, and does its own domain decomposition unrelated to file geometry
- Domain-wide 2D floating point arrays of selected fields written utilizing pHDF5
  - 2D data is easy to visualize quickly and tells much of the storm's story without necessitating a full 3D visualization session

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Visualizing the storm

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  - This approach has been found to be practical, since the vast majority of our simulations do not produce the storms we wish to explore
  - I/O load was high and did increase wallclock time but not inordinately
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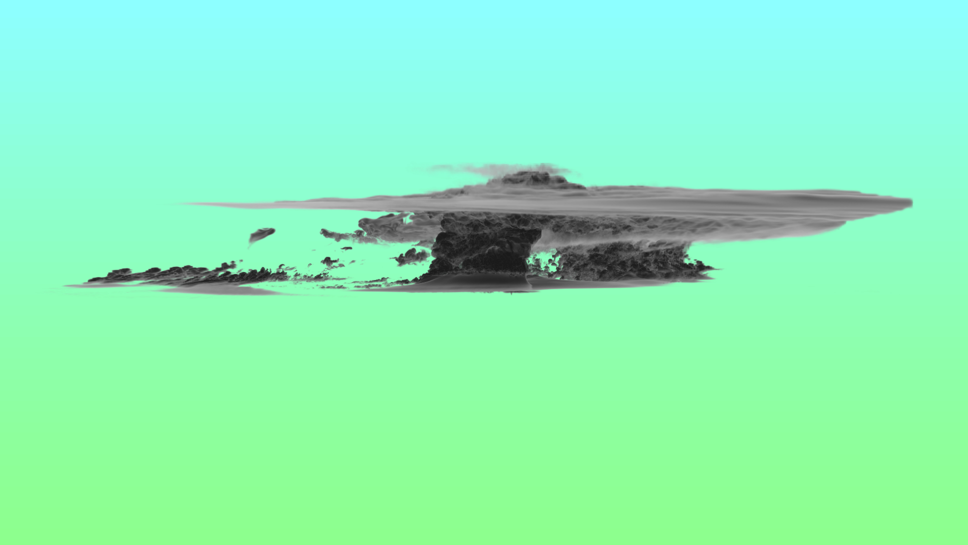
Far view of cloud field



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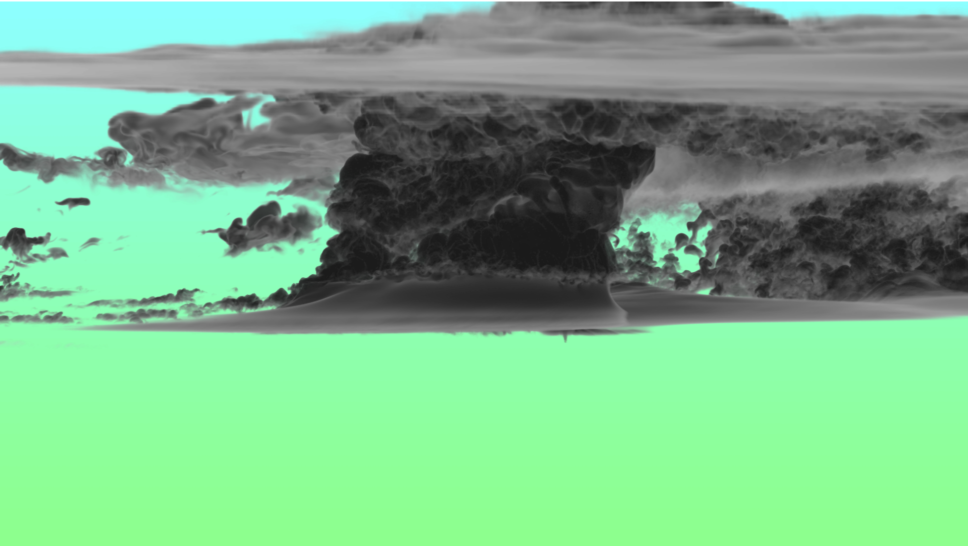

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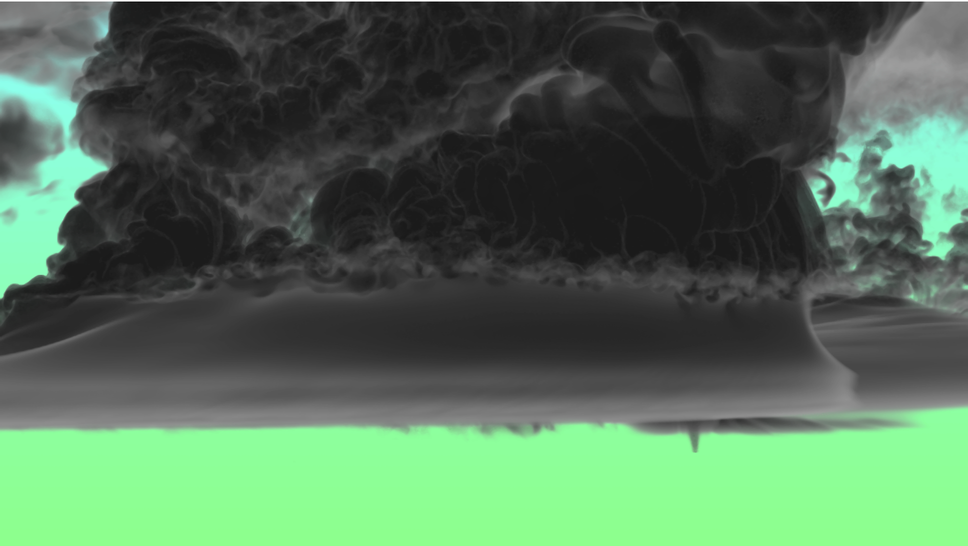
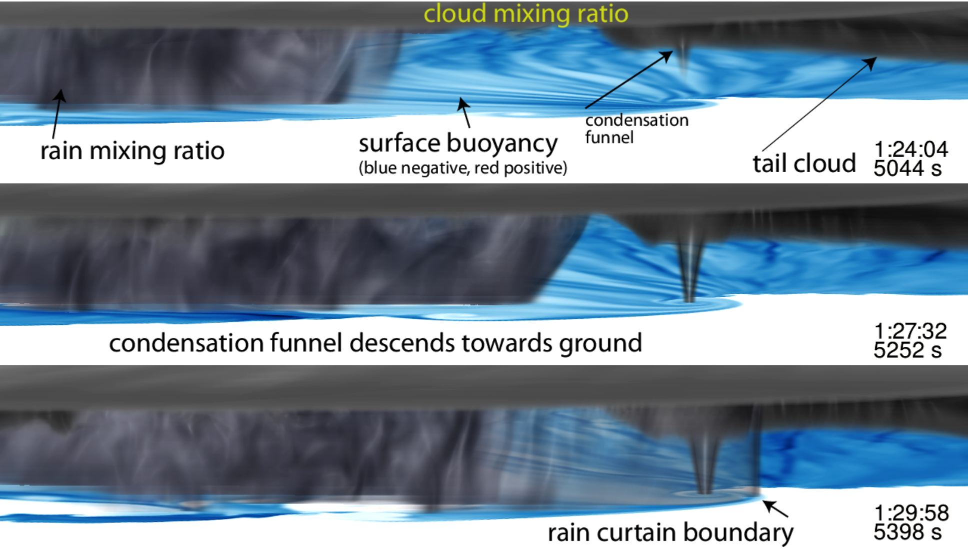


Near view of cloud/rain fields



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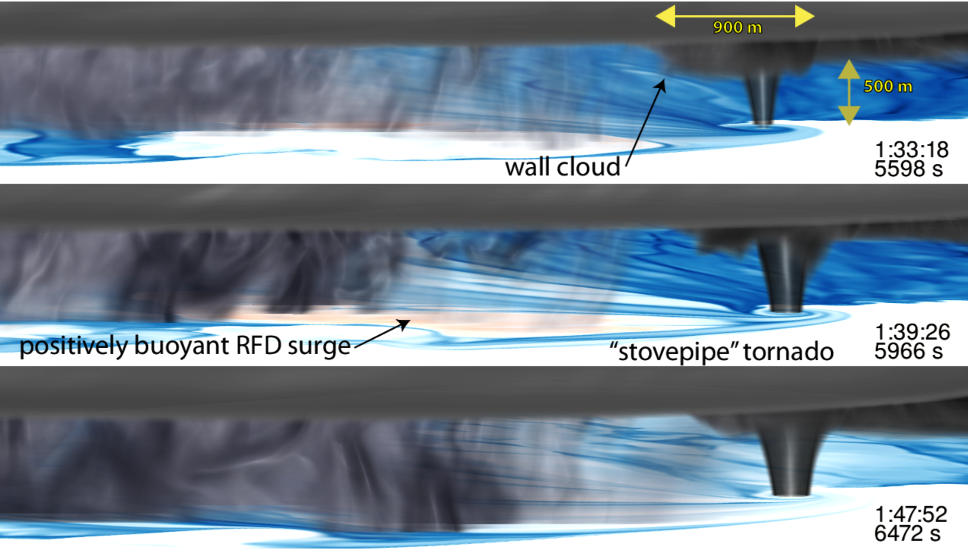

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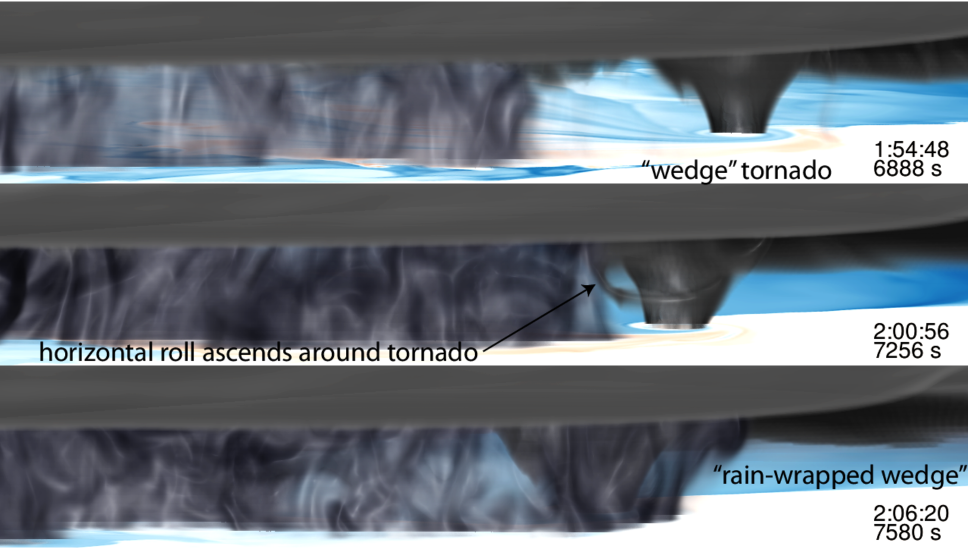
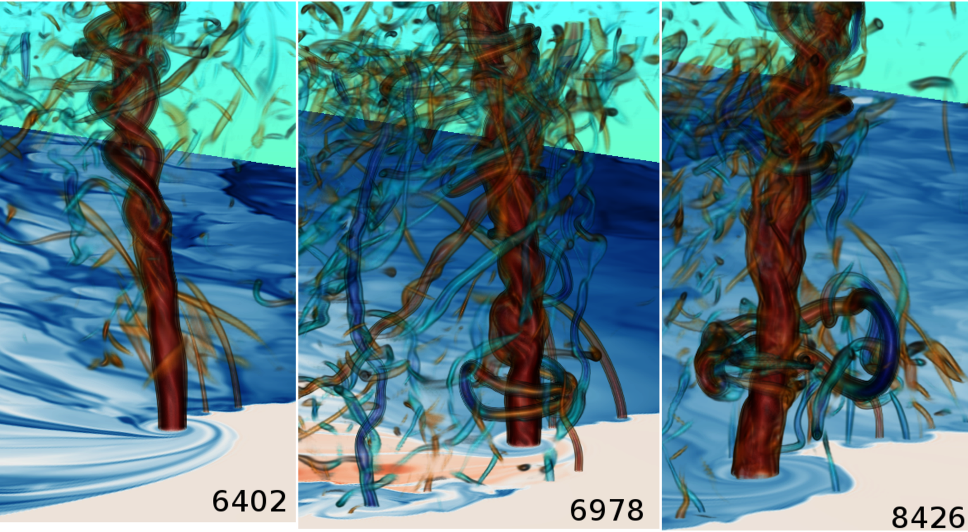


Near view of vorticity field



Issues with VisIt raycasting

- In order to achieve high quality imagery without artifacts, the "number of samples per ray" must be increased to 2000 or more
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- Each 1920x1080 frame took roughly 20-25 minutes to render, utilizing about 30 GB of memory
- Automation was achieved using the VisIt python interface
- Master python script created a bunch of python scripts, each of which was executed using
  `visit -nowin -cli -s [scriptXXX.py]`
- Shell script fired off 90 jobs, each of which rendered 40 frames
- Due to the way VisIt works, each job stays attached to the login node from which the job is executed. Many files are opened; ran into `ulimit -n` issues (too many files open)
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Animations

- Movies can be found at http://orf5.com/bw2014

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  - Rain gets caught in tornado due to lack of hydrometeor centrifuging
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Closing remarks

- A breakthrough simulation has been achieved - to the best of our knowledge, this is the first time a supercell producing long-track EF5 has been simulated
- The Blue Waters environment was crucial to the development, execution, data management, visualization, and post-processing (“end-to-end”)
- Existing tools are solid and now the real fun begins