NIST Special Publication 1017-3

Smokeview (Version 5) - A Tool for Visualizing Fire Dynamics Simulation Data Volume III: Verification Guide

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National Institute of
Standards and Technology
U.S. Department of Commerce

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Volume III: Verification Guide

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September 2009
SVNRepository Revision : 5224

U.S. Department of Commerce
Gary Locke, Secretary

National Institute of Standards and Technology
Patrick Gallagher, Acting Director

National Institute of Standards and Technology Special Publication 1017-3
Natl. Inst. Stand. Technol. Spec. Publ. 1017-3, 69 pages (September 2009)
CODEN: NSPUE2

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 2009

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov – Phone: (202) 512-1800 – Fax: (202) 512-2250
Mail: Stop SSOP, Washington, DC 20402-0001

Preface

Smokeview is a software tool designed to visualize numerical calculations generated by fire models such as the Fire Dynamics Simulator (FDS), a computational fluid dynamics (CFD) model of fire-driven fluid flow or the Consolidated Fire and Smokeview Transport (CFAST) model, a zone fire model. This Guide is Volume 3 of the Smokeview Reference Guides. This guide presents a series of images derived from FDS and Smokeview. The intent is to to verify that the algorithms used by Smokeview for visualizing data are implemented correctly. These images are generated automatically through the use of scripts by first running FDS on a series of input cases and then running Smokeview, again using a set of scripts. The correctness of Smokeview may then be verified more easily as FDS and Smokeview are updated since the reference figures in this document may be generated simply and automatically.

Smokeview and associated documentation for Windows, Linux and Mac/OSX may be downloaded from http://fire.nist.gov/fds .

About the Author

Glenn Forney is a computer scientist at the Building and Fire Research Laboratory (BFRL) of NIST. He received a bachelors of science degree in mathematics from Salisbury State College in 1978 and a master of science and a doctorate in mathematics at Clemson University in 1980 and 1984. He joined the NIST staff in 1986 (then the National Bureau of Standards) and has since worked on developing tools that provide a better understanding of fire phenomena, most notably Smokeview, a software tool for visualizing Fire Dynamics Simulation data.

Disclaimer

The US Department of Commerce makes no warranty, expressed or implied, to users of Smokeview, and accepts no responsibility for its use. Users of Smokeview assume sole responsibility under Federal law for determining the appropriateness of its use in any particular application; for any conclusions drawn from the results of its use; and for any actions taken or not taken as a result of analysis performed using this tools.

Smokeview and the companion program FDS is intended for use only by those competent in the fields of fluid dynamics, thermodynamics, combustion, and heat transfer, and is intended only to supplement the informed judgment of the qualified user. These software packages may or may not have predictive capability when applied to a specific set of factual circumstances. Lack of accurate predictions could lead to erroneous conclusions with regard to fire safety. All results should be evaluated by an informed user.

Throughout this document, the mention of computer hardware or commercial software does not constitute endorsement by NIST, nor does it indicate that the products are necessarily those best suited for the intended purpose.

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Chapter 1

Overview

Smokeview is a scientific software tool designed to visualize numerical predictions generated by fire models such as the Fire Dynamics Simulator (FDS), a computational fluid dynamics (CFD) model of fire-driven fluid flow [1, 2] or the Consolidate Fire and Smoke Transport (CFAST) model, a zone model of compartment fire phenomena [3]. The feature set and user interface for Smokeview is complex making it difficult to adequately test all of its features manually. A scripting capability has been added to Smokeview to solve this problem. Many of Smokeview's features may now be run without user intervention through the use of scripts. A script is simply a text file containing one or more commands. Smokeview when *requested* by the user reads in this script and performs the actions listed. Some of these actions are loading data files, setting view points, setting times and most importantly rendering images. By designing a set of scenarios and corresponding images that demonstrate Smokeview's feature set, one may test Smokeview simply by 1) running one master batch file that generates all of the images of this document and 2) examining these images to ensure that Smokeview is working as expected.

This document then verifies that various Smokeview features are working as intended by presenting a series of FDS simulation results in the form of Smokeview images. These images are generated using the various visualization features of Smokeview such as tracer particles, 2D or 3D contours, or realistic smoke.

Verification in the context of Smokeview is a process to check the correctness of the visualization. Verification does not imply that the underlying data is correct, only that the data is presented or visualized correctly. A separate Guide [4] documents verification for FDS. One set of scripts is used to run FDS cases and a second set of scripts is used by Smokeview to generate images. The verification process then becomes much easier to accomplish since the use of scripts (*i.e.* a non manual methods) guarantees that consistent figures (same view points, same time points, same data files loaded *etc.*) are produced as new versions of this verification document are generated using updated version of FDS and/or Smokeview. Another way of looking at this verification process is to consider this document and the FDS verification document [4] as being a *live* (not a static) document, easily updated as algorithms in FDS and/or Smokeview are enhanced and improved.

Smokeview has several limitations that need to be addressed. The 32 bit[1] version of Smokeview can only allocate or use around 3GB of memory. Larger cases can be visualized with the 64 bit version of Smokeview but the time required to load large data files makes viewing these types of cases slow and tedious. The program smokezip exists in order to compress FDS generated data files making viewing large files more practical. A second limitation involves the use of color to display volumetric or 3D smoke/fire data. The color is intended to represent where the heat release per unit volume data (*ie* the fire) is located. The color itself is not what the fire actually looks like. 3D smoke is visualized assuming surfaces are lit uniformly and obscured by varying thicknesses of smoke. The 3D smoke visualization does not take into

[1] The term 32 bit refers to the number of bits used to address memory.

account, for example, external lighting such as man made lights within the scene or light generated by the fire. The opacity model used to draw the 3D smoke assumes a particular wavelength of visible light. Smokeview cannot now visualize FDS generated data at other wavelengths (such as infrared).

Details on setting up and running FDS cases may be found in the FDS User's Guide [2]. Details on visualizing FDS simulated data using Smokeview may be found in the Smokeview User's Guide [5]. Details on some of the technical aspects used to implement algorithms in Smokeview may be found in the Smokeview Technical Guide [6].

The FDS version used to run the cases illustrated in this document is

```
Fire Dynamics Simulator

Version: 5.4.3; MPI Disabled; OpenMP Disabled
SVN Revision Number: 5210
Compile Date: Thu, 03 Dec 2009

Consult FDS Users Guide Chapter, Running FDS, for further instructions.

Hit Enter to Escape...
```

The Smokeview version used to generate the verification figures in this document is

```
Texture directory: c:\program files\fds\fds5\bin\textures

Smokeview 5.4.8 - Dec  3 2009

Version: 5.4.8
Smokeview (32 bit) Revision Number: 5220
Compile Date: Dec  3 2009
Platform: WIN32  (Intel C/C++)
```

FDS generated data is presumed to be correct. FDS has its own set of verification cases to test the correctness of the data. The purpose of the cases used here is to confirm that data is drawn or visualized correctly. In particular these cases confirm that correct files are loaded, data is scaled and drawn correctly, geometry is drawn correctly *etc.* Three types of verification cases are presented. The first set are the most important. Those cases verify that data is drawn correctly. The second set of cases verify that various geometric elements are drawn correctly and the third set verifies that the various options and underlying features are implemented and perform properly.

The FDS input files used for the verification cases are documented in Appendix A. The Smokeview scripts used to generate the verification figures are documented in Appendix B. Note that these input files and scripts are located in the FDS svn repository. In fact, the entries in the appendices are included directly from the repository, and will therefore be up to date as this document is regenerated.

Chapter 2

Data File Tests

The tests in this chapter verify whether visualization types such as surface contours (boundary files), isosurfaces, particles, slice files, 3D smoke files, PLOT3D files and fire lines (for WUI simulations) are working as intended. These verifications use the FDS input files `plume5c.fds` (see Appendix A.1) and `fireline.fds` (see Appendix A.2) to generate the simulation data. The case, `plume5c.fds`, models a simple fire plume with two blockages. The upper blockage is initialized to 600 °C. The lower blockage is initialized to 20 °C. The gas phase is initialized to 600 °C within an interior region colored blue as illustrated in Figure 2.1 and 20 °C everywhere else. This is done in order to verify that a known temperature is converted to the proper color (as shown in the colorbar). The `fireline.fds` test case is a terrain test case. The center of the case has a *hill*. The fire line data displayed conforms to this hill.

The verification figures are generated automatically using the Smokeview script files `plume5c.ssf` (see Appendix B.1) and `fireline.ssf` (see Appendix B.2). The use of scripting allows the figures and hence this document to be updated easily as changes are made in FDS, Smokeview or the FDS input data files. This allows the verification process to be ongoing.

2.1 Surface contours (Boundary Files)

Figure 2.2 presents images verifying the display of surface contours or boundary file data. A series of boundary file images are drawn at 0.0 s, 10.0 s and 30.0 s seconds. The temperature of the upper obstacle is initialized to 600 °C hence the red colors for the $t = 0.0$ s images. The first column of images colors data at cell nodes using temperatures averaged at surrounding cell centers. The second column of images colors data using data values at cell centers. The FDS input file for this test is `plume5c.fds`. The images for this test were created automatically by running the smokeview script, `plume5c.ssf`.

2.2 Iso-surfaces

An isosurface is a surface in 3-D space that defines constant values of a dependent variable. Figures 2.3 and 2.4 present images verifying the display of isosurfaces. A series of temperature isosurfaces are drawn at 0.0 s, 10.0 s and 30.0 s. A portion of the interior gas temperature is initialized to 600.0 °C hence the rectangular block that appears in the $t = 0.0$ s images. The first column in Figure 2.3 presents the iso-surface using points. The second column presents the iso-surface using triangulated outlines. The first column in Figure 2.4 presents the iso-surface using a solid surface. The second column also presents the iso-surface using a solid surface but also includes normal vectors. The FDS input file for this test is `plume5c.fds`. The images for this test were created automatically by running the smokeview script, `plume5c.ssf`.

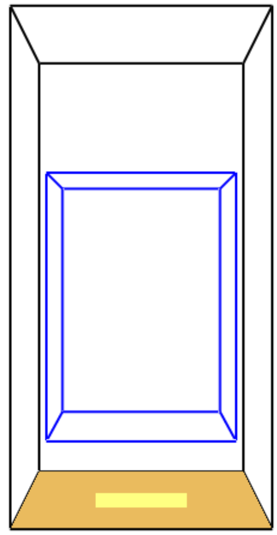


Figure 2.1: The temperatures in the plume5c.fds case are initialized to 600 °C in the region outlined in blue.

2.2.1 Sensitivity Analysis

Given that data used to generate an isosurface has uncertainty, an important question to consider is how sensitive is the isosurface location to uncertainty in the data used to define it? Figure 2.5 shows a portion of an iso-surface, $f(x,y,z) = T_m$, passing through a line segment at (x_m,y,z). The line segment is defined by endpoints (x_1,y,z) and (x_2,y,z). The key step in constructing an isosurface is solving an inverse interpolation problem. That is, determining the location, (x_m,y,z) between two grid nodes, (x_1,y,z) and (x_2,y,z) where interpolated data takes on a particular value (the isosurface level, T_m, being constructed).

Suppose, as illustrated in Figure 2.6, that (x_1,y,z), T_1 and (x_2,y,z), T_2 represent two known data location, data value pairs and that T_m is also known satisfying $T_1 \le T_m \le T_2$. The inverse interpolation problem then is to find the location (x_m,y,z) that takes on the data value T_m. The location x_m is given by

$$x_m = (1-\alpha)x_1 + \alpha x_2$$

where

$$\alpha = \frac{T_m - T_1}{T_2 - T_1}$$

The sensitivity of x_m due to a change ΔT_1 in T_1 and to a change ΔT_2 in T_2 is given by

$$\Delta x_m = \frac{\partial x_m}{\partial T_1}\Delta T_1 + \frac{\partial x_m}{\partial T_2}\Delta T_2 \tag{2.1}$$

where

$$\frac{\partial x_m}{\partial T_1} = \frac{\partial x_m}{\partial \alpha}\frac{\partial \alpha}{\partial T_1} \tag{2.2}$$

$$\frac{\partial x_m}{\partial T_2} = \frac{\partial x_m}{\partial \alpha}\frac{\partial \alpha}{\partial T_2} \tag{2.3}$$

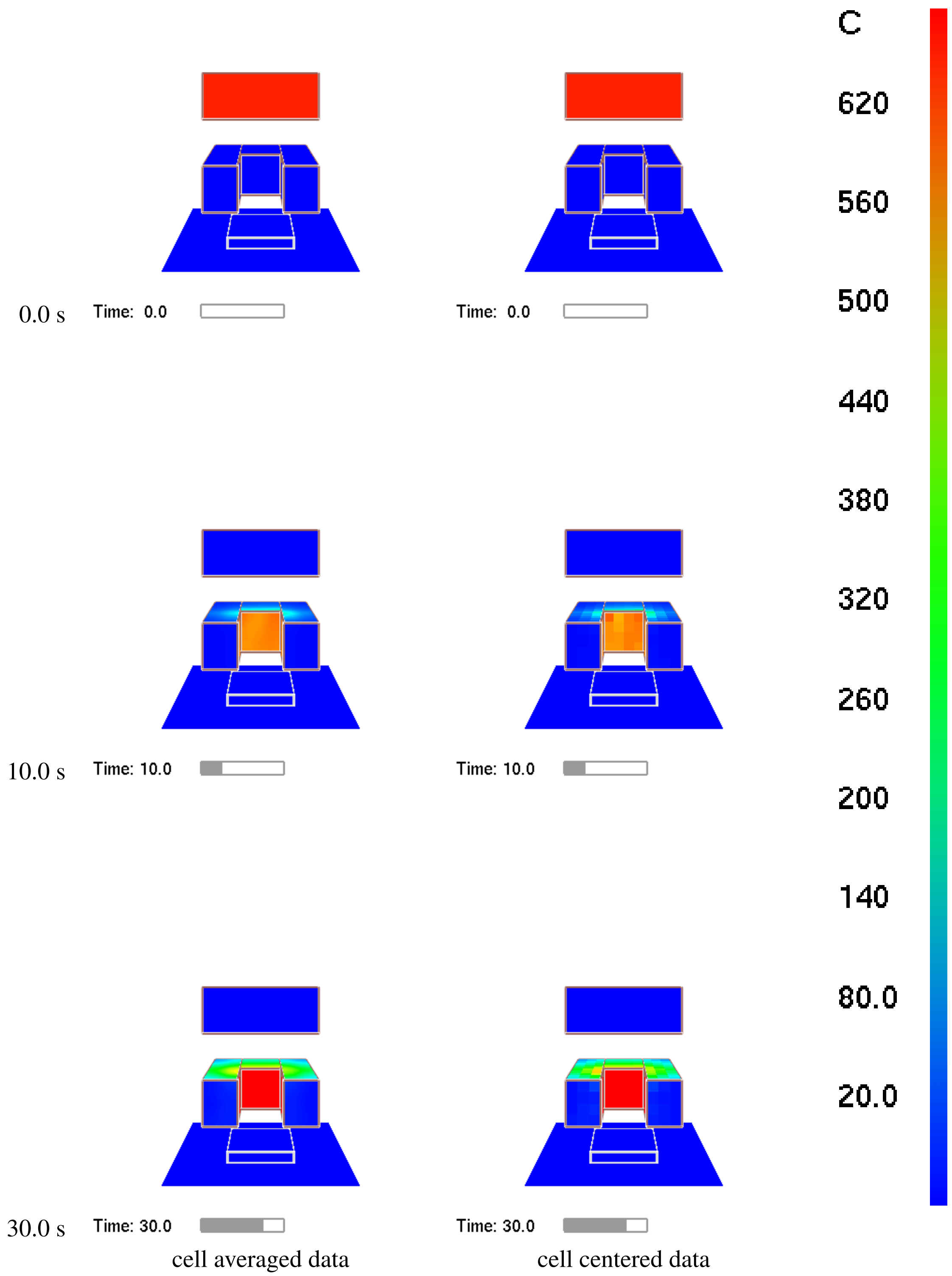


Figure 2.2: Boundary file test. The upper obstacle is initialized to 600.0 °C and should be red for the $t = 0.0$ s images.

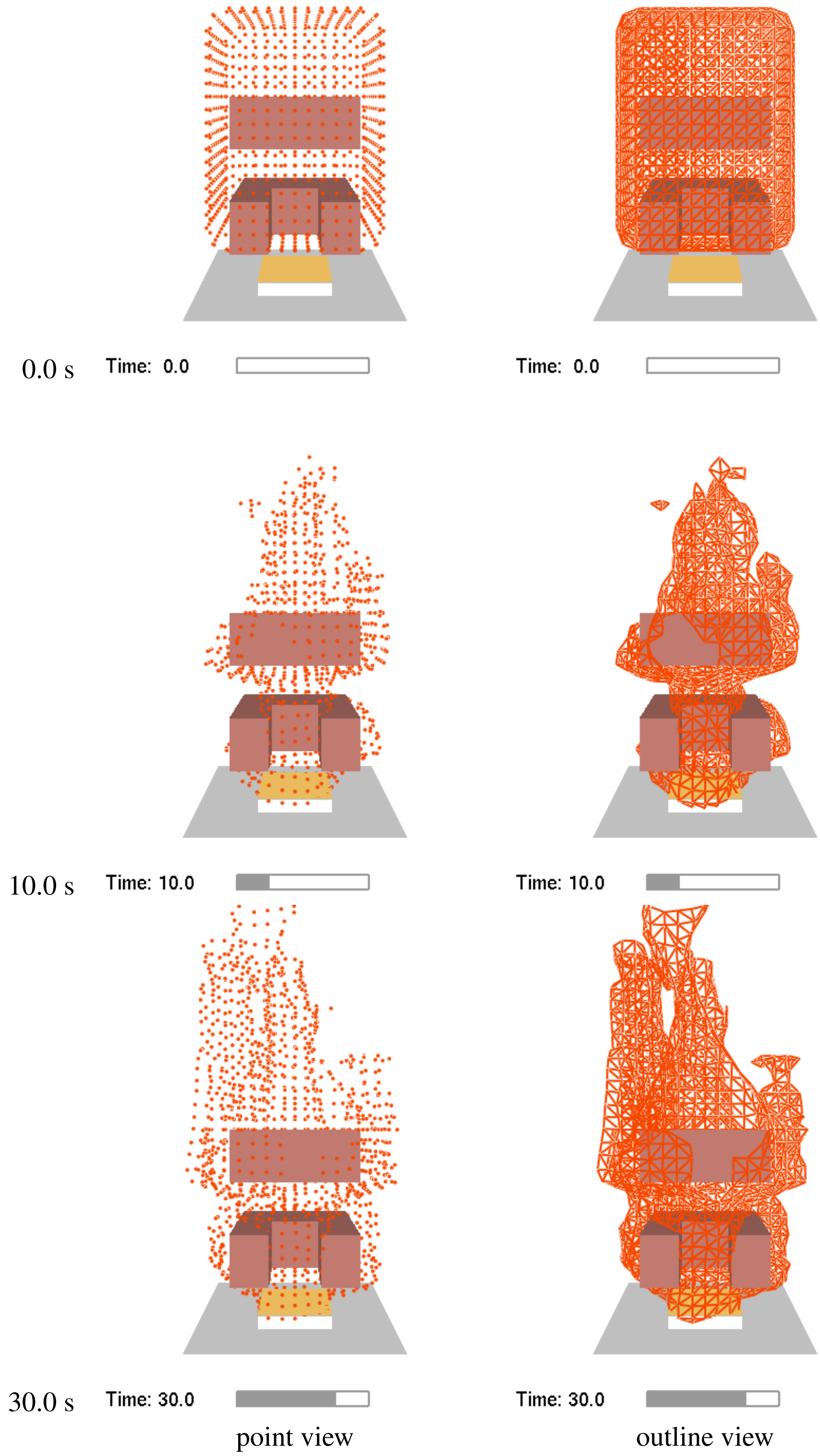


Figure 2.3: Isosurface file test 1. A portion of the interior gas temperature is initialized to 600.0 °C. The isosurface should surround this region for the $t = 0.0$ s images.

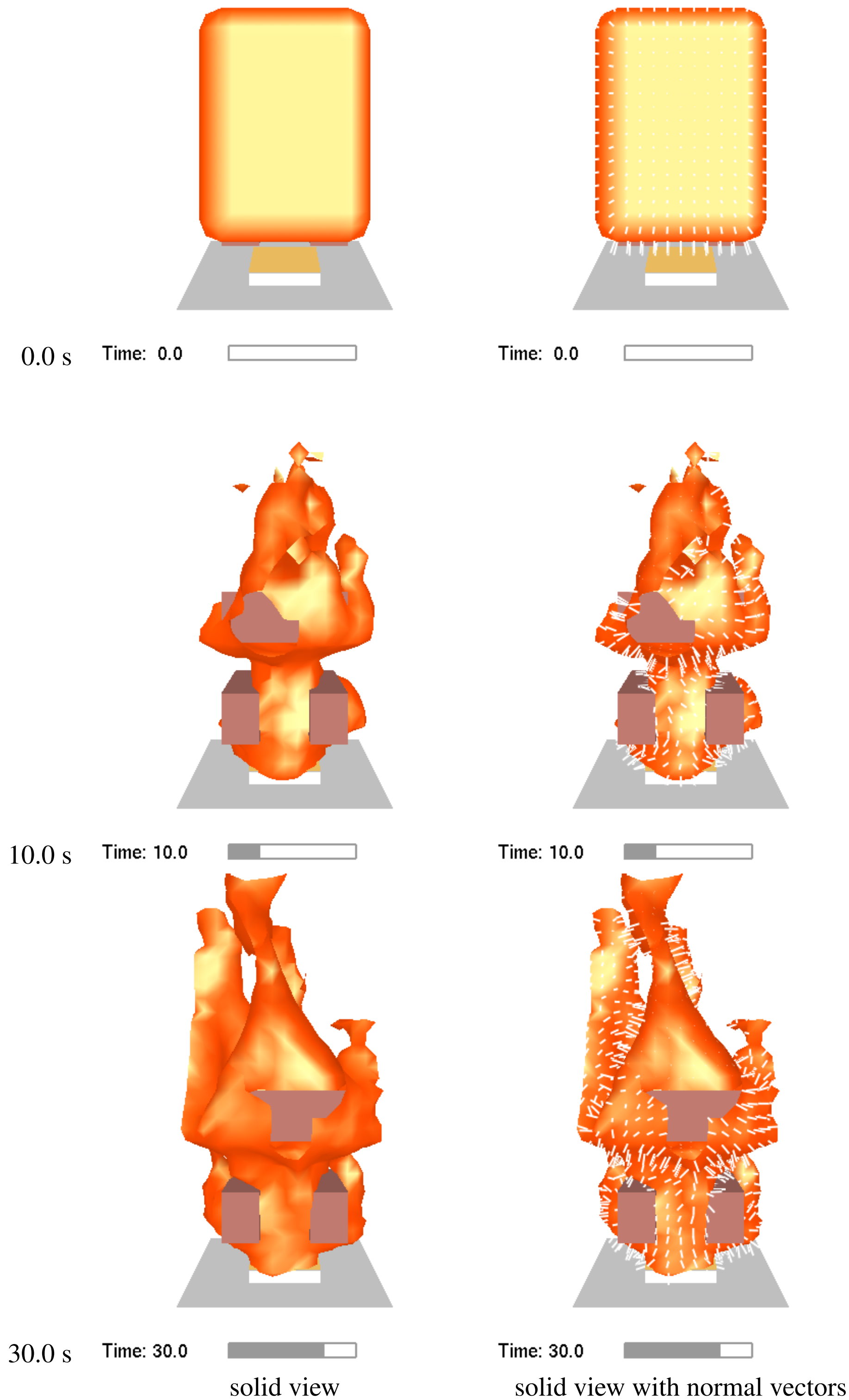


Figure 2.4: Isosurface file test 2. A portion of the interior gas temperature is initialized to 600.0 °C. The isosurface should surround this region for the $t = 0.0$ s images.

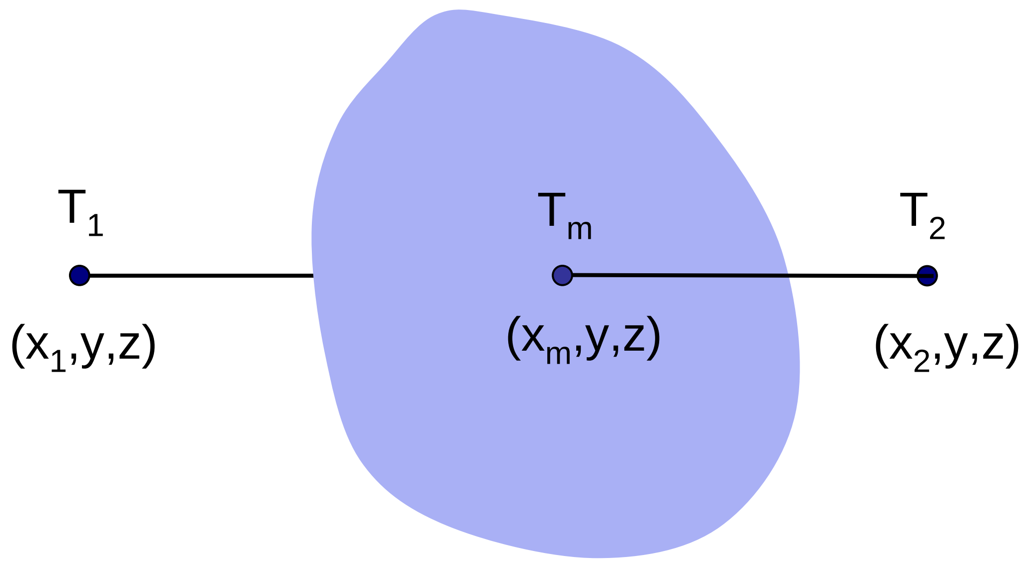


Figure 2.5: A portion of an iso-surface defined by $f(x,y,z) = T_m$ (for some function f) crossing a line segment at (x_m, y, z).

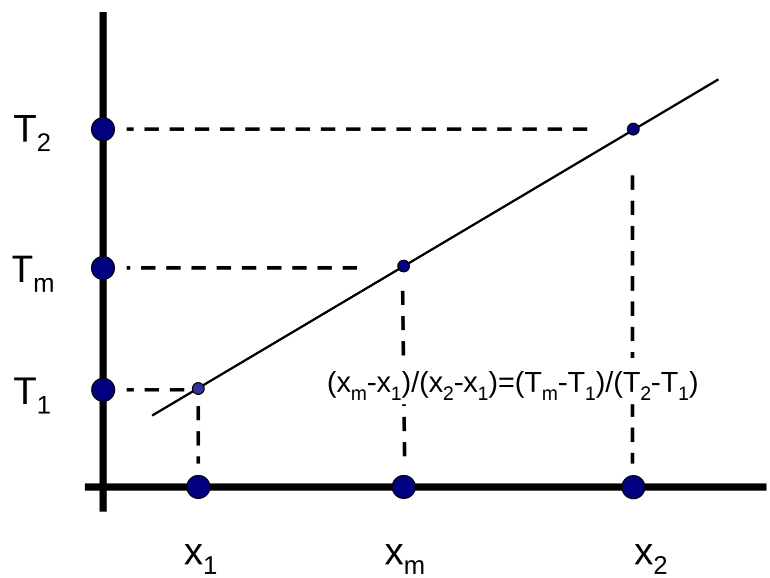


Figure 2.6: Inverse linear interpolation setup. The dependent data values T_1 and T_2 are known at locations x_1 and x_2. The inverse interpolation problem is to find the location x_m that has value T_m. This is found noting that $(x_m - x_1)/(x_2 - x_1) = (T_m - T_1)/(T_2 - T_1)$.

and

$$\frac{\partial x_m}{\partial \alpha} = x_2 - x_1 \tag{2.4}$$

$$\frac{\partial \alpha}{\partial T_1} = \frac{T_m - T_2}{(T_2 - T_1)^2} \tag{2.5}$$

$$\frac{\partial \alpha}{\partial T_2} = -\frac{T_m - T_1}{(T_2 - T_1)^2} \tag{2.6}$$

Equation (2.1) may be re-written using terms in equations (2.2) through (2.6) to obtain

$$\frac{\Delta x_m}{x_2 - x_1} = \frac{T_m - T_2}{(T_2 - T_1)^2}\Delta T_1 - \frac{T_m - T_1}{(T_2 - T_1)^2}\Delta T_2 = -\left((1-\alpha)\frac{\Delta T_1}{T_2 - T_1} + \alpha\frac{\Delta T_2}{T_2 - T_1}\right) \tag{2.7}$$

Equation (2.7) relates the relative error of x_m to the relative errors of T_1 and T_2 in terms of the interpolation parameter α. The error Δx_m may then be bounded to obtain

$$|\Delta x_m| \le |x_2 - x_1| \frac{\max(|\Delta T_1|, |\Delta T_2|)}{|T_2 - T_1|} \tag{2.8}$$

Uncertainty in isosurface location is then proportional to the magnitude of data uncertainty, $\max(|\Delta T_1|, |\Delta T_2|)$, and inversely proportional to the data variation, $|T_2 - T_1|$.

2.3 Particles

Figure 2.7 presents images verifying the display of particles and streaks. Images are drawn at 1.0 s, 10.0 s and 30.0 s. The first column shows particles while the second and third columns shows streaks with duration 0.5 s and 1.0 s. Streaks are a good way of visualizing motion in a still image (*i.e.* on paper) since the streak shows a history of where the particle has been. The FDS input file for this test is `plume5c.fds`. The images for this test were created automatically by running the smokeview script.

2.4 Slices

Figure 2.8 present images verifying the display of slices. Images are drawn at 0.0 s, 10.0 s and 30.0 s. A portion of the interior gas temperature is initialized to 600.0 °C corresponding to the red rectangular block appearing in the $t = 0.0$ s images. The first column visualizes all of the data in the slice. The second data discards or chops data below 140 °C. Note that the color near the chopped boundary should match the color in the colorbar near 140.0 °C. Figure 2.9 present images verifying the display of vector slices. Again, vector slice file images are drawn at 5.0 s, 10.0 s and 30.0 s. The first column draws all vectors while the second column discards or chops vectors below 140 °C. The FDS input file for this test is `plume5c.fds`. The images for this test were created automatically by running the smokeview script, `plume5c.ssf`.

2.5 3D Smoke

Figure 2.10 presents images verifying the display of 3D smoke and fire (heat release per unit volume). A series of 3D smoke images are drawn at 1.0 s, 10.0 s and 30.0 s. The images contain semi-transparent slices derived from both soot density and heat release rate per unit volume (HRRPUV) data. The FDS input file for this test is `plume5c.fds`. The images for this test were created automatically by running the smokeview script, `plume5c.ssf`.

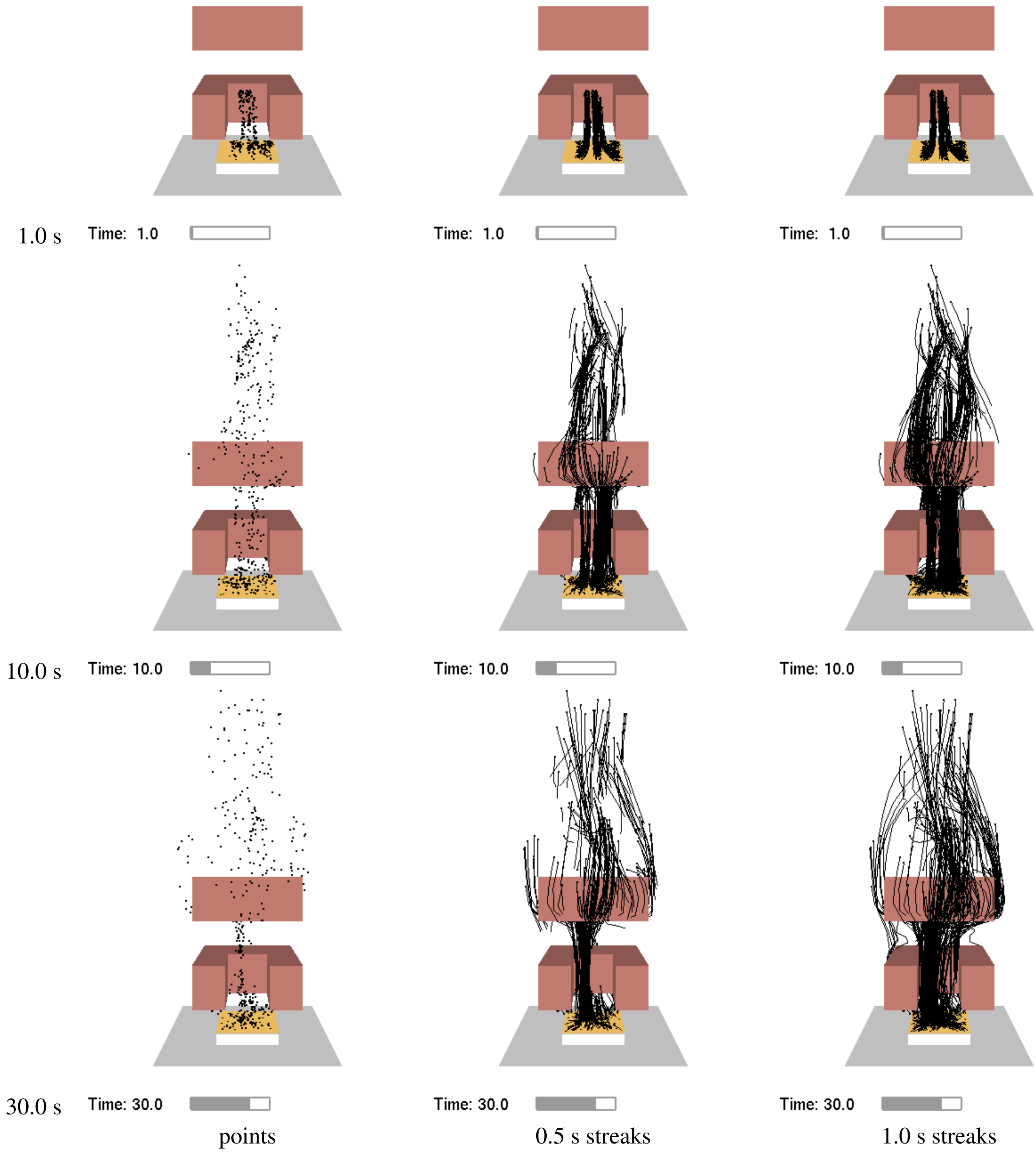


Figure 2.7: Particle file test.

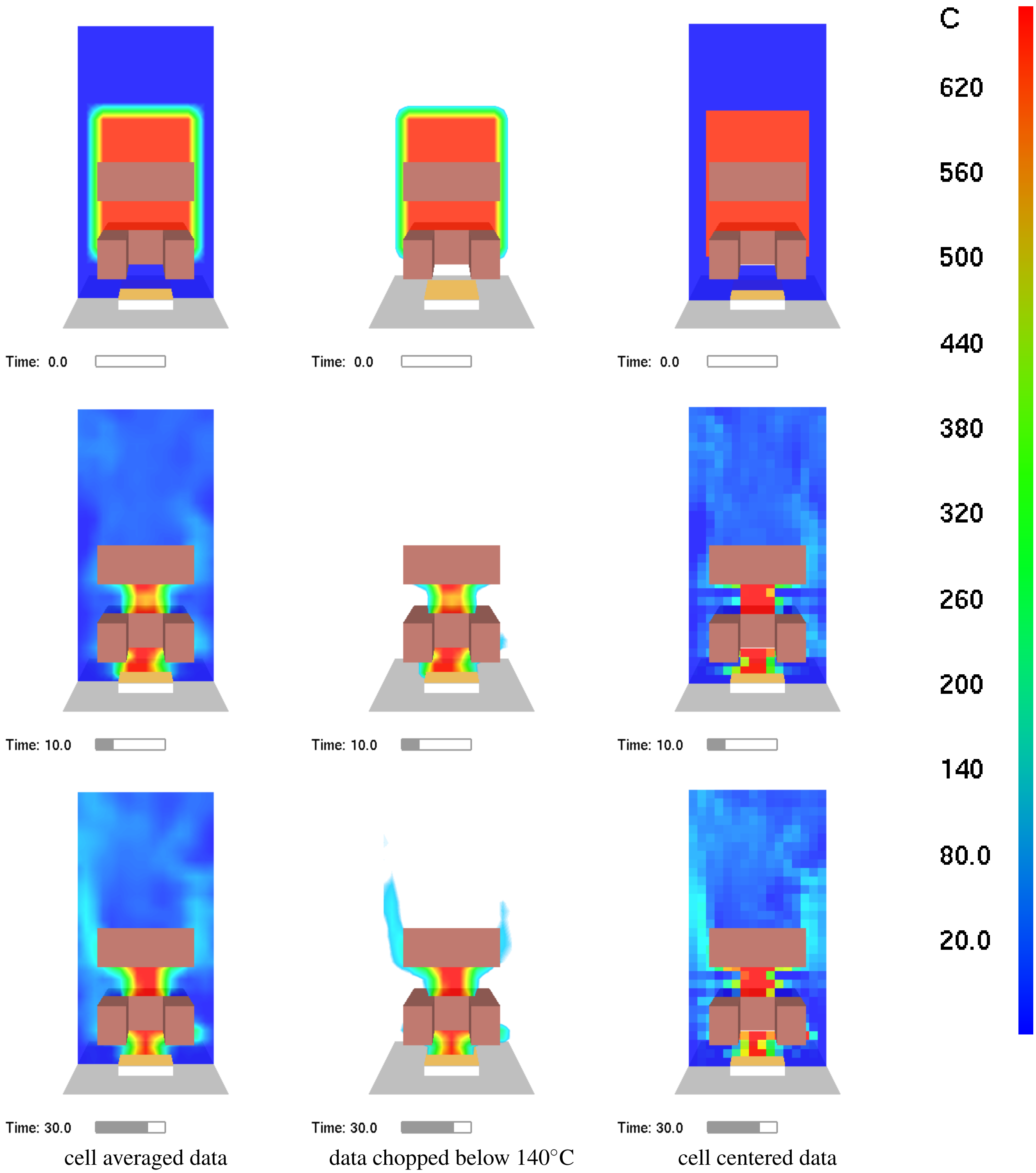


Figure 2.8: Slice file test. A portion of the interior gas temperature is initialized to 600.0 °C. The slice file in this region should be red for the $t = 0.0$ s images. For the chopped contours, the color near the chop boundary should match the color near 140.0 °C in the colorbar.

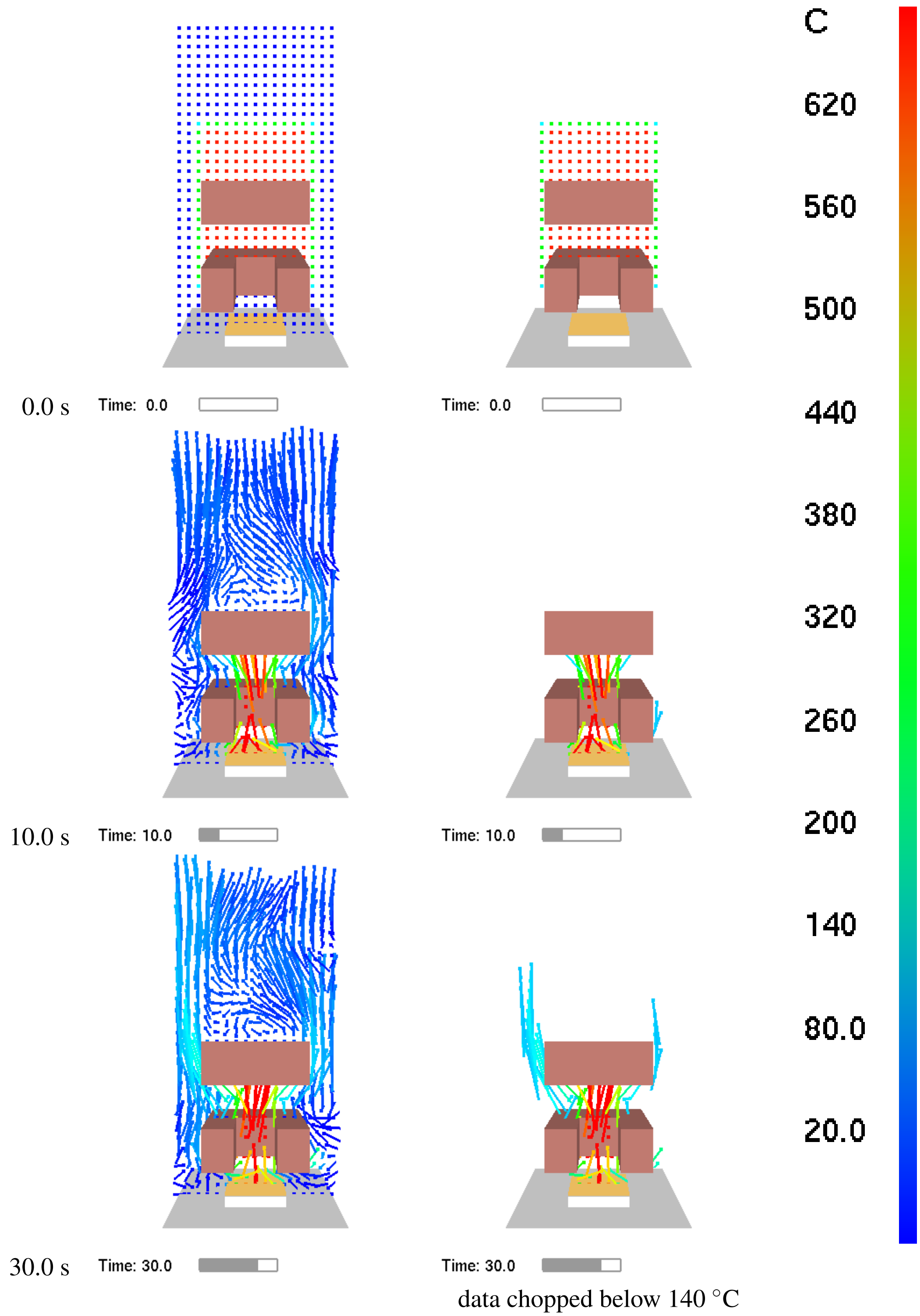
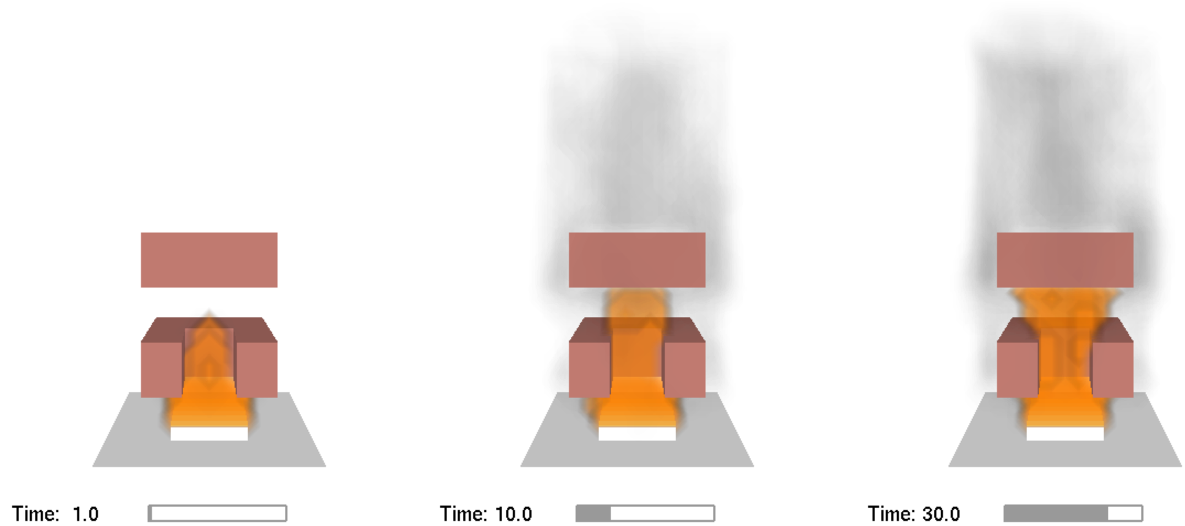


Figure 2.9: Vector slice file test. A portion of the interior gas temperature is initialized to 600.0 °C. The vectors in this region should be red for the $t = 0.0$ s images. For the chopped contours, the color near the chop boundary should match the color near 140.0 °C in the colorbar.



1.0 s 10.0 s 30.0 s

Figure 2.10: 3D smoke file test.

2.6 Plot3D

Figure 2.11 present images verifying the display of PLOT3D contours. Three types of contours are available for visualizing PLOT3D data: line, stepped and continuous. This figure shows all three contour types. The FDS input file for this test is `plume5c.fds`. The images for this test were created automatically by running the smokeview script, `plume5c.ssf`.

2.7 Fire Lines

Figure 2.15 presents images verifying the display of a fire line. A fire line is used with wildland fire simulations as an efficient method for visualizing the motion of a fire across the simulation. A fire line in the context of Smokeview is just a special case of a temperature slice file. The fire line slice is formed by setting the min and max temperature bounds to 20°C and 200°C respectively and chopping data below 150°C. The fire line slice file can then be made very small using Smokezip to compress it. Fire line images are drawn at 10.0 s, 20.0 s, 30.0 s and 40.0 s. The fire lines conform to the hill going through the middle of the scene. The FDS input file for this test is `fire_line.fds`. The images for this test were created automatically by running the smokeview script, `fire_line.ssf`.

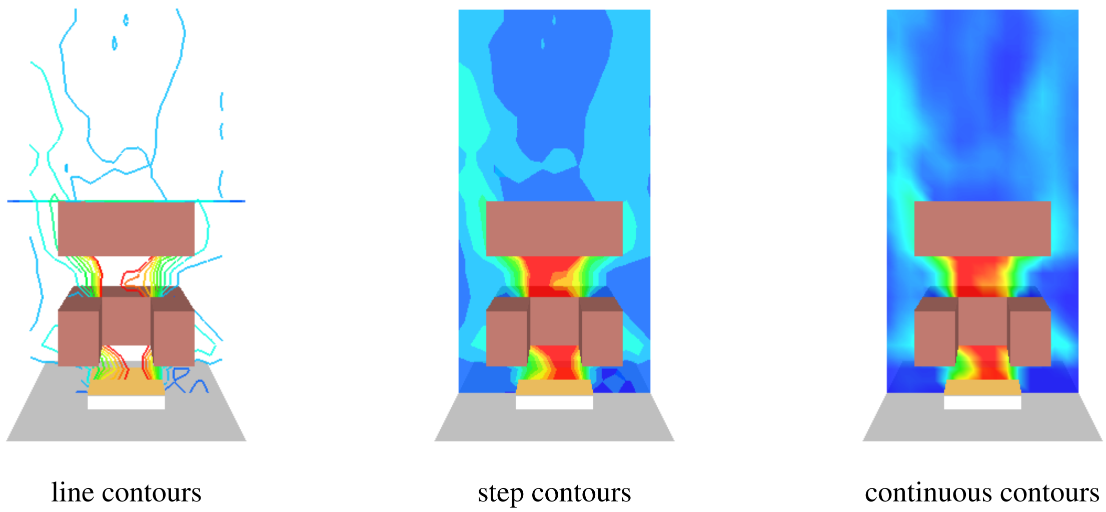


Figure 2.11: PLOT3D file test showing three different types of temperature contours (line, stepped, continuous) .

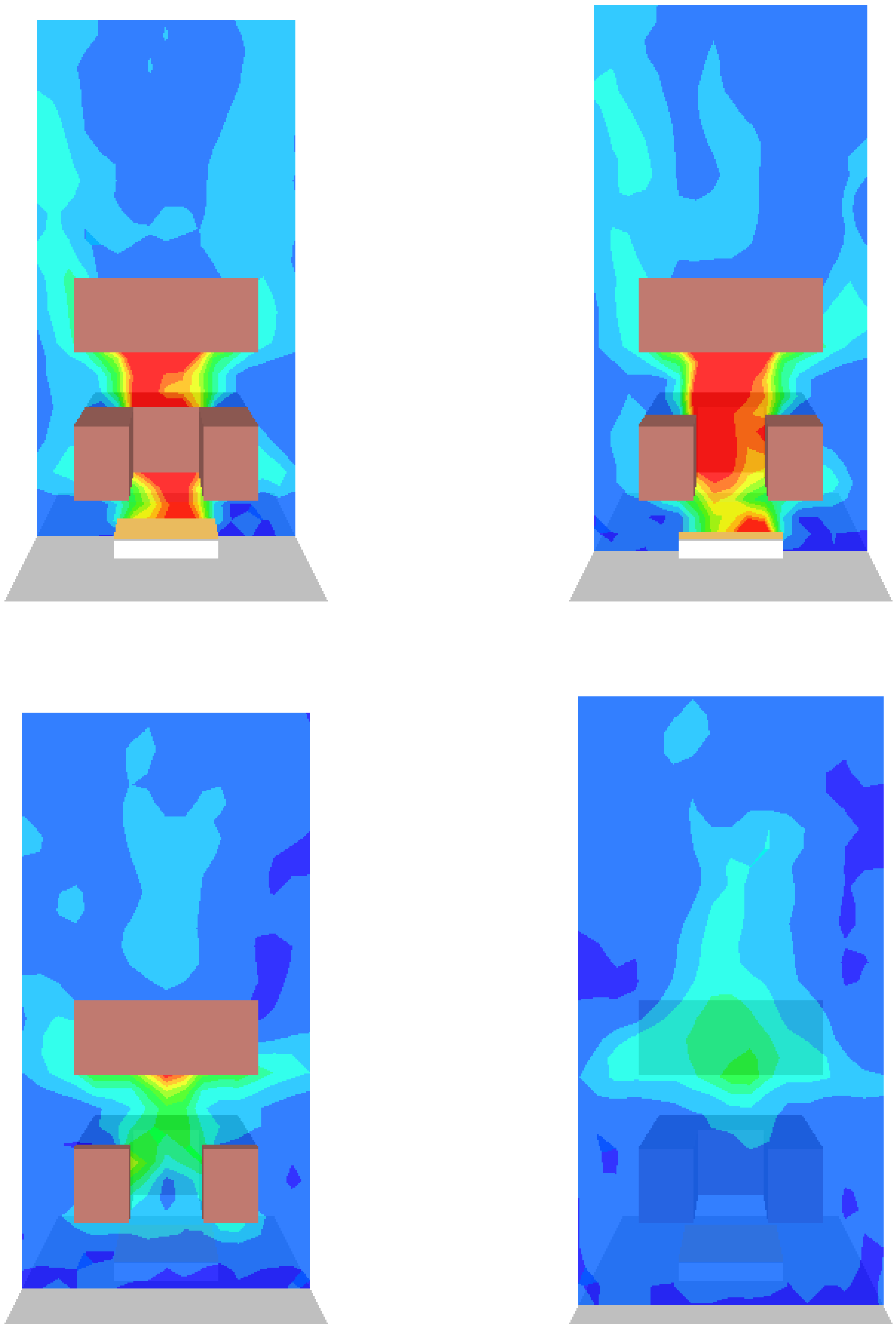


Figure 2.12: PLOT3D file test showing a stepped contours in a vertical plane at four positions along the y axis.

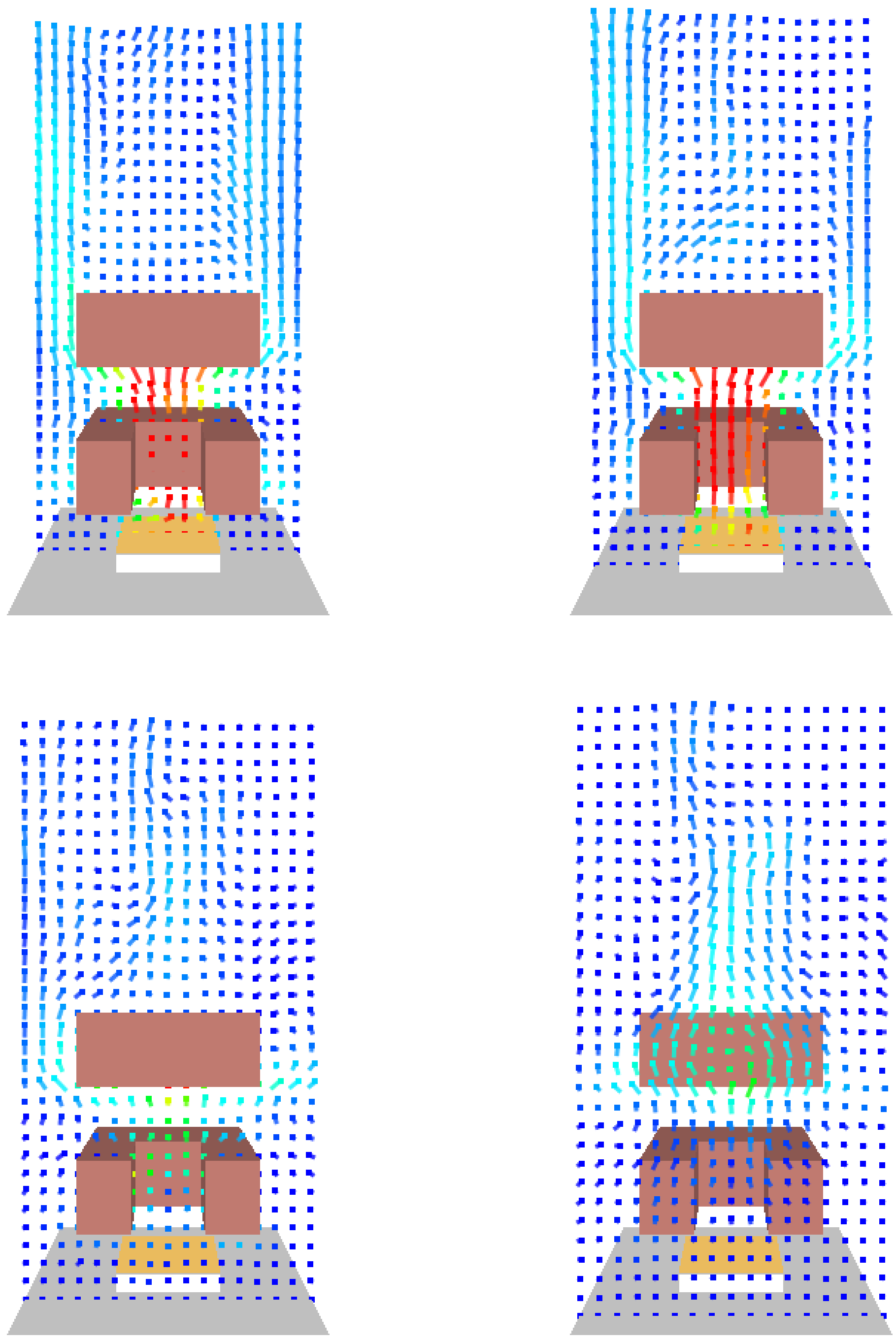


Figure 2.13: PLOT3D file test showing a velocity vectors shaded by temperature in a vertical plane at four positions along the y axis.

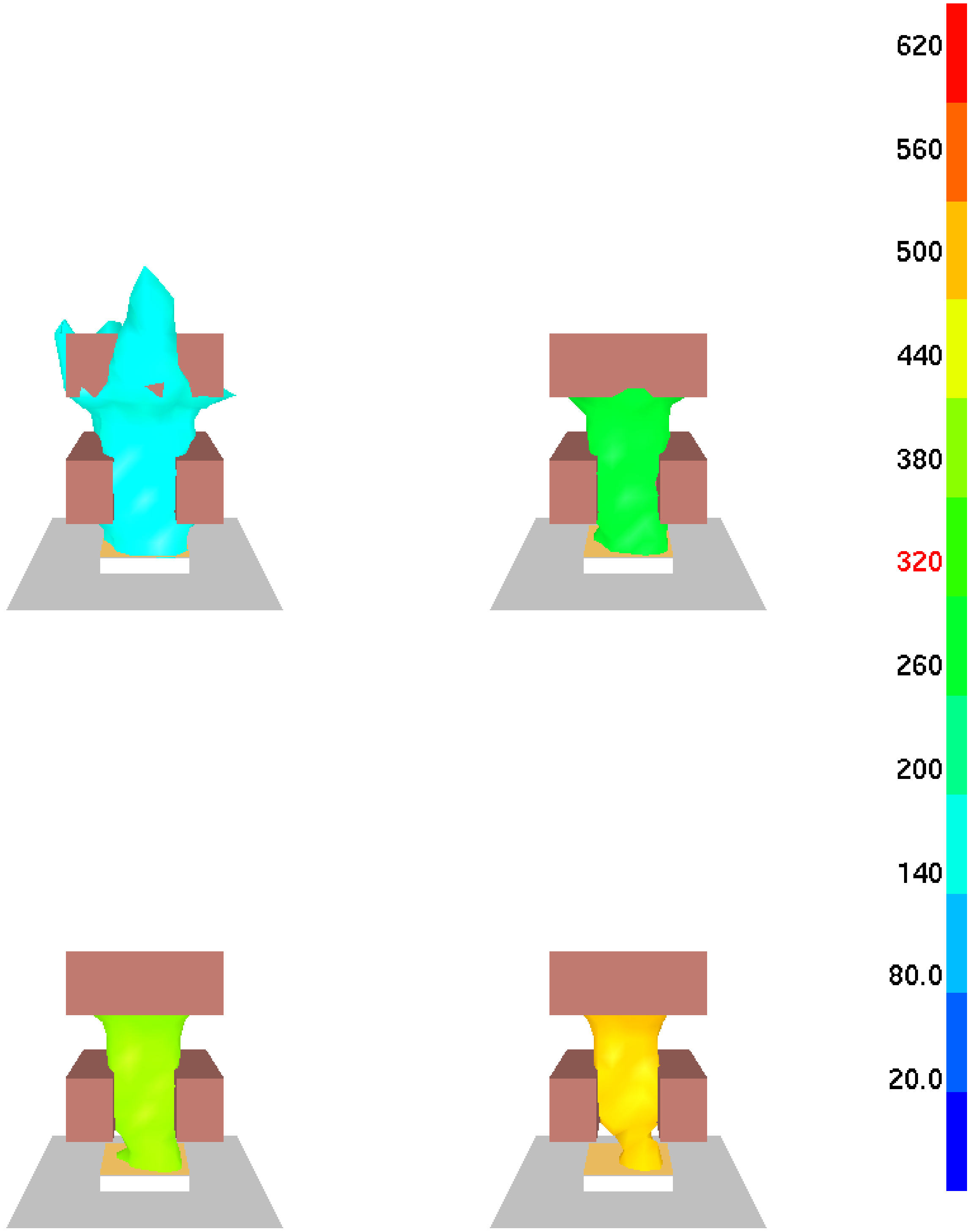


Figure 2.14: PLOT3D file test showing iso-surface for 140 °C, 260 °C, 380 °Cand 500 °C.

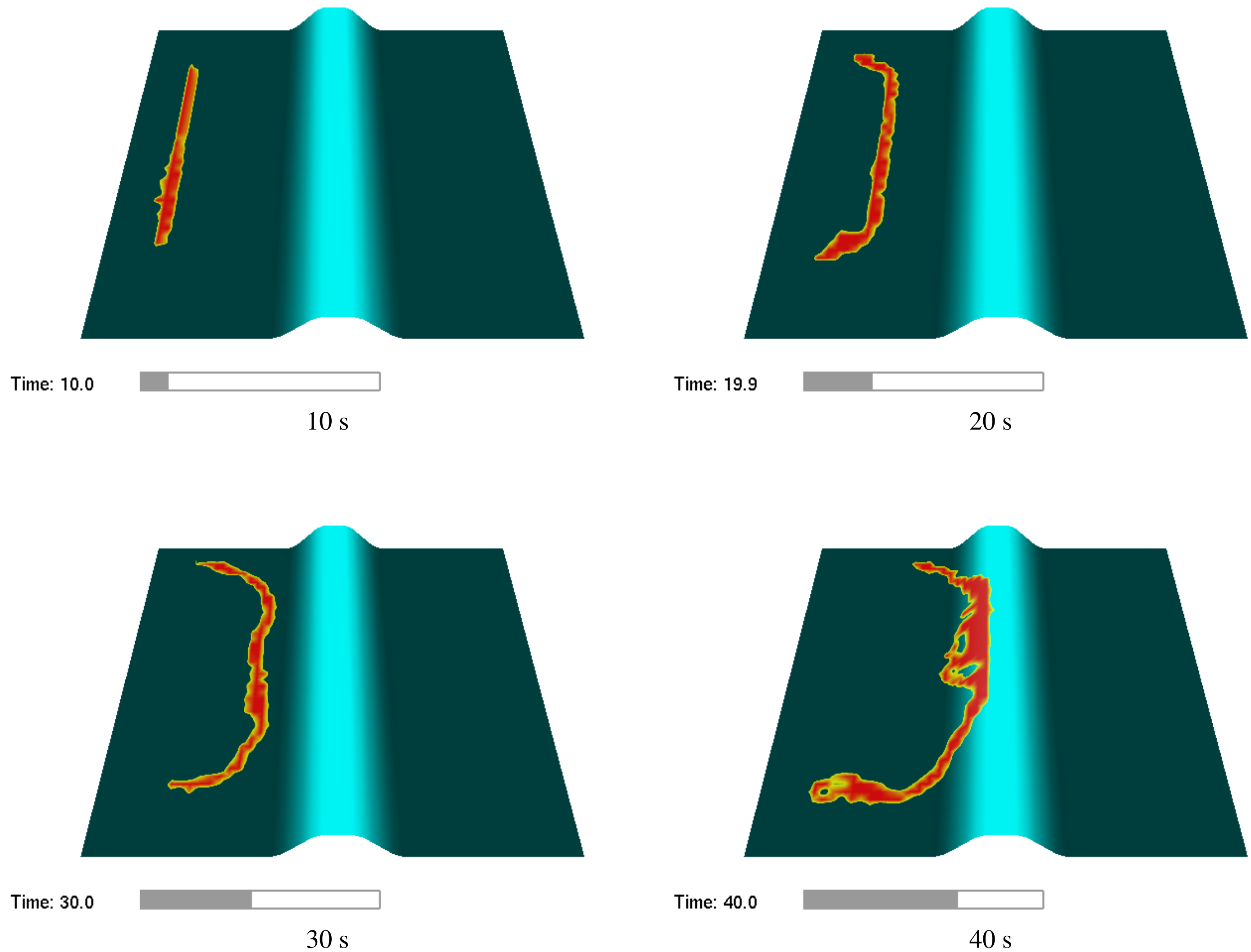


Figure 2.15: Fire line test. The fire line, a region of high temperature, follows the terrain as it progresses from left to right.

Chapter 3

Smoke Visualization Tests

Proper smoke visualization requires that smoke flow be both computed and drawn correctly. The FDS Verification Guide [4] addresses the question of correct computation in terms of soot/smoke production, transport *etc.* In this chapter, it is presumed that the FDS component of verification is correct and considers the question, "Is the smoke drawn correctly?". More precisely, given a known density and distribution of soot does the 3D smoke drawn by Smokeview match how *theory* suggests it should look. Presently, the main interest is in how smoke obscures objects in the background. Visualization effects due to light scattering are not modeled except to consider the smoke albedo when drawing its grey level.

The smoke drawing verification problem can be broken down into two steps. The first step is to verify that Smokeview can record or denote the correct grey level of smoke that is drawn. The second step is to verify that Smokeview can draw the correct shade of grey given a known soot density level.

3.1 Recording Smoke Levels

To record smoke grey levels, Smokeview makes use of a special FDS sensor or device. This device behaves like other FDS devices but has the additional property that when used by Smokeview, it displays the grey level as viewed by the observer. This grey level is displayed as a number between 0 and 255. The grey level is simply Smokeview's computation of the integrated *smoke thickness* along a path between the sensor location and the eye. These computations are performed by the video card using OpenGL, the graphics library used by Smokeview to visualize FDS scenarios. The user places a device of type `smoke_sensor` at a particular (x,y,z) location. Smokeview displays the sensor as a white disk with color (255,255,255) always oriented towards the observer. When drawing smoke that resides between the sensor and the observer (your eye) the smoke sensor is partially obscured by the smoke. Smokeview then alters the smoke sensor color according to how much and how thick the intervening smoke is. It does this by blending each smoke plane one plane at a time using the color and opacity levels of that plane.

Figure 3.1 illustrates an initial test of this process. It verifies that Smokeview correctly *knows* where the sensor is located and can correctly record its grey level even when surrounded by other objects of different colors. In this case, the smoke sensor is white and there is no intervening smoke. The background is a neutral grey with grey level of 128. The value displayed over the sensor then should always be 255 no matter how the scene is oriented. The figure shows two extreme orientations of the box containing the sensor.

Figure 3.2 shows two colorbars, both containing shades of grey. One shows white and near-white shades, the other shows black and near black shades. This figure illustrates the difficulty one has in distinguishing nearly equal shades and by inference the difficulty in distinguishing two smoke scenes drawn using nearly the same *amounts* of smoke. When comparing a computed smoke shade with the actual (as in Figure 3.4) one must keep in mind the eye's inability to distinguish nearly equal shades of grey.

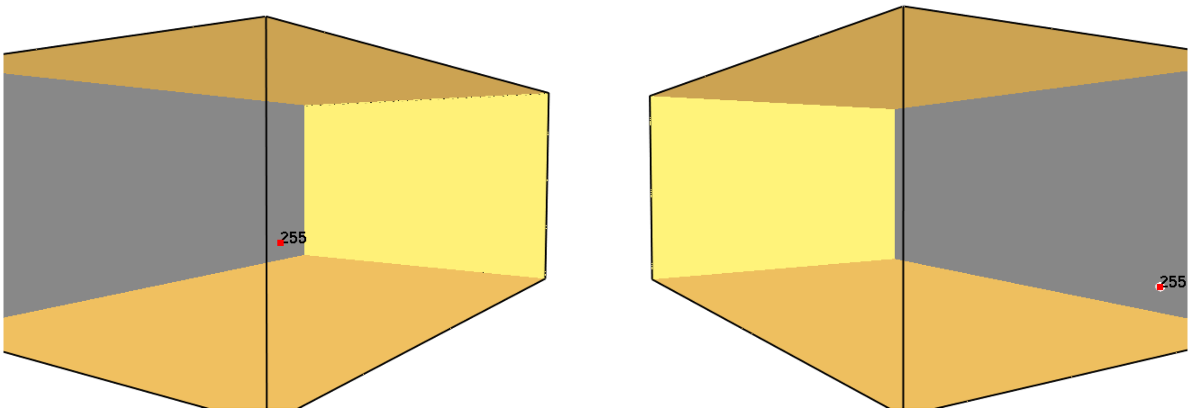


Figure 3.1: Smoke sensor test. A small white (255,255,255) smokesensor appears in front of a grey (128,128,128) obstacle. The red dot indicates where the smoke opacity is recorded.

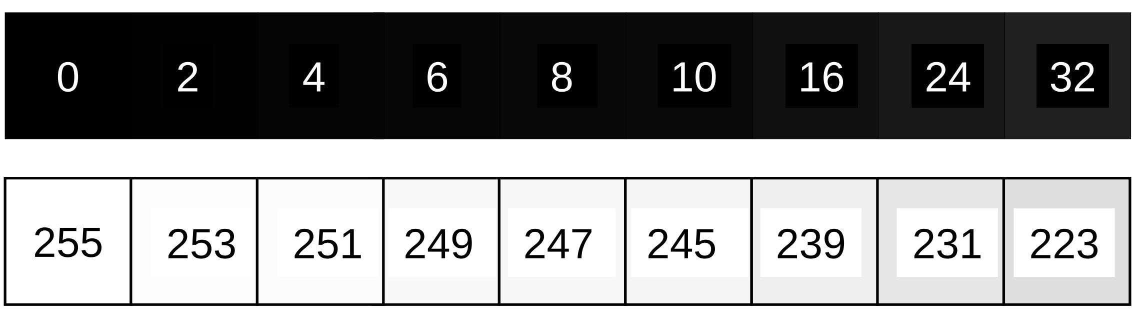


Figure 3.2: Shade of grey resolution test. The number within each square represents the shade of grey used to color that square, 0 for black and 255 for white. Adjacent squares are drawn with nearly equal shades testing the ability of sensors such as the eye, computer monitor or the printed page to distinguish them.

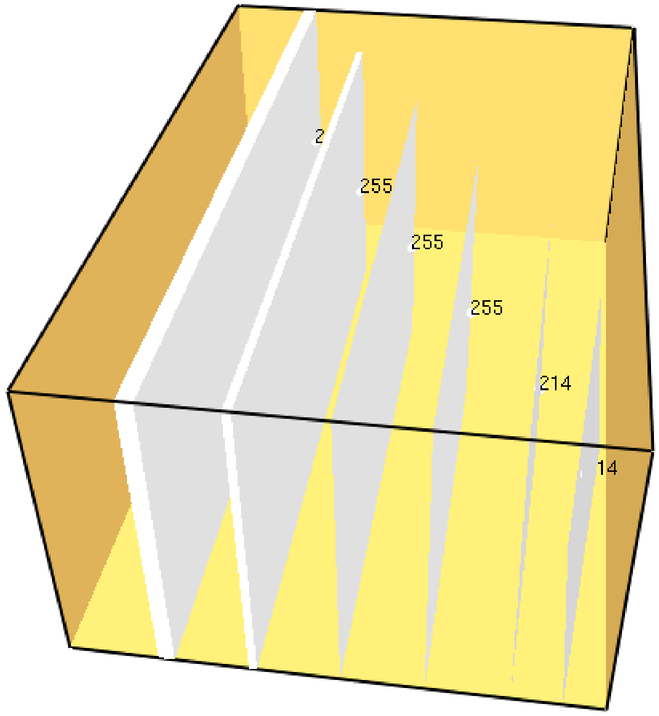


Figure 3.3: Side view of the numerical smoke test compartment. Walls are placed at 0.4 m, 1.0 m, 2.0 m, 3.0 m, 4.0 m and 5.0 m from the front to make the theoretical grey levels work out to 8, 16, 32, 64, 128 and 192 .

3.2 Verifying Smoke Levels

The strategy for verifying smoke levels in Smokeview is to set up an FDS case with constant smoke density throughout the domain. The smoke density and the mass extinction coefficient are chosen in concert to generate a predetermined opacity for a given path length. These predetermined opacities or grey levels are 8, 16, 32, 64, 128 and 192. Beer's law in the form of

$$\alpha = 255 \exp(-KS\Delta x)$$

is used to relate these predetermined opacities to path length where α is a scaled opacity (from 0 to 255 rather than the usual 0.0 to 1.0), K is the mass extinction coefficient[1], S is the soot density and Δx is the path length. For the verification case it is assumed that S is constant enabling α to be computed simply.

Figure 3.3 shows a side view of the numerical smoke box used to perform this test. In addition to the walls surrounding the box, this box consists of six parallel walls within the box spaced 1.0 m apart. The widths increase from one wall to the next (from front to back) so that when looking at the box from the front a different distance or path length occurs between the observer and the portion of the wall that is visible. Again, the spacing between the walls, the distance between the walls and the observer and the initial soot densities is chosen so that the computed smoke obscurations work out to *nice* values.

Figure 3.4 shows quantitative tests of the smoke opacity calculation performed in Smokeview for two

[1] For most flaming fuels, a suggested value for K is 8700 $m^2/kg \pm 1100$ m^2/kg at a wavelength of 633 nm [7]

different FDS grid resolutions and three different skip levels.[2] This figure also gives the predicted shades of grey based upon the inputted soot densities, mass extinction coefficient and path lengths. The smoke visualization algorithm is verified then if the shades of grey in the Smokeview visualizations match the corresponding predicted shades of grey. Each shaded rectangle is accompanied by a numerical value that can also be used to judge whether the visualization is verified.

The numbers displayed in this Figure 3.4 represent the shade of the underlying rectangle. These numbers may be verified by using a program such as Adobe Photoshop to examine the pixel values of this rectangular region. The numbers are verified when they match the pixel values as reported by Photoshop or any other program that can report image values.

When soot densities are constant, smoke grey level or opacity, α may be computed by using

$$\alpha = 255\exp(-KS\Delta x) \tag{3.1}$$

where $K = 8700$ m^2/kg is the mass extinction value, $S = 79.67$ mg/m^3 is the soot density and Δx is the smoke path length. Solving equation (3.1) for Δx gives

$$\Delta x = -\frac{\ln(\alpha/255)}{KS} \tag{3.2}$$

Path lengths (smoke sensor locations) are chosen to obtain grey levels (α) of 192, 128, 64, 32, 16 and 8. These path lengths may be found by substituting these grey levels into equation (3.2) to obtain Δx values of 0.41 m, 1.0 m, 2.0 m, 3.0 m, 4.0 m and 5.0 m respectively. The walls in `smoketest2.fds` are placed at these distances from the front of the simulation domain. Comparing the Smokeview generated smoke levels with theoretical values one finds as expected that better results are achieved when using a more refined grid (0.1 m rather than 0.2 m) and using all planes (no skipping).

[2]Smokeview allows one to skip grid planes when visualizing smoke. The smoke opacity is adjusted by Smokeview to account for the skips.

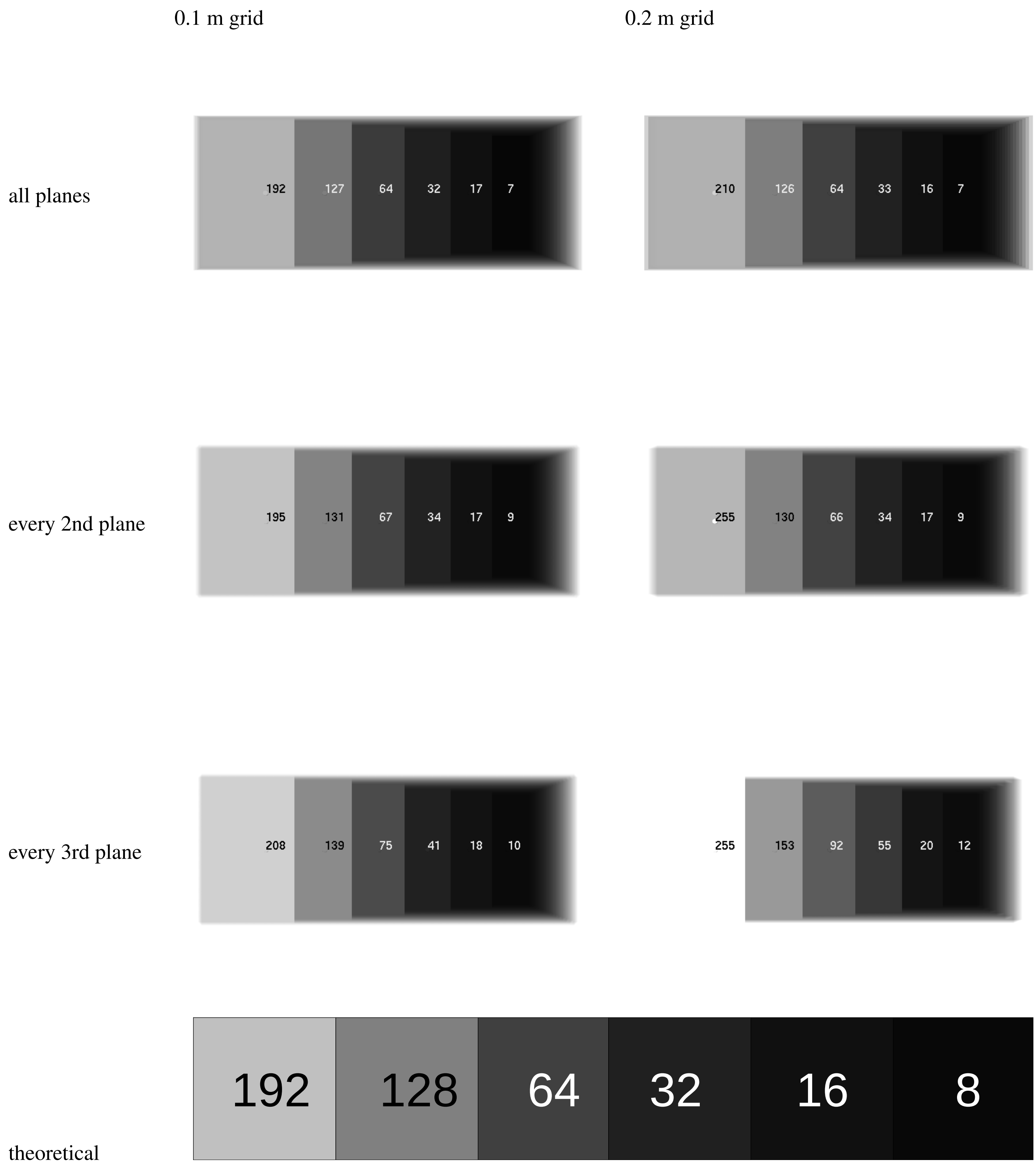


Figure 3.4: 3D smoke file test 2. A quantitative test of the smoke opacity calculation in Smokeview. This test simplifies the general case by assuming a uniform distribution of smoke. The test is repeated for two grid resolutions and three grid spacings. The FDS input file is set up to result in theoretical grey levels of 8, 16, 32, 64, 128 and 192 for the different regions of the test.

Chapter 4

Other Tests

4.1 Obstacles

Figures 4.1 and 4.2 tests different methods for displaying obstacles. Figure 4.1 shows obstacles drawn as solids, as outlines or hidden. Figure 4.2 shows obstacles drawn transparently. The left view shows the opaque obstacle drawn in front (and blocking) a portion of the transparent obstacle behind. The center view shows both obstacles unobscured. The right view shows the transparent blockage drawn in front with the opaque blockage visible behind. The images for this test were created automatically by running the smokeview script, `plume5c.ssf` (see Appendix B.1.

4.2 Devices

The case illustrated in Figure 4.3 tests how good Smokeview can display many devices. This Figure shows a series of sprinklers with three different levels of detail. Smokeview should be able to smoothly move this scene on computers with good video cards. The images for this test were created automatically by running the smokeview script, `sprinkler_many.ssf` (see Appendix B.6.

4.3 Vents

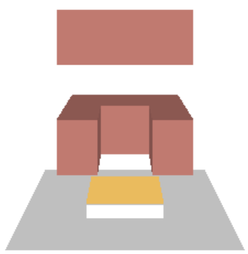
Figure 4.4 tests vent display. This figure shows three different levels of vent visibility: all vents displayed, only non-open vents displayed and all vents hidden. The images for this test were created automatically by running the smokeview script, `plume5c.ssf` (see Appendix B.1.

4.4 Conversion to Color

Smokeview converts data values obtained from an FDS calculation to color using a linear scaling of the form

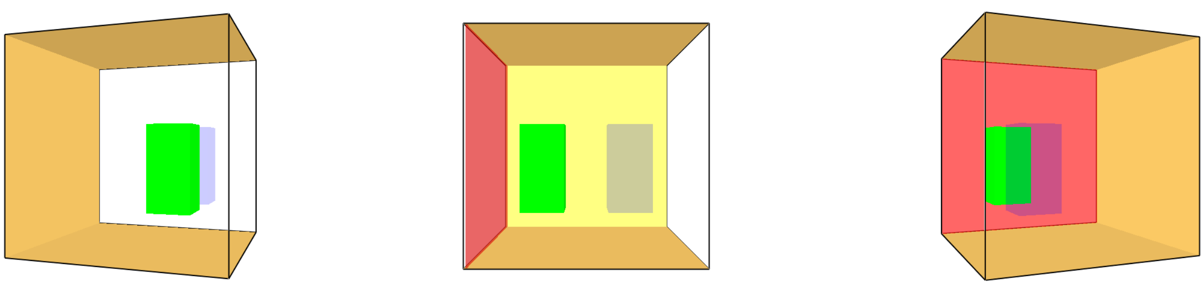
$$C_i = 255\frac{V_i - V_{min}}{V_{max} - V_{min}}$$

where C_i is an index into a color table between 0 and 255, V_{min} and V_{max} are data bounds and V_i is a data value to be converted. Figure 4.5 presents images verifying the conversion of data to colors. The input file, `colorconv.fds` (see Appendix A.8), for this test was set up so that initially the left half of the domain (it is a 2D case) is 20 °C and the right half is 100 °C. The images for this test were created automatically by running the smokeview script, `colorconv.ssf` (see Appendix B.9).



solid view of obstacles | outline view of obstacles | obstacles hidden

Figure 4.1: Obstacle view test.



left view - opaque obstacle in front | center view - both obstacles visible | right view - transparent obstacle in front

Figure 4.2: Transparency view test.

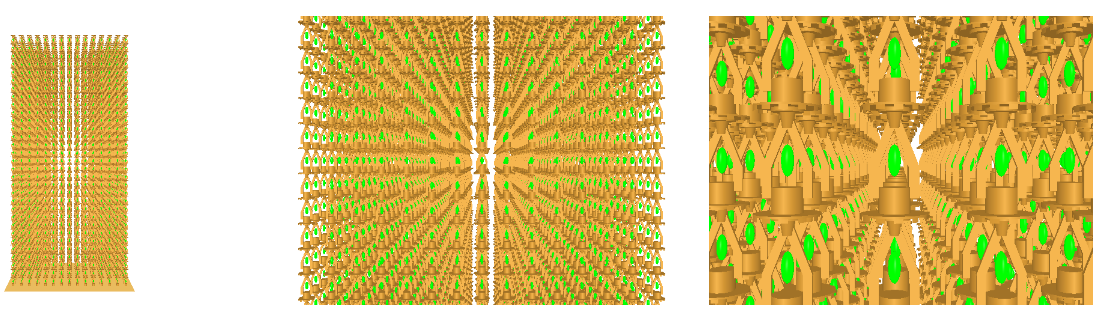


Figure 4.3: Device view test.

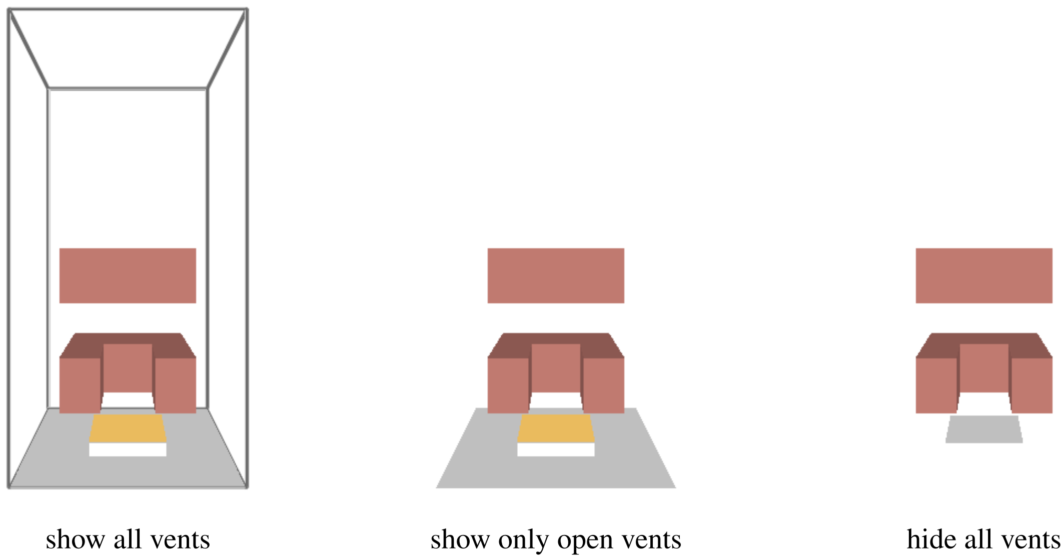


Figure 4.4: Vent view test.

A second color conversion test involves the use of the colorbar to highlight portions of the data. The case was set up so that the vertical slice aligns with the colorbar. The gas temperatures were defined to increase from 20 °C to 100 °C from the floor to the ceiling. As a result, when one selects the colorbar, the selected region in the colorbar should match the selected region in the vertical slice. The images for this test were created automatically by running the smokeview script, `colorbar.ssf` (see Appendix B.8).

4.5 GPU Test

Figure 4.7 tests whether Smokeview produces identical images when using the GPU and CPU for drawing 3D smoke. The first column shows CPU generated images at 5 s, 10 s and 30 s while the second column shows GPU generated images at the same times. The corresponding images in each column should be identical.

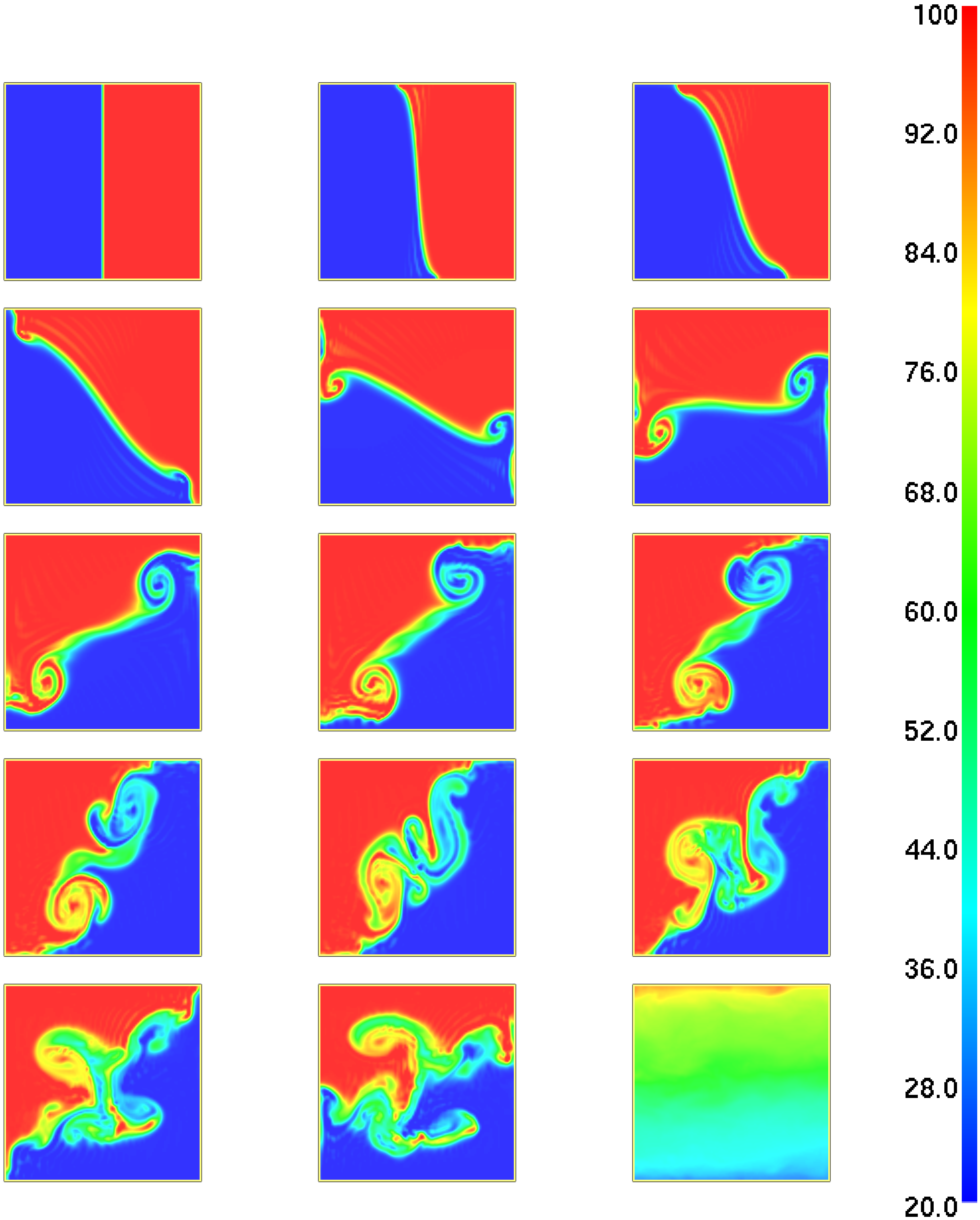


Figure 4.5: Color conversion test. Temperature between 20 °C and 100 °C are converted to colors between blue and red.

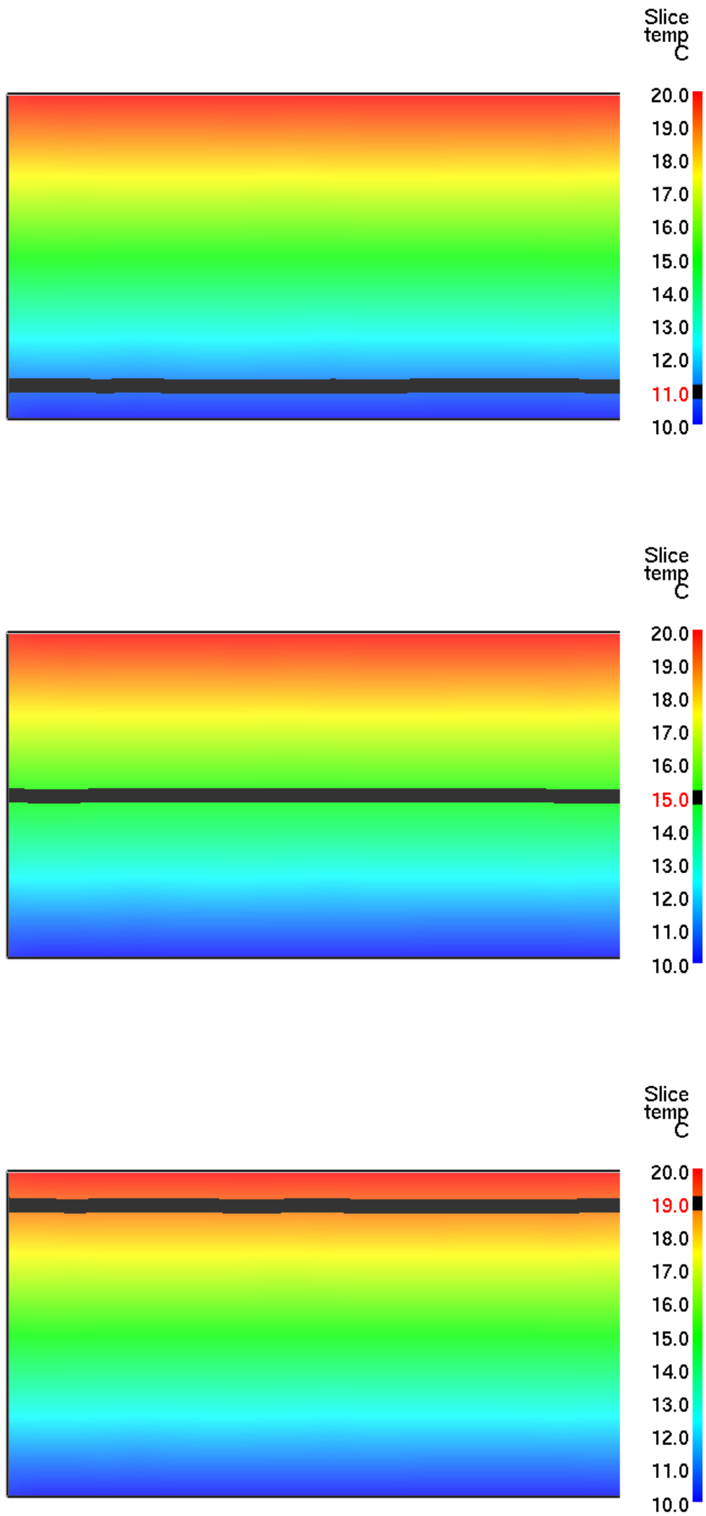
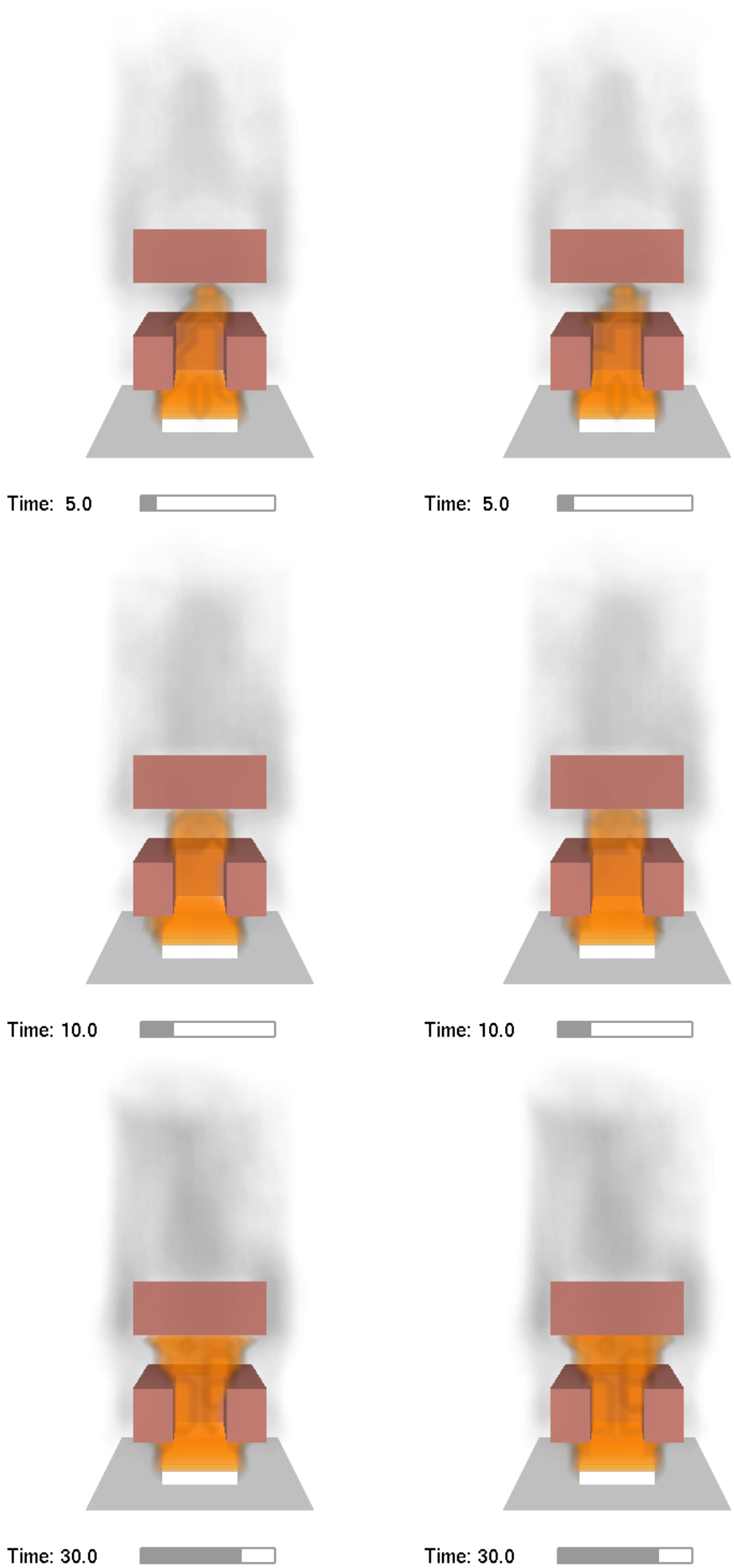


Figure 4.6: Color conversion test. Temperature between 20 °C and 100 °C are converted to colors between blue and red. The highlighted region in the colorbar matches the highlighted region in the vertical slice.



CPU generated GPU generated

Figure 4.7: GPU smoke drawing test

Chapter 5

Future Work

General strategies for improving Smokeview's ability to visualize cases and therefore to improve the understanding of computed fire flow are discussed in the Smokeview Technical Guide [8]. The plume cases in this document are set up so that a portion of the interior domain is initialized to a known temperature. The reader can then perform a quantitative comparison to verify that the various visualization types are being drawn correctly - at least at $t = 0$ where the values to be visualized are known. This is also the case with the 3D smoke. The 3D smoke case is set up so that the obscuration levels are known. Some areas of future work pertaining to the verification of Smokeview include improving the quantitative verification of Smokeview's visualization algorithms - to take those verifications that are now qualitative and add a quantitative component. In the qualitative verifications, a figure caption describes what the figure should look like and the reader notes whether the figure and caption are consistent - this is the verification. A second area of improvement is to add more cases to this document, to verify more aspects of Smokeview. In the final analysis, Smokeview is now complex to the point that it is difficult to verify its features by simply running it manually. Automatic verification methods are required to ensure that all of its features, at least those features that are checked are working as designed.

Bibliography

[1] K.B. McGrattan, S. Hostikka, J.E. Floyd, H.R. Baum, R.G. Rehm, W.E. Mell, and R. McDermott. Fire Dynamics Simulator (Version 5), Technical Reference Guide, Volume 1: Mathematical Model. NIST Special Publication 1018-5, National Institute of Standards and Technology, Gaithersburg, Maryland, October 2007.

[2] K.B. McGrattan, S. Hostikka, and J.E. Floyd. Fire Dynamics Simulator (Version 5), User's Guide. NIST Special Publication 1019-5, National Institute of Standards and Technology, Gaithersburg, Maryland, October 2007.

[3] W. W. Jones, R. D. Peacock, G. P. Forney, and P. A. Reneke. CFAST, Consolidated Model of Fire Growth and Smoke Transport (Version 5. technical reference guide. NIST Special Publication 1030, National Institute of Standards and Technology, Gaithersburg, Maryland, October 2004.

[4] R. McDermott, K.B. McGrattan, S. Hostikka, and J.E. Floyd. Fire Dynamics Simulator (Version 5), Technical Reference Guide, Volume 2: Verification. NIST Special Publication 1018-5, National Institute of Standards and Technology, Gaithersburg, Maryland, October 2007.

[5] G.P. Forney. Smokeview (Version 5), A Tool for Visualizing Fire Dynamics Simulation Data, Volume I: User's Guide. NIST Special Publication 1017-1, National Institute of Standards and Technology, Gaithersburg, Maryland, August 2007.

[6] G.P. Forney. Smokeview (Version 5), A Tool for Visualizing Fire Dynamics Simulation Data, Volume II: Technical Reference Guide. NIST Special Publication 1017-2, National Institute of Standards and Technology, Gaithersburg, Maryland, May 2009.

[7] G.W. Mulholland and C. Croarkin. Specific Extinction Coefficient of Flame Generated Smoke. *Fire and Materials*, 24:227–230, 2000.

[8] G.P. Forney. Smokeview (Version 5), A Tool for Visualizing Fire Dynamics Simulation Data, Volume III: Verification Guide. NIST Special Publication 1017-3, National Institute of Standards and Technology, Gaithersburg, Maryland, May 2009.

Appendix A

Input Files

A.1 plume5c

```
&HEAD CHID='plume5c',TITLE='Plume whirl case SVN $Revision: 4861 $' /

  same as plume5a except there is a blockage in the middle of the scene to block the flow
  The purpose of this case is to demonstrate the curved flow (via streak lines) that results.

&MESH IJK=16,16,32, XB=0.0,1.6,0.0,1.6,0.0,3.2 /

&DUMP NFRAMES=400 /

&INIT XB=0.2,1.4,0.2,1.4,0.5,2.2  TEMPERATURE=600.0 /

&TIME TWFIN=40. /  Total simulation time

&MATL ID                    = 'FABRIC'
      FYI                   = 'Properties completely fabricated'
      SPECIFIC_HEAT         = 1.0
      CONDUCTIVITY          = 0.1
      DENSITY               = 100.0
      N_REACTIONS           = 1
      NU_FUEL               = 1.
      REFERENCE_TEMPERATURE = 350.
      HEAT_OF_REACTION      = 3000.
      HEAT_OF_COMBUSTION    = 15000. /

&MATL ID                    = 'FOAM'
      FYI                   = 'Properties completely fabricated'
      SPECIFIC_HEAT         = 1.0
      CONDUCTIVITY          = 0.05
      DENSITY               = 40.0
      N_REACTIONS           = 1
      NU_FUEL               = 1.
      REFERENCE_TEMPERATURE = 350.
      HEAT_OF_REACTION      = 1500.
      HEAT_OF_COMBUSTION    = 30000. /

&SURF ID              = 'UPHOLSTERY_LOWER'
      FYI             = 'Properties completely fabricated'
      RGB             = 151,96,88
      BURN_AWAY       = .FALSE.
      MATL_ID(1:2,1)  = 'FABRIC','FOAM'
      THICKNESS(1:2)  = 0.002,0.1
/

&SURF ID              = 'UPHOLSTERY_UPPER'
      FYI             = 'Properties completely fabricated'
      RGB             = 151,96,88
```

```
      BURN_AWAY      = .FALSE.
      MATL_ID(1:2,1) = 'FABRIC','FOAM'
      THICKNESS(1:2) = 0.002,0.1
      TMP_INNER      = 600.0
/

&SURF ID='BURNER',HRRPUA=600.0,PART_ID='tracers' /  Ignition source

&VENT XB=0.5,1.1,0.5,1.1,0.1,0.1,SURF_ID='BURNER' /  fire source on kitchen stove

&OBST XB=0.5,1.1,0.5,1.1,0.0,0.1 /
&OBST XB=0.3,1.3,0.3,1.3,0.4,0.8 SURF_ID='UPHOLSTERY_LOWER'/
&HOLE XB=0.6,1.0,0.2,0.8,0.3,0.9 /
&OBST XB=0.3,1.3,0.3,1.3,1.2,1.6 SURF_ID='UPHOLSTERY_UPPER' /

&VENT XB=0.0,1.6,0.0,0.0,0.0,3.2,SURF_ID='OPEN'/
&VENT XB=1.6,1.6,0.0,1.6,0.0,3.2,SURF_ID='OPEN'/
&VENT XB=0.0,1.6,1.6,1.6,0.0,3.2,SURF_ID='OPEN'/
&VENT XB=0.0,0.0,0.0,1.6,0.0,3.2,SURF_ID='OPEN'/
&VENT XB=0.0,1.6,0.0,1.6,3.2,3.2,SURF_ID='OPEN'/

&ISOF QUANTITY='TEMPERATURE',VALUE(1)=100.0 /  Show 3D contours of temperature at 100 C
&ISOF QUANTITY='TEMPERATURE',VALUE(1)=200.0 /  Show 3D contours of temperature at 200 C
&ISOF QUANTITY='TEMPERATURE',VALUE(1)=620.0 /  Show 3D contours of temperature at 620 C
&ISOF QUANTITY='MIXTURE_FRACTION',VALUE(1)=0.07 /  Show 3D contours of mixture fraction at 0.07
&ISOF QUANTITY='TEMPERATURE',VALUE(1)=200.0, COLOR_QUANTITY='VELOCITY' /  Show 3D contours of temperature at 200

&PART ID='tracers',MASSLESS=.TRUE.,
   QUANTITIES(1:4)='U-VELOCITY','V-VELOCITY','W-VELOCITY'
   SAMPLING_FACTOR=10 /  Description of massless tracer particles. Apply at a
                                                             solid surface with the PART_ID='tracers'

&SLCF PBX=0.8,QUANTITY='TEMPERATURE',VECTOR=.TRUE. /  Add vector slices colored by temperature
&SLCF PBY=0.8,QUANTITY='TEMPERATURE',VECTOR=.TRUE. /
&SLCF PBZ=0.4,QUANTITY='TEMPERATURE',VECTOR=.TRUE. /
&SLCF PBZ=1.6,QUANTITY='TEMPERATURE',VECTOR=.TRUE. /
&SLCF PBZ=3.2,QUANTITY='TEMPERATURE',VECTOR=.TRUE. /
&SLCF XB=0.0,1.6,0.0,1.6,0.0,3.2, QUANTITY='TEMPERATURE',VECTOR=.TRUE. / 3D slice

&SLCF PBX=0.8,QUANTITY='TEMPERATURE',CELL_CENTERED=.TRUE. /
&SLCF PBY=0.8,QUANTITY='TEMPERATURE',CELL_CENTERED=.TRUE. /
&SLCF PBZ=0.4,QUANTITY='TEMPERATURE',CELL_CENTERED=.TRUE. /
&SLCF PBZ=1.6,QUANTITY='TEMPERATURE',CELL_CENTERED=.TRUE. /
&SLCF PBZ=3.2,QUANTITY='TEMPERATURE',CELL_CENTERED=.TRUE. /

&BNDF QUANTITY='GAUGE_HEAT_FLUX' /   Common surface quantities. Good for monitoring fire spread.
&BNDF QUANTITY='BURNING_RATE' /
&BNDF QUANTITY='WALL_TEMPERATURE' /
&BNDF QUANTITY='WALL_TEMPERATURE' CELL_CENTERED=.TRUE. /
```

A.2 fire_line

```
&HEAD CHID='fire_line', TITLE='Test FIRE_LINE keyword,SVN $Revision: 5160 $' /

&MESH IJK=50,50,25, XB=0,50,-25,25,0,25 /

&MISC U0=1,TERRAIN_CASE=.TRUE. /
&TIME TWFIN=60. /

&REAC ID='WOOD'
      FYI='Ritchie, et al., 5th IAFSS, C_3.4 H_6.2 O_2.5, dHc = 15MW/kg'
      SOOT_YIELD = 0.02
      O          = 2.5
      C          = 3.4
      H          = 6.2
      HEAT_OF_COMBUSTION = 17700 /
```

```
&SPEC ID='WATER VAPOR' /

&PART ID='AUF19GRASS',TREE=.TRUE.,QUANTITIES='DROPLET_TEMPERATURE',
      VEG_INITIAL_TEMPERATURE=20.,
      VEG_SV=12240.,VEG_MOISTURE=0.058,VEG_CHAR_FRACTION=0.20,
      VEG_DRAG_COEFFICIENT=0.375,VEG_DENSITY=512.,VEG_BULK_DENSITY=0.626,
      VEG_BURNING_RATE_MAX=0.45,VEG_DEHYDRATION_RATE_MAX=0.45,
      VEG_REMOVE_CHARRED=.TRUE. /

- Ignitor fire
&SURF ID='LINEFIRE',HRRPUA=240,RAMP_Q='RAMPIGN',RGB=255,0,0 /
&RAMP ID='RAMPIGN',T=0,F=0 /
&RAMP ID='RAMPIGN',T=1,F=0 /
&RAMP ID='RAMPIGN',T=2,F=1 /
&RAMP ID='RAMPIGN',T=10,F=1 /
&RAMP ID='RAMPIGN',T=11,F=0 /
&VENT XB=5,6,-15,15,0,0,SURF_ID='LINEFIRE' /

&SURF ID='WIND',VEL=-1 /
&VENT XB =  0,  0, -25,  25,  0, 25, SURF_ID = 'WIND' /
&VENT XB = 50, 50, -25,  25,  0, 25, SURF_ID = 'OPEN' /
&VENT XB =  0, 50, -25, -25,  0, 25, SURF_ID = 'OPEN' /
&VENT XB =  0, 50,  25,  25,  0, 25, SURF_ID = 'OPEN' /
&VENT XB =  0, 50, -25,  25, 25, 25, SURF_ID = 'OPEN' /

- Hill and grass on slope
-- Grass on flat upwind of hill
&TREE XB=5,20,-20,20,0,1,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /

-- upslope
&OBST XB=20,21,-25,25, 0, 1 /
&TREE XB=20,21,-20,20, 1, 2,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /
&OBST XB=21,22,-25,25, 0, 2 /
&TREE XB=21,22,-20,20, 2, 3,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /
&OBST XB=22,23,-25,25, 0, 3 /
&TREE XB=22,23,-20,20, 3, 4,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /
&OBST XB=23,24,-25,25, 0, 4 /
&TREE XB=23,24,-20,20, 4, 5,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /

-- flat top
&OBST XB=24,28,-25,25, 0, 4 /
&TREE XB=24,28,-20,20, 4, 5,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /

-- downslope
&OBST XB=28,29,-25,25, 0, 3 /
&TREE XB=28,29,-20,20, 3, 4,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /
&OBST XB=29,30,-25,25, 0, 2 /
&TREE XB=29,30,-20,20, 3, 3,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /
&OBST XB=30,31,-25,25, 0, 1 /
&TREE XB=30,31,-20,20, 1, 2,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /

-- grass down wind of hill
&TREE XB=31,45,-20,20, 0, 1,PART_ID="AUF19GRASS",FUEL_GEOM="RECTANGLE" /


- Outputs
&DUMP NFRAMES=600 /
&SLCF QUANTITY='TEMPERATURE',VECTOR=.TRUE. AGL_SLICE=1.0/
&SLCF FIRE_LINE=.TRUE./

&TAIL /
```

A.3 smoke_sensor

```
&HEAD CHID='smoke_sensor', TITLE='Test smokesensor device, SVN $Revision: 4751 $' /

  A small white (255,255,255) smokesensor appears over top a grey (128,128,128) obstacle.
  A red dot indicates where the smoke opacity is recorded and should appear in the middle of the
  sensor.  Another check is that the sensor should display 255 (the color fo the sensor) not
  128 (the color of the background).

&MESH IJK=100,64,40, XB=0.0,10.0,0.0,6.4,0.0,4.0 /

&TIME T_END=1.0 /

 define fuel so that it only contains carbon and yields 100% soot
 so that MASS_FRACTION(2) may be used to define soot density directly

&REAC ID         = 'CARBONSOOT'
      FYI        = 'ficticious fuel, 100% soot'
      SOOT_YIELD = 1.0
      SOOT_H_FRACTION = 0.0
      N          = 0.0
      C          = 1.0
      H          = 0.0
      O          = 0.0
      MASS_EXTINCTION_COEFFICIENT=8700.0
 /

&INIT MASS_FRACTION(2)=0.00007967 DENSITY=1.0/

&OBST XB=0.0,10.0,6.3,6.4,0.0,4.0 RGB=128,128,128/
&PROP ID='smoketest' SMOKEVIEW_ID='smokesensor' /
&DEVC XYZ=8.5,6.0,0.50, ID='vis1' QUANTITY='TEMPERATURE' PROP_ID='smoketest' /

&TAIL /
```

A.4 smoke_test

```
&HEAD CHID='smoke_test', TITLE='Verify Smokeview Smoke3D Feature, SVN $Revision: 4751 $' /

  A quantitative test of the smoke opacity calculation in Smokeview.  This test simplifies
  the general case by assuming a uniform distribution of smoke.  Smoke grey levels are computed
  using

     grey level (GL) = 255*exp(-K*S*DX)

  where K=8700 m2/kg is the mass extinction value, S=79.67 mg/m3 is the soot sensity
  and DX is the path length through the smoke.  This equation is inverted to obtain

    DX = -LN(GL/255)/(K*S)

  and is used to place smoke sensors at particular distances so that the predicted
  grey levels are 192, 128, 64, 32, 16 and 8 .

&MESH IJK=100,64,40, XB=0.0,10.0,0.0,6.4,0.0,4.0 /

&TIME T_END=1.0 /

 specify soot density using MASS_FRACTION(2)


 define fuel so that it only contains carbon and yields 100% soot
 so that MASS_FRACTION(2) may be used directly to define soot density

&REAC ID         = 'CARBONSOOT'
      FYI        = 'ficticious fuel, 100% soot'
```

```
      SOOT_YIELD = 1.0
      SOOT_H_FRACTION = 0.0
      N          = 0.0
      C          = 1.0
      H          = 0.0
      O          = 0.0
      MASS_EXTINCTION_COEFFICIENT=8700.0
 /

&INIT MASS_FRACTION(2)=0.00007967 DENSITY=1.0/

&OBST XB=0.0,2.5, 0.45,0.5,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,4.0, 1.05,1.1,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,5.5, 2.05,2.1,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,7.0, 3.05,3.1,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,8.5, 4.05,4.2,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,10.0,5.05,5.3,0.0,4.0, RGB=255,255,255 /

&PROP ID='smoketest' SMOKEVIEW_ID='smokesensor' /
&DEVC XYZ=1.75,0.45,2.00, QUANTITY='visibility', ID='vis1' PROP_ID='smoketest' /
&DEVC XYZ=3.25,1.05,2.00, QUANTITY='visibility', ID='vis2' PROP_ID='smoketest' /
&DEVC XYZ=4.75,2.05,2.00, QUANTITY='visibility', ID='vis3' PROP_ID='smoketest' /
&DEVC XYZ=6.25,3.05,2.00, QUANTITY='visibility', ID='vis4' PROP_ID='smoketest' /
&DEVC XYZ=7.75,4.05,2.00, QUANTITY='visibility', ID='vis5' PROP_ID='smoketest' /
&DEVC XYZ=9.25,5.05,2.00, QUANTITY='visibility', ID='vis6' PROP_ID='smoketest' /

&SLCF PBX=5.0, QUANTITY='soot density' /
&SLCF PBY=5.0, QUANTITY='soot density' /
&SLCF PBZ=2.0, QUANTITY='soot density' /

&TAIL /
```

A.5 smoke_test2

```
&HEAD CHID='smoke_test2', TITLE='Verify Smokeview Smoke3D Feature, SVN $Revision: 2155 $' /

&MESH IJK=40,40,40, XB=0.0,10.0,0.0,10.0,0.0,4.0 /

&TIME T_END=1.0 /

 specify soot density using MASS_FRACTION(2)


 define fuel so that it only contains carbon and yields 100% soot
 so that MASS_FRACTION(2) may be used to define soot density directly

&REAC ID         = 'CARBONSOOT'
      FYI        = 'ficticious fuel, 100% soot'
      SOOT_YIELD = 1.0
      SOOT_H_FRACTION = 0.0
      N          = 0.0
      C          = 1.0
      H          = 0.0
      O          = 0.0
      MASS_EXTINCTION_COEFFICIENT=8700.0
 /

&INIT MASS_FRACTION(2)=0.00007967 DENSITY=1.0/

&OBST XB=0.0,2.5, 0.4,0.5,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,4.0, 1.0,1.1,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,5.5, 2.0,2.1,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,7.0, 3.0,3.1,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,8.5, 4.1,4.2,0.0,4.0, RGB=255,255,255 /
&OBST XB=0.0,10.0,5.2,5.3,0.0,4.0, RGB=255,255,255 /
```

```
&SLCF PBX=5.0, QUANTITY='soot density' /
&SLCF PBY=5.0, QUANTITY='soot density' /
&SLCF PBZ=2.0, QUANTITY='soot density' /

&PROP ID='smoketest' SMOKEVIEW_ID='smokesensor' /
&DEVC XYZ=1.75,0.30,2.00, QUANTITY='visibility', ID='vis2' PROP_ID='smoketest' /
&DEVC XYZ=3.25,0.90,2.00, QUANTITY='visibility', ID='vis3' PROP_ID='smoketest' /
&DEVC XYZ=4.75,1.90,2.00, QUANTITY='visibility', ID='vis4' PROP_ID='smoketest' /
&DEVC XYZ=6.25,2.90,2.00, QUANTITY='visibility', ID='vis5' PROP_ID='smoketest' /
&DEVC XYZ=7.75,4.00,2.00, QUANTITY='visibility', ID='vis6' PROP_ID='smoketest' /
&DEVC XYZ=9.25,5.10,2.00, QUANTITY='visibility', ID='vis7' PROP_ID='smoketest' /


&TAIL /
```

A.6 transparency

```
&HEAD CHID='transparency', TITLE='Test of transparent vents SVN $Revision: 2722 $' /
&MESH IJK=10,10,10, XB=0.0,1.0,0.0,1.0,0.0,1.0 /

&TIME TWFIN=0.0 /

&SURF ID='BURNER',HRRPUA=600.0 /

&MISC RADIATION=.FALSE., LAPSE_RATE=10.0, TMPA=10. /

&SLCF PBY=0.6, QUANTITY='TEMPERATURE' /

&VENT MB='XMIN', SURF_ID='BURNER' RGB=255,0,0 TRANSPARENCY=0.6/
&VENT MB='XMAX', SURF_ID='OPEN' /

&OBST XB=0.2,0.4,0.2,0.4,0.2,0.6 RGB=0,255,0/
&OBST XB=0.6,0.8,0.2,0.4,0.2,0.6 RGB=0,0,255 TRANSPARENCY=0.2 /



&TAIL /
```

A.7 colorbar

```
&HEAD CHID='colorbar', TITLE='Test of colorbar selection' /
REM This test case is used to test Smokeview's ability to
REM correctly select the colorbar and shade the appropriate
REM region black.

REM To do this,
REM  1) press "g" to turn on the grid.
REM  2) "Page Up" and put a horizonal grid slice "somewhere"
REM  3) select the colorbar, centering the resulting black band
REM     on the horizontal grid plane. Note the value.
REM  4) Use the File/BOunds dialog box to change the min and or max
REM     setting for the temperature slice file.
REM  5) repeaset setp 3.  Value noted should remain the same.

&MESH IJK=20,10,10, XB=0.0,2.0,0.0,1.0,0.0,1.0 /

&TIME TWFIN=10.0 /

&MISC RADIATION=.FALSE., LAPSE_RATE=10.0, TMPA=10. /

&SLCF PBY=0.6, QUANTITY='TEMPERATURE' /
```

```
&VENT MB='XMAX', SURF_ID='OPEN' /
&VENT MB='YMAX', SURF_ID='OPEN' /
&VENT MB='ZMAX', SURF_ID='OPEN' /
&VENT MB='XMIN', SURF_ID='OPEN' /
&VENT MB='YMIN', SURF_ID='OPEN' /
&VENT MB='ZMIN', SURF_ID='OPEN' /


&TAIL /
```

A.8 colorconv

```
A simple two-dimensional case testing data to color conversion

&HEAD CHID='colorconv', TITLE='Test data to color conversion, SVN $Revision: 4751 $' /
&DUMP NFRAMES=4000 /

&MESH IJK=100,1,100, XB=0.0,100.0,-1.0,1.0,0.0,100.0 /
&SURF ID='COOLWALL' TMP_FRONT=20.0 /
&SURF ID='HOTWALL' TMP_FRONT=100.0 /
&SURF ID='INSWALL' ADIABATIC=.TRUE. /

&TIME T_END=1000.0 /

&MISC RADIATION=.FALSE. /
&INIT XB= 0.0, 50.0,-2.0,2.0,0.0,100.0, TEMPERATURE=20. /
&INIT XB=50.0,100.0,-2.0,2.0,0.0,100.0, TEMPERATURE=100. /

&OBST XB= 0.0, 100.0, -2.0,2.0,0.0,1.0, SURF_ID='COOLWALL' /
&OBST XB= 0.0, 100.0, -2.0,2.0,99.0,100.0, SURF_ID='HOTWALL' /
&OBST XB= 0.0, 1.0, -2.0, 2.0, 1.0, 99.0 SURF_ID='INSWALL' /
&OBST XB= 99.0, 100.0, -2.0, 2.0, 1.0, 99.0 SURF_ID='INSWALL' /

&SLCF PBY=0.0, QUANTITY='TEMPERATURE' /

&TAIL /
```

Appendix B

Smokeview Scripts

B.1 plume5c

```
// put rendered files in specified directory

RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures

// render slice files

UNLOADALL
LOADINIFILE
 plume5c_slice.ini
LOADFILE
 plume5c_05.sf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_slice_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_slice_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_slice_30

// render cell centered slice files

UNLOADALL
LOADINIFILE
 plume5c_slice_cell.ini
LOADFILE
 plume5c_26.sf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_slice_cell_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_slice_cell_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_slice_cell_30

// render slice files with data chopping
```

```
UNLOADALL
LOADINIFILE
 plume5c_slicechop.ini
LOADFILE
 plume5c_05.sf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_slice_chop_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_slice_chop_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_slice_chop_30

// render vector slice files

UNLOADALL
LOADINIFILE
 plume5c_vslice.ini
LOADVFILE
 plume5c_05.sf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_vslice_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_vslice_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_vslice_30

// render vector slice files with chopping

UNLOADALL
LOADINIFILE
 plume5c_vslicechop.ini
LOADVFILE
 plume5c_05.sf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_vslicechop_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_vslicechop_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_vslicechop_30

// render iso files (solid)

UNLOADALL
UNLOADALL
LOADINIFILE
 plume5c_iso.ini
LOADFILE
 plume5c_01.iso
SETTIMEVAL
```

```
 0.0
RENDERONCE
 plume5c_iso_solid_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_iso_solid_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_iso_solid_30

// render iso files (solid with normals)

LOADINIFILE
 plume5c_iso_normal.ini
LOADFILE
 plume5c_01.iso
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_iso_solid_normal_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_iso_solid_normal_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_iso_solid_normal_30

// render iso files (outline)

LOADINIFILE
 plume5c_iso_outline.ini
UNLOADALL
LOADFILE
 plume5c_01.iso
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_iso_outline_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_iso_outline_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_iso_outline_30

// render iso files (points)

LOADINIFILE
 plume5c_iso_points.ini
UNLOADALL
LOADFILE
 plume5c_01.iso
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_iso_points_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_iso_points_10
SETTIMEVAL
 30.05
```

```
RENDERONCE
 plume5c_iso_points_30

// render particle files using points

LOADINIFILE
 plume5c_part.ini
UNLOADALL
LOADFILE
 plume5c.prt5
PARTCLASSCOLOR
 Uniform color
SETTIMEVAL
 1.05
RENDERONCE
 plume5c_part_01
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_part_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_part_30

// render particle files using streaks

UNLOADALL
LOADINIFILE
 plume5c_part_streak.ini
LOADFILE
 plume5c.prt5
PARTCLASSCOLOR
 Uniform color
SETTIMEVAL
 1.05
RENDERONCE
 plume5c_part_streak_01
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_part_streak_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_part_streak_30

// render particles using streaks (different length)

UNLOADALL
LOADINIFILE
 plume5c_part_streak2.ini
LOADFILE
 plume5c.prt5
PARTCLASSCOLOR
 Uniform color
SETTIMEVAL
 1.05
RENDERONCE
 plume5c_part_streak2_01
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_part_streak2_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_part_streak2_30
```

```
// render boundary files

UNLOADALL
LOADINIFILE
 plume5c_bound.ini
LOADFILE
 plume5c_03.bf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_bound_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_bound_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_bound_30

// render cell centered boundary files

UNLOADALL
LOADINIFILE
 plume5c_bound.ini
LOADFILE
 plume5c_04.bf
SETTIMEVAL
 0.0
RENDERONCE
 plume5c_bound_cell_00
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_bound_cell_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_bound_cell_30

// render 3D smoke files

UNLOADALL
LOADFILE
 plume5c_01.s3d
LOADFILE
 plume5c_02.s3d
SETTIMEVAL
 1.05
RENDERONCE
 plume5c_smoke_01
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_smoke_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_smoke_30

// render PLOT3D stepped contours

UNLOADALL
LOADINIFILE
 plume5c_plot3d_step.ini
LOADPLOT3D
 1 40.0
```

```
RENDERONCE
 plume5c_plot3d_step

// render PLOT3D line contours

UNLOADALL
LOADINIFILE
 plume5c_plot3d_line.ini
LOADPLOT3D
 1 40.0
RENDERONCE
 plume5c_plot3d_line

// render PLOT3D continuous contours

UNLOADALL
LOADINIFILE
 plume5c_plot3d_shaded.ini
LOADPLOT3D
 1 40.0
RENDERONCE
 plume5c_plot3d_shaded


// render OBSTs using solid view

UNLOADALL
LOADINIFILE
 plume5c_solid.ini
RENDERONCE
 plume5c_solid

// render OBSTs using outline view

LOADINIFILE
 plume5c_outline.ini
RENDERONCE
 plume5c_outline

// render geometry using hidden view (ie don't draw OBSTs)

LOADINIFILE
 plume5c_hidden.ini
RENDERONCE
 plume5c_hidden

// render vents - don't show open vents

LOADINIFILE
 plume5c_noopenvents.ini
SETVIEWPOINT
 external
RENDERONCE
 plume5c_noopen

// render vents - don't show any vents

LOADINIFILE
 plume5c_novents.ini
SETVIEWPOINT
 external
RENDERONCE
 plume5c_novents

// render vents - show all vents

LOADINIFILE
 plume5c_allvents.ini
```

```
SETVIEWPOINT
 external
RENDERONCE
 plume5c_allvents

// render 3D smoke GPU off

UNLOADALL
LOADINIFILE
 plume5c_nongpu.ini
LOADFILE
 plume5c_01.s3d
LOADFILE
 plume5c_02.s3d
SETTIMEVAL
 5.05
RENDERONCE
 plume5c_smoke_nongpu_05
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_smoke_nongpu_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_smoke_nongpu_30

// render 3D smoke GPU on

UNLOADALL
LOADINIFILE
 plume5c_gpu.ini
LOADFILE
 plume5c_01.s3d
LOADFILE
 plume5c_02.s3d
SETTIMEVAL
 5.05
RENDERONCE
 plume5c_smoke_gpu_05
SETTIMEVAL
 10.05
RENDERONCE
 plume5c_smoke_gpu_10
SETTIMEVAL
 30.05
RENDERONCE
 plume5c_smoke_gpu_30

// render PLOT3D contours

UNLOADALL
LOADINIFILE
 plume5c_plot3d.ini
LOADPLOT3D
 1 40.009998
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.800000
SHOWPLOT3DDATA
 1 3 1 1 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_y1
```

```
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.600000
SHOWPLOT3DDATA
 1 3 1 1 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_y2
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.400000
SHOWPLOT3DDATA
 1 3 1 1 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_y3
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.200000
SHOWPLOT3DDATA
 1 3 1 1 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_y4

// render PLOT3D vectors

SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.800000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 1 6 1
RENDERONCE
plume5c_plot3d_v1
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.600000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 1 6 1
RENDERONCE
plume5c_plot3d_v2
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.400000
SHOWPLOT3DDATA
```

```
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 1 6 1
RENDERONCE
plume5c_plot3d_v3
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 1 0.200000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 0 6
PLOT3DPROPS
 1 1 6 1
RENDERONCE
plume5c_plot3d_v4
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 0 0.400000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 1 3
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_i1

// render PLOT3D iso-surface

SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 0 0.400000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 1 5
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_i2
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 0 0.400000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 1 7
PLOT3DPROPS
 1 0 6 1
RENDERONCE
plume5c_plot3d_i3
SHOWPLOT3DDATA
 1 1 1 0 0.800000
SHOWPLOT3DDATA
 1 2 1 0 0.400000
SHOWPLOT3DDATA
 1 3 1 0 1.600000
SHOWPLOT3DDATA
 1 4 1 1 9
PLOT3DPROPS
 1 0 6 1
```

```
RENDERONCE
plume5c_plot3d_i4
```

B.2 fire_line

B.3 smoke_sensor

```
RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
SETVIEWPOINT
 external
RENDERONCE
 smoke_sensor_c
SETVIEWPOINT
 view 1
RENDERONCE
 smoke_sensor_l
SETVIEWPOINT
 view 2
RENDERONCE
 smoke_sensor_r
```

B.4 smoke_test

```
RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
UNLOADALL
LOADFILE
 smoke_test_01.s3d
SETTIMEVAL
 0.159000
LOADINIFILE
 smoke_test_all.ini
RENDERONCE
 smoke_test_all
LOADINIFILE
 smoke_test_every2.ini
RENDERONCE
 smoke_test_every2
LOADINIFILE
 smoke_test_every3.ini
RENDERONCE
 smoke_test_every3
UNLOADALL
LOADINIFILE
 smoke_test.ini
SETVIEWPOINT
 view 1
RENDERONCE
 smoke_test_side
```

B.5 smoke_test2

```
RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
UNLOADALL
LOADFILE
 smoke_test2_01.s3d
SETTIMEVAL
```

```
 0.159000
LOADINIFILE
 smoke_test2_all.ini
RENDERONCE
 smoke_test2_all
LOADINIFILE
 smoke_test2_every2.ini
RENDERONCE
 smoke_test2_every2
LOADINIFILE
 smoke_test2_every3.ini
RENDERONCE
 smoke_test2_every3
```

B.6 sprinkler_many

```
RENDERDIR
  ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
SETVIEWPOINT
 view1
RENDERONCE
 sprink_many_view1
RENDERONCE
 sprink_many_view1
SETVIEWPOINT
 view2
RENDERONCE
 sprink_many_view2
SETVIEWPOINT
 view3
RENDERONCE
 sprink_many_view3
```

B.7 transparency

```
RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
SETVIEWPOINT
 view_left
RENDERONCE
 transparency_left
RENDERONCE
 transparency_left
SETVIEWPOINT
 view_center
RENDERONCE
 transparency_center
SETVIEWPOINT
 view_right
RENDERONCE
 transparency_right
```

B.8 colorbar

```
RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
LOADFILE
 colorbar_01.sf
SETTIMEVAL
 9.961175
```

```
LOADINIFILE
 colorbar_low.ini
SETVIEWPOINT
 view1
SETVIEWPOINT
 view1
RENDERONCE
 colorbar_low
RENDERONCE
 colorbar_low
LOADINIFILE
 colorbar_med.ini
SETVIEWPOINT
 view1
SETVIEWPOINT
 view1
RENDERONCE
 colorbar_med
RENDERONCE
 colorbar_med
LOADINIFILE
 colorbar_high.ini
SETVIEWPOINT
 view1
SETVIEWPOINT
 view1
RENDERONCE
 colorbar_high
RENDERONCE
 colorbar_high
```

B.9 colorconv

```
RENDERDIR
 ..\..\Manuals\SMV_5_Verification_Guide\scriptfigures
LOADINIFILE
 colorconv_slice.ini
LOADFILE
 colorconv_01.sf
SETTIMEVAL
 0.000000
RENDERONCE
 colorconv_slice_00000
SETTIMEVAL
 2.557976
RENDERONCE
 colorconv_slice_00025
SETTIMEVAL
 5.039277
RENDERONCE
 colorconv_slice_00050
SETTIMEVAL
 7.506437
RENDERONCE
 colorconv_slice_00075
SETTIMEVAL
 10.023949
RENDERONCE
 colorconv_slice_00100
SETTIMEVAL
 12.538355
RENDERONCE
 colorconv_slice_00125
SETTIMEVAL
 15.063926
```

```
RENDERONCE
 colorconv_slice_00150
SETTIMEVAL
 17.526268
RENDERONCE
 colorconv_slice_00175
SETTIMEVAL
 20.040606
RENDERONCE
 colorconv_slice_00200
SETTIMEVAL
 22.521618
RENDERONCE
 colorconv_slice_00225
SETTIMEVAL
 25.042652
RENDERONCE
 colorconv_slice_00250
SETTIMEVAL
 27.545835
RENDERONCE
 colorconv_slice_00275
SETTIMEVAL
 30.060387
RENDERONCE
 colorconv_slice_00300
SETTIMEVAL
 32.531887
RENDERONCE
 colorconv_slice_00325
SETTIMEVAL
 35.000896
RENDERONCE
 colorconv_slice_00350
SETTIMEVAL
 1000.157959
RENDERONCE
 colorconv_slice_10000
UNLOADALL
```