Putting the Smoke into Smokeview

Recent Updates and Enhancements

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Fire and Evacuation Modeling
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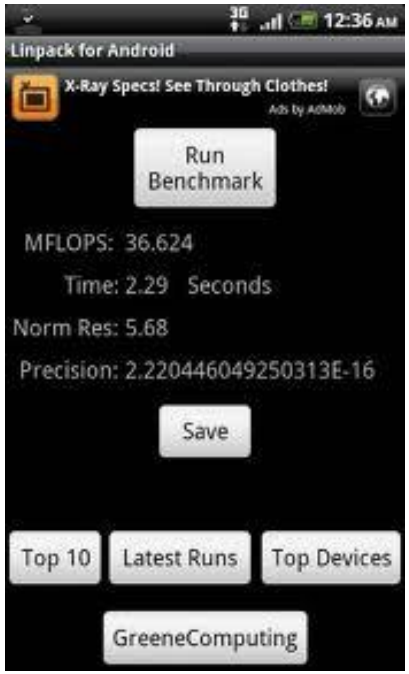
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Overview

- Improve algorithms for visualizing smoke
- Exploit the GPU (video card) to perform computations more efficiently
- Make better use of color for examining FDS results

Problem or Opportunity?

What do we do with all the numbers?
What can we do with all the numbers!



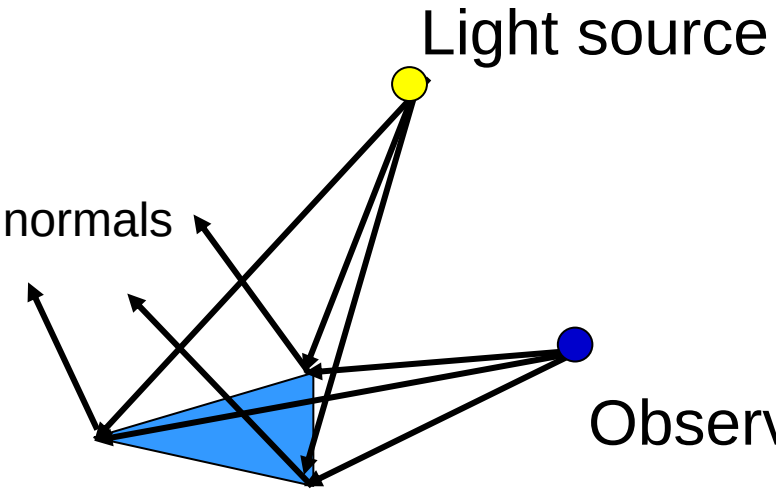
Cray 1
12 Mflops

Android smart phone
36 Mflops

NIST Fire Cluster
2240 Gflops

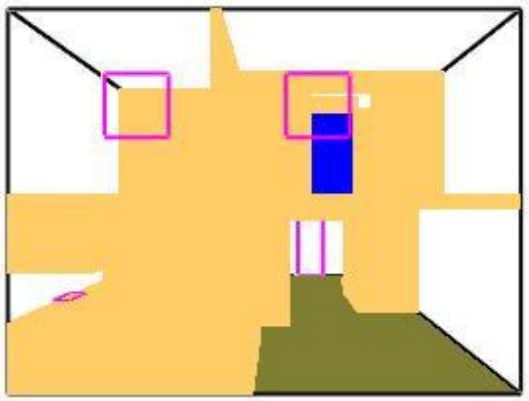
186,000 speedup!!

Lighting/Shading

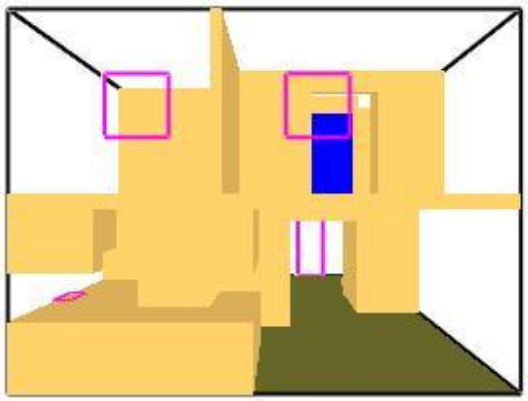


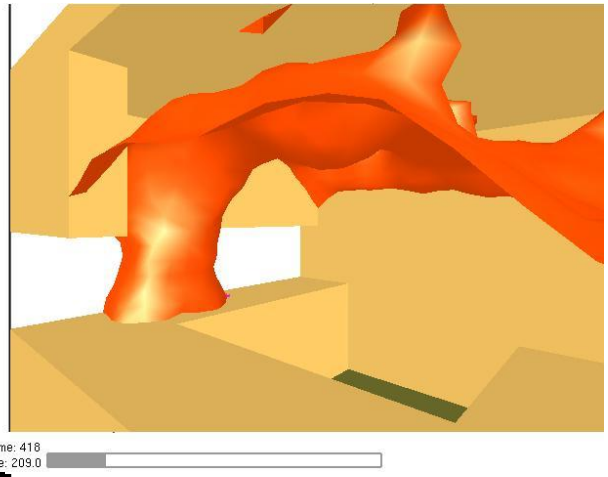
Lighting

- Adds more realism to 3D scenes
- Computed using normal vectors light source direction vectors



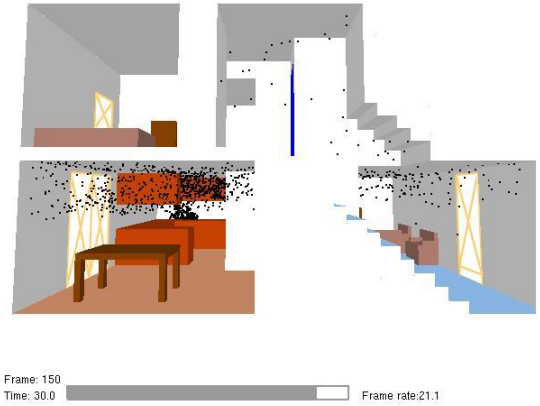
Unlit



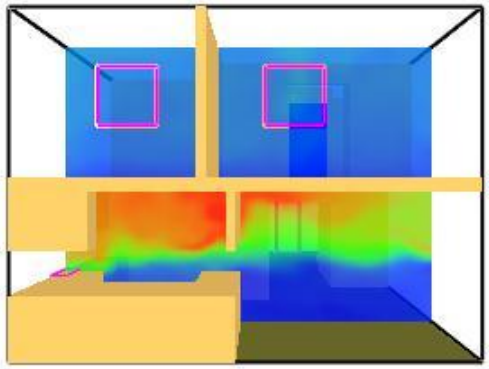


Lit

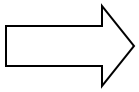
Evolution of Smoke Visualization Methods

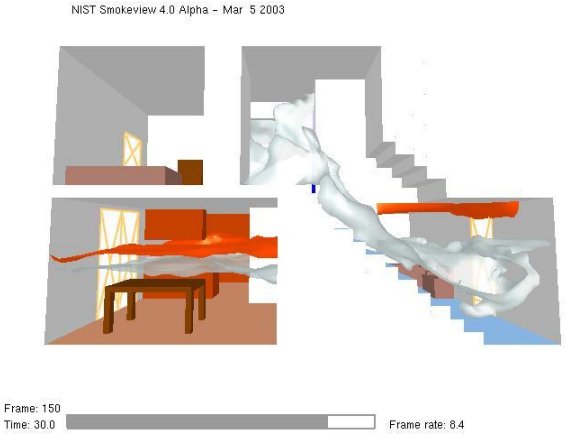


tracer particles

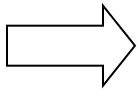


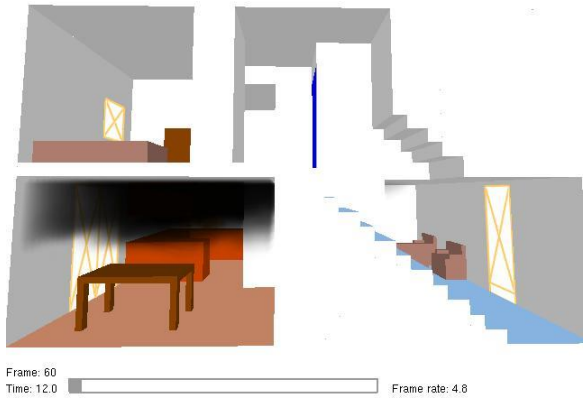
2d contours





3d contours





realistic/3D smoke

Light/Smoke interactions

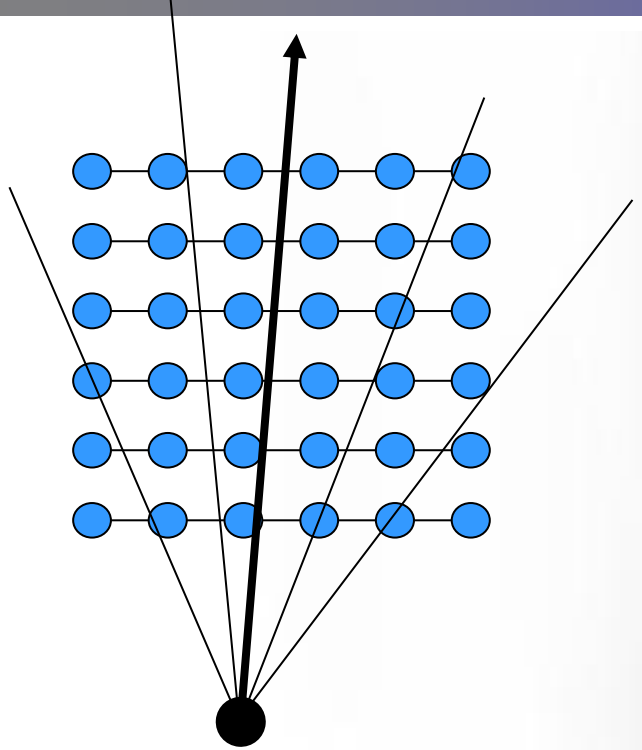
absorption out-scattering emission in-scattering

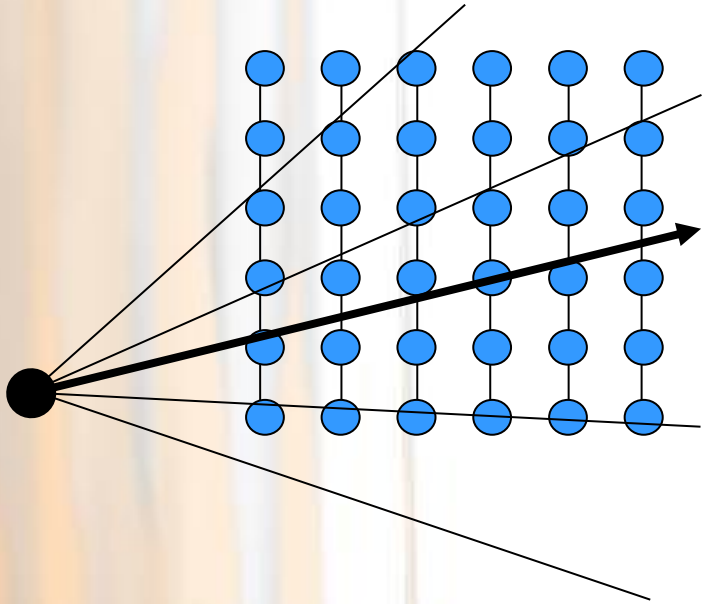
Volume Rendering Equation – Radiation Transport Equation

$$(\omega \cdot \nabla) L(x,\omega) = -\sigma_a(x) L(x,\omega) - \sigma_s(x) L(x,\omega) + \sigma_a(x) L_e(x,\omega) + \sigma_s(x) \int_{4\pi} p(x,\omega,\omega') L_i(x,\omega') d\omega'$$

$$\frac{dL(x)}{dx} = -\sigma_t(x) L(x) \quad \Longrightarrow \quad \frac{L(x)}{L_0} = e^{-\sigma_t x}$$

Beer's law

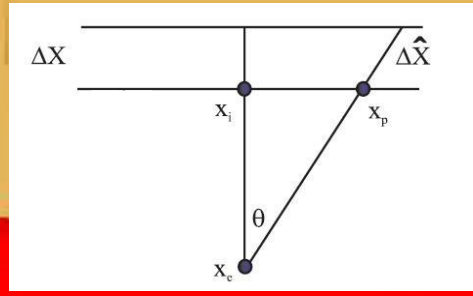




Beer's law
$I/I_0=\exp(-k_s\Delta x)$

Orient planes to be most perpendicular to line of sight

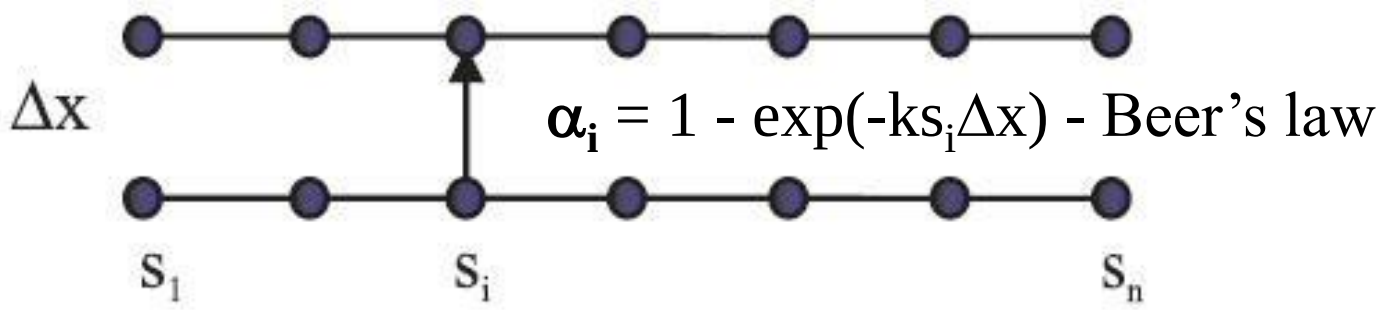
ΔX



3D Smoke

Δx	distance between adjacent grid planes
S_i	soot density
α_i	opacity

- FDS computes α for each grid node
- Smokeview combines α's using the video card



3D Smoke

Correcting α

FDS computed:

$$\alpha = 1 - \exp(-ks\Delta x)$$

Smokeview computed:

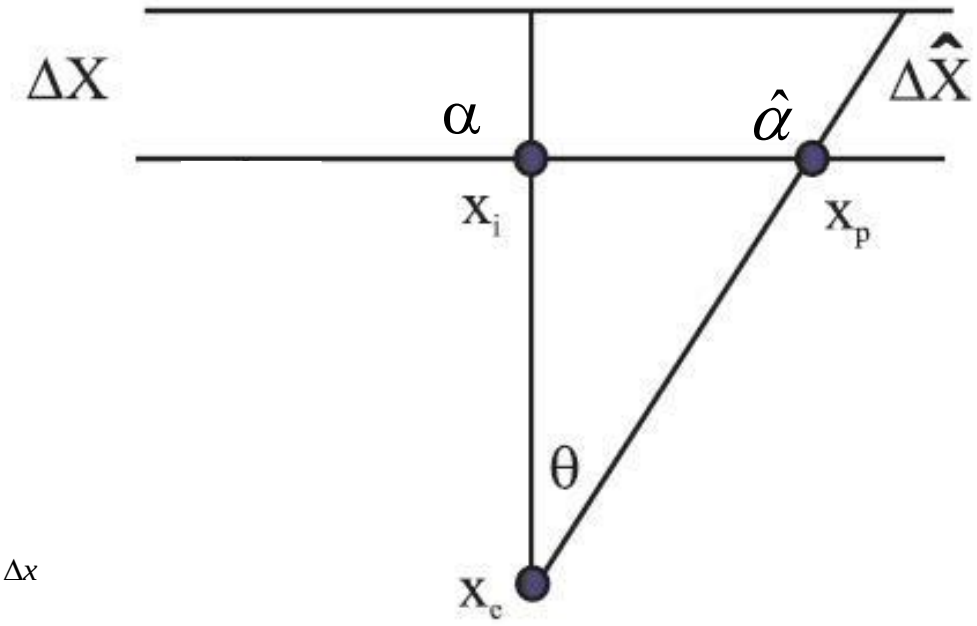
$$\hat{\alpha} = 1 - \exp(-ks\Delta \hat{x})$$

Solve for exp(-ks):

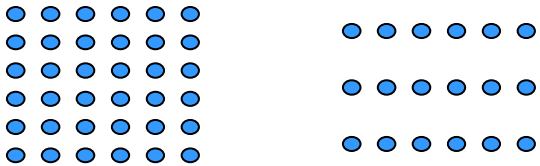
$$(1-\hat{\alpha})^{1/\Delta\hat{x}} = \exp(-ks) = (1-\alpha)^{1/\Delta x}$$

Solve for $\hat{\alpha}$

$$\boxed{\hat{\alpha} = 1 - (1-\alpha)^{\Delta\hat{x}/\Delta x}}$$



Skipping Frames



$$\Delta\hat{X}/\Delta X = 2 \qquad \hat{\alpha} = 2\alpha - \alpha^2$$

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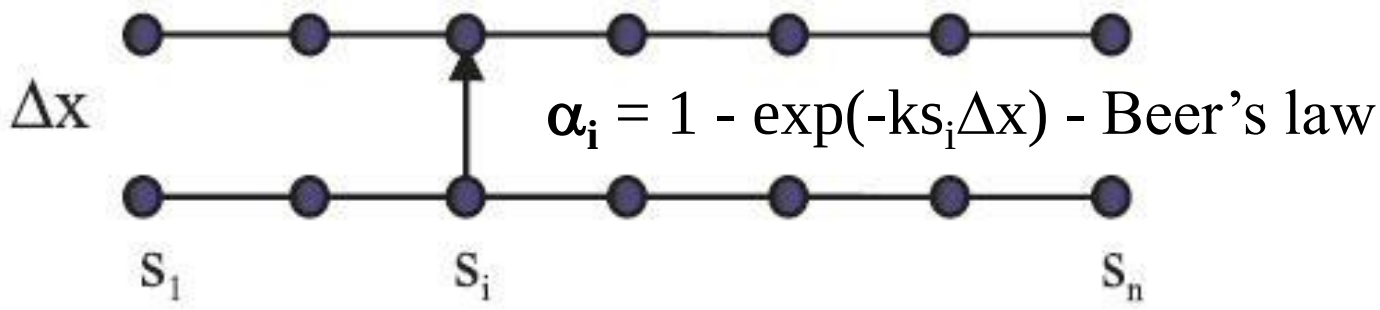
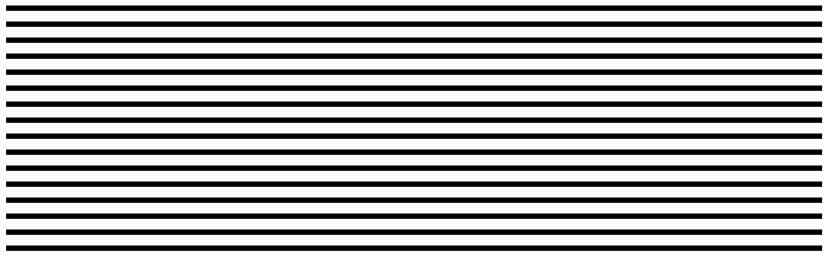
3D Smoke

Problems can occur for large grids (ΔX small)



More refined grids ➔ smaller Δx ➔ smaller α ➔ increased error



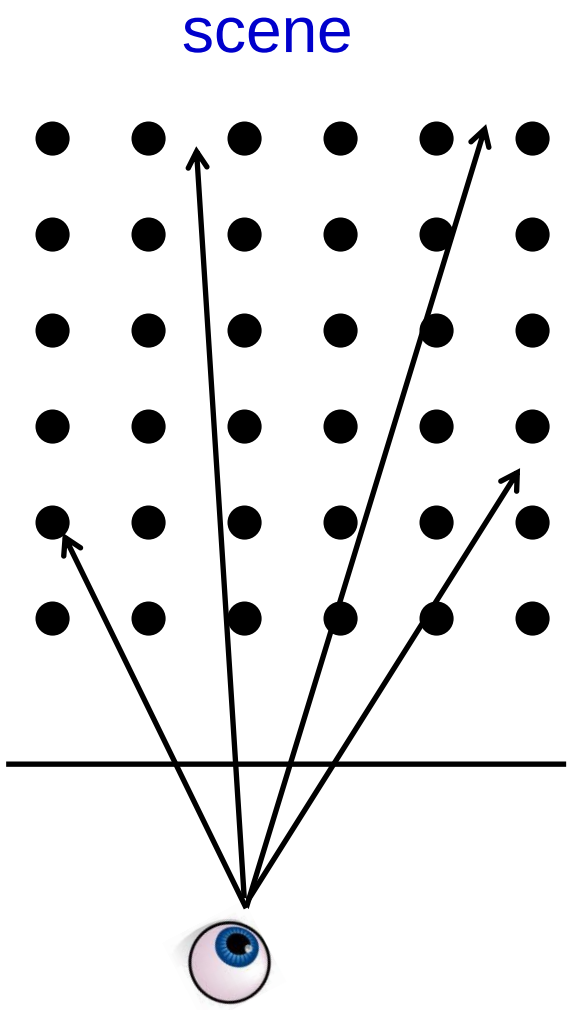
3D Smoke

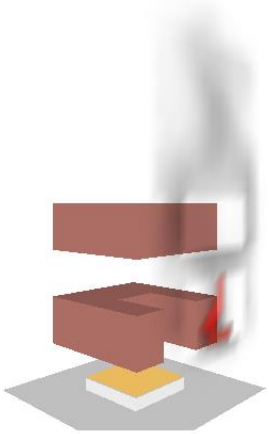
Solution: Integrate across entire mesh rather than one grid slice

$$\alpha = 1 - e^{-\int ksdx}$$

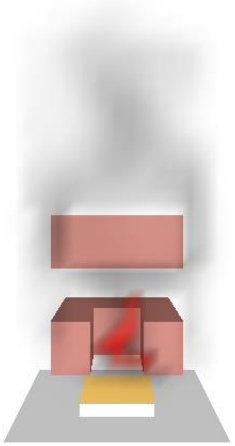
- Use 3D slice files (full precision)
- Compute a line integral for each pixel using the video card (GPU)

- Color – use a transfer function to map temperature to color
- Opacity - integrate soot densities

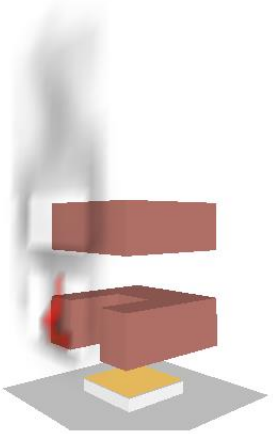




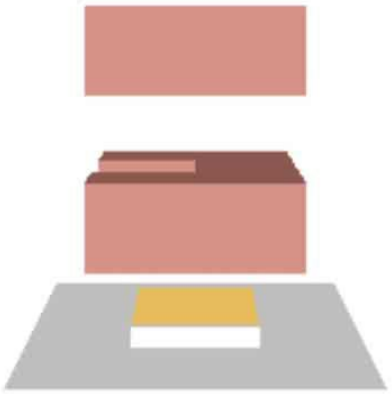
Time: 14.8



Time: 14.8

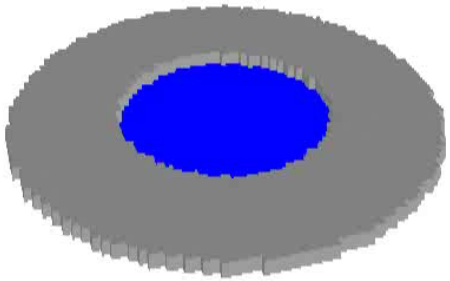


Time: 14.8



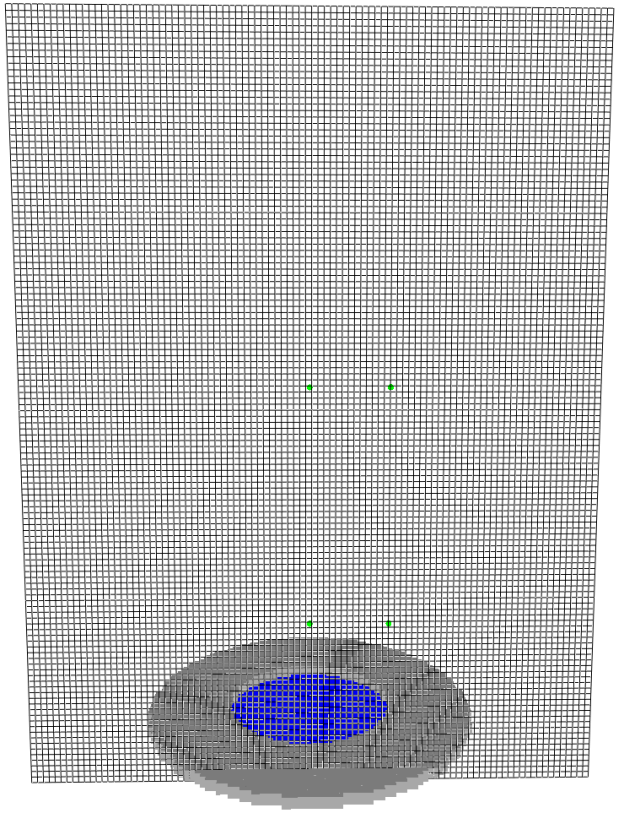
Time: 0.0

3D Smoke



Time: 0.05

96x96x64
16 meshes
300 frames
21 GB
1-3 minutes load time



Challenges

- Memory
- Computation
- Data load time

Solution Approaches

- compress data
- use the video card (GPU)
- load data in the background (while it is being displayed)
- load data as it is required
- Treat Smokeview more like FDS

Using the New Method

- Add following keyword to the &DUMP line

  DT_SL3D=xxx

  (where xxx is desired output time step)

- Add following &SLCF lines to case

  &SLCF XB=…, QUANTITY='TEMPERATURE‘, CELL_CENTERED=.TRUE. /

  &SLCF XB=…, QUANTITY='DENSITY',SPEC_ID='SOOT',CELL_CENTERED=.TRUE. /

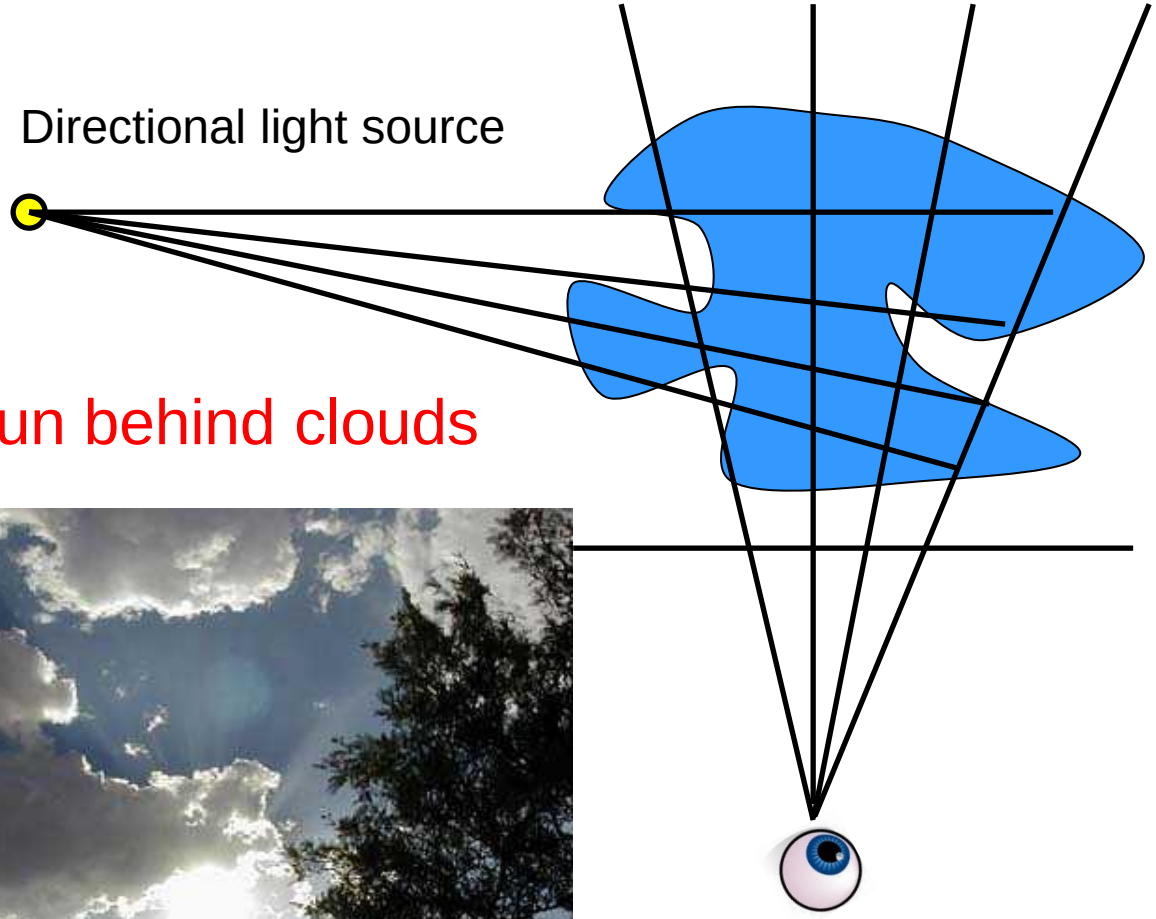
  where “…” are the bounds for your simulation domain

- In Smokeview load file type labeled “3D smoke (volume rendered)”
- In the repository look at cases in Verification/Visualization: plume5c, mplume8, vis_test1, vis_test2 or vis_test3

Future Possibilities

Include more terms in the Radiation Transport Equation

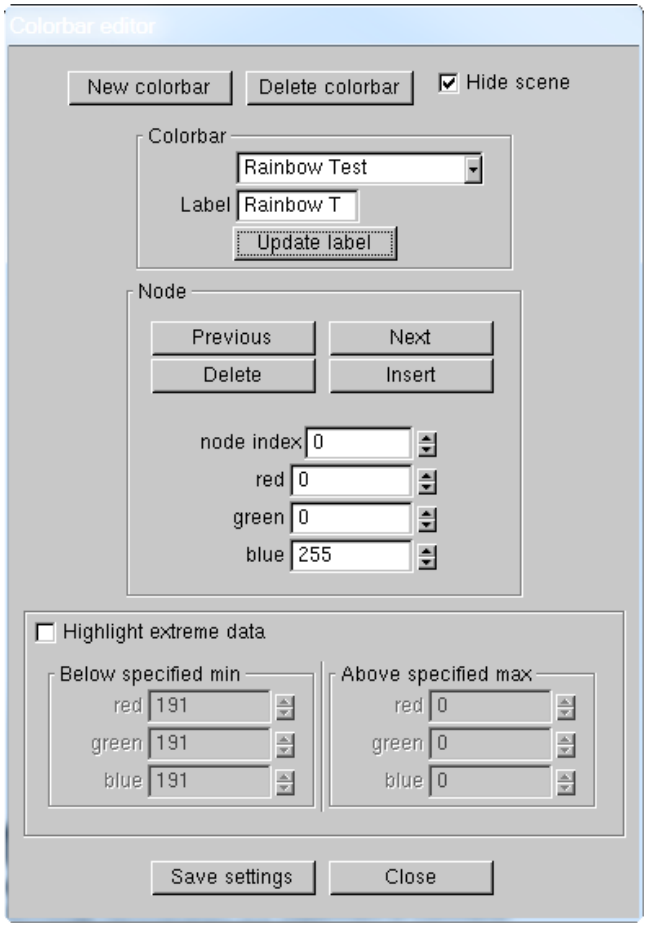
$$(\omega \cdot \nabla) L(x,\omega) = -\sigma_a(x) L(x,\omega) - \sigma_s(x) L(x,\omega) + \sigma_a(x) L_e(x,\omega) + \sigma_s(x) \int_{4\pi} p(x,\omega,\omega') L_i(x,\omega') d\omega'$$

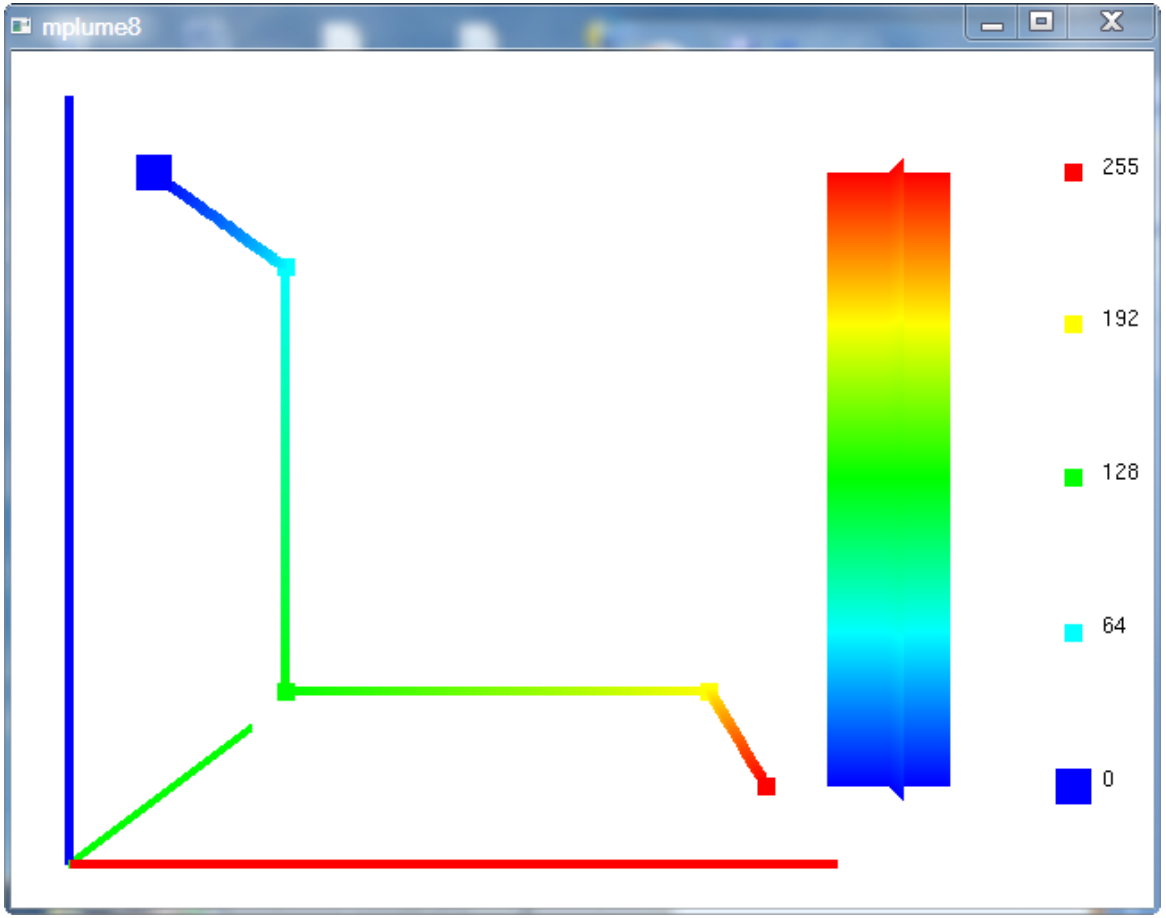


Sun behind clouds

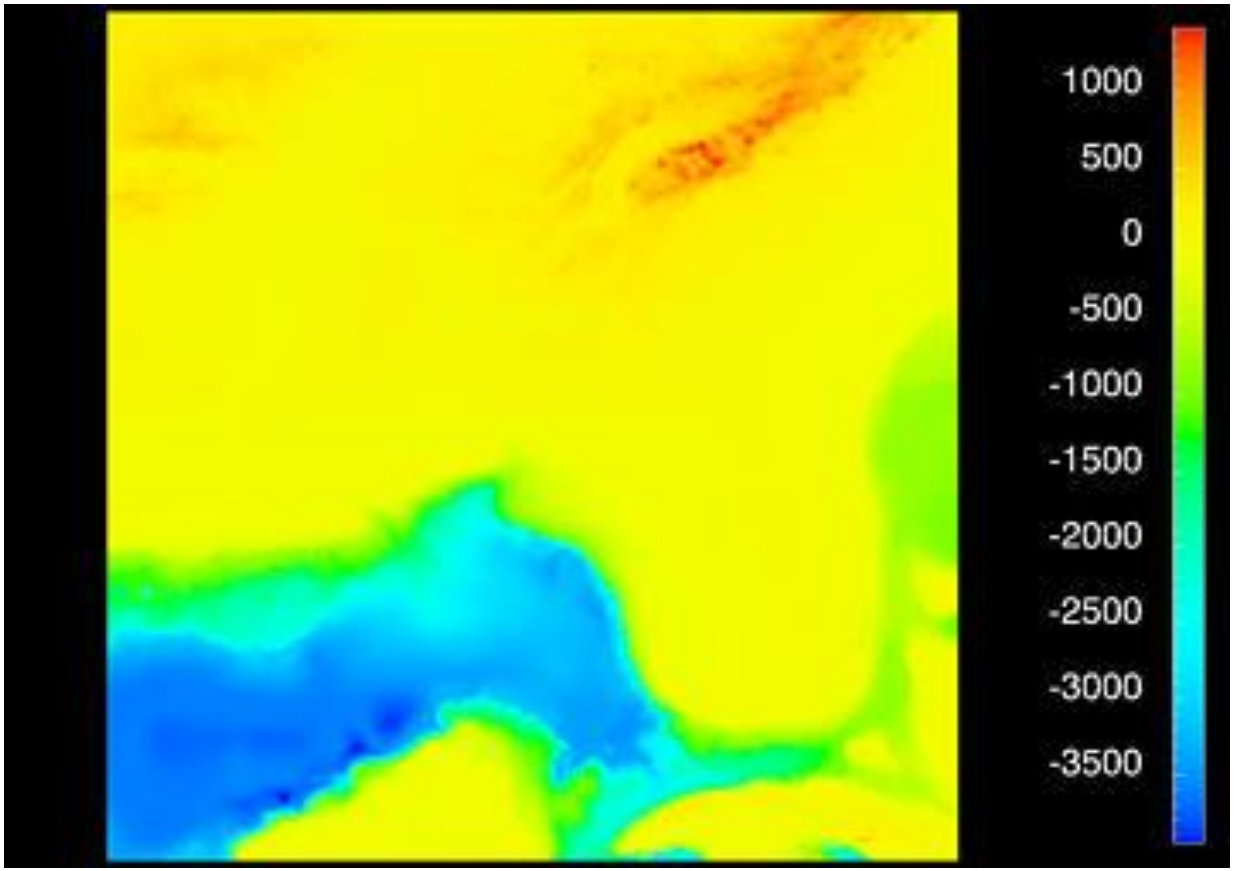
Diffuse/Ambient Light

Coloring Data

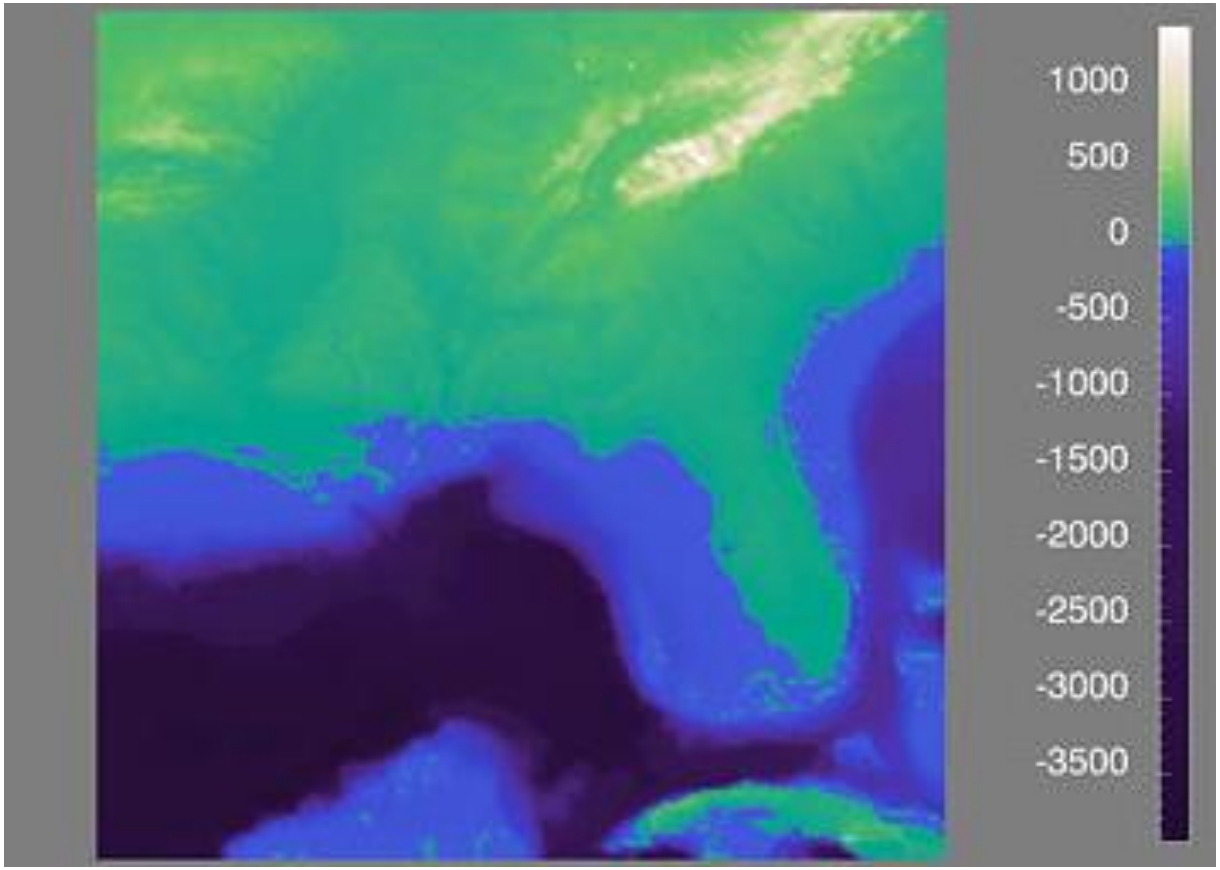




Rainbow Colorbar



Discontinous Colorbar



Summary

- Improve algorithms for visualizing smoke
- Exploit the GPU (video card) to perform computations more efficiently
- Make better use of color to examine FDS data

New Smokeview Capabilities

- New more flexible method for visualizing smoke
- Large cases (and small) may be visualized in “batch” mode one frame at a time
- Smokeview may be run remotely (using Linux command Xvfb)
- Smoke may be visualized immediately while the data is loading
- Smoke may be colored arbitrarily with user specified colorbars