

Advanced Training: Selected Post-Processing Topics

Rosemary Clark
CFPD, LLC

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Outline

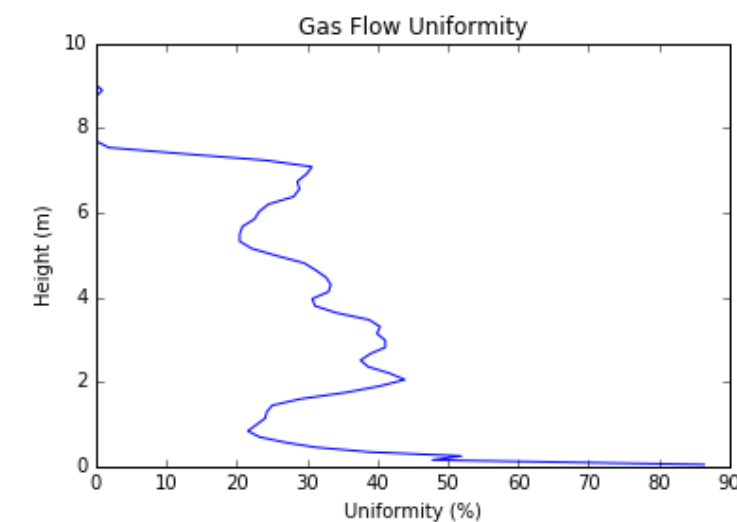
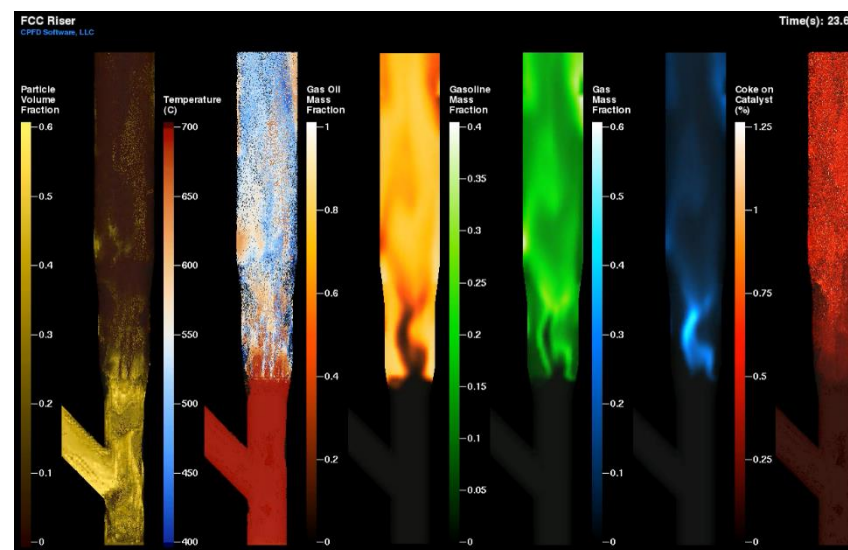
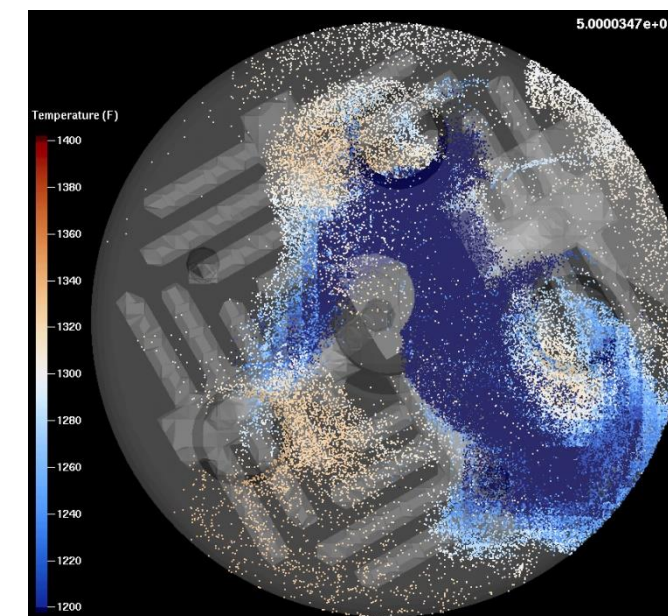
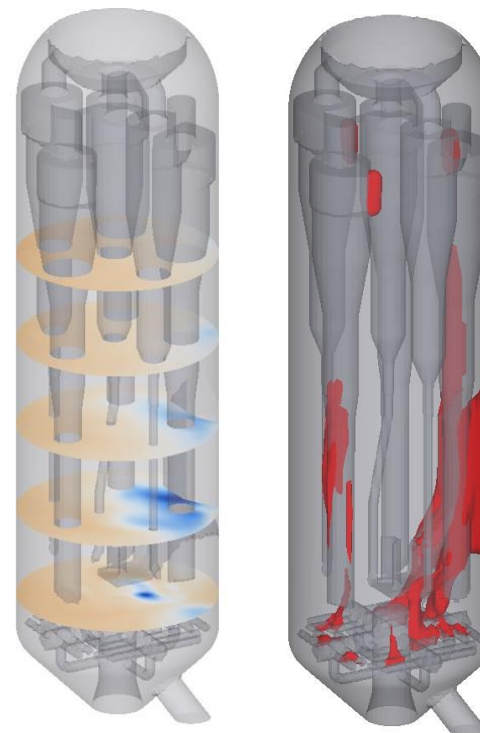
Cutplanes and colormaps

Isovolumes

Particle select

Montage animations

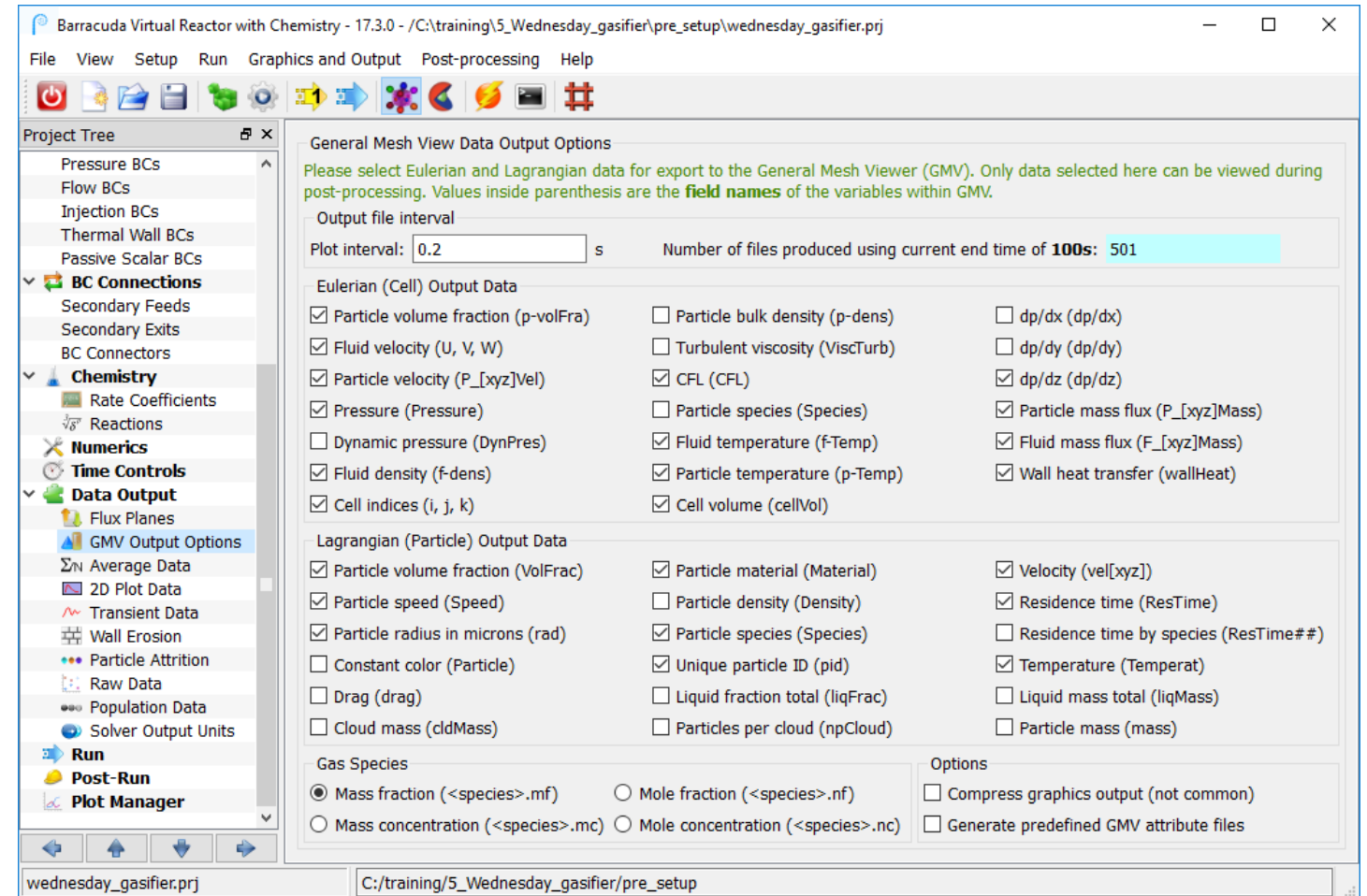
Uniformity



Easy to Say, Easy to Forget: Select All Desired Output

Double-check *Data Output* options

- *GMV Output Options*: make sure you have all necessary variables selected
- *Average Data*: select data and set a good *Averaging start time*
- *Raw Data*: select data and set a good *Time interval*



Cutplanes

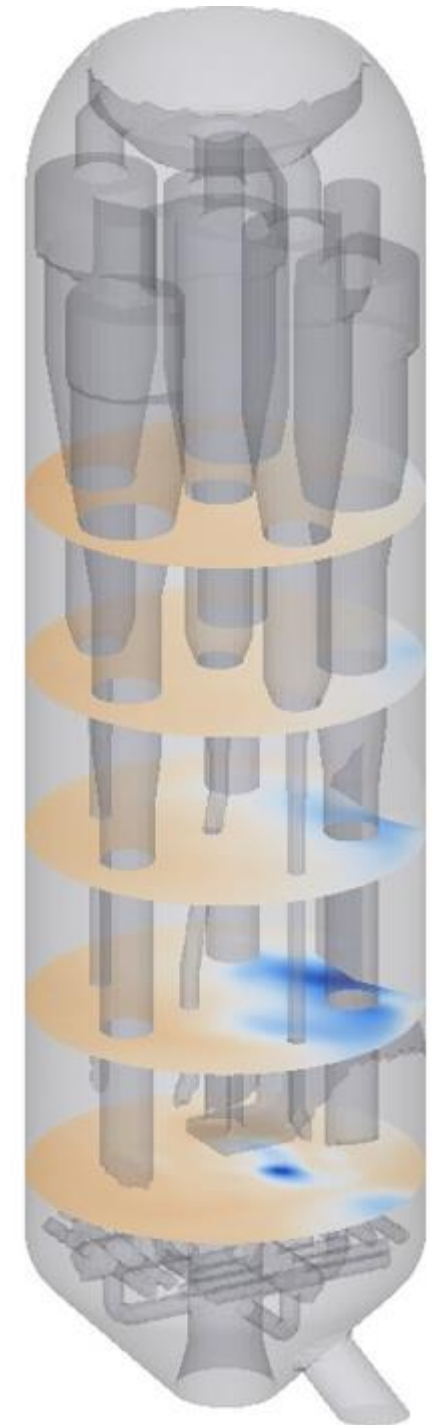
Ability to view multiple cutplanes simultaneously can be helpful during presentation of results

- GMV has a limit of 5 cutplanes
- Possible to use image processing techniques to create images that show more than 5 cutplanes

<http://cpfd-software.com/customer-support/knowledge-base/using-cutplanes-in-gmv>

Can be used with:

- Any GMV output data and field calculations
- Animations and BATCHMOVIE.sh



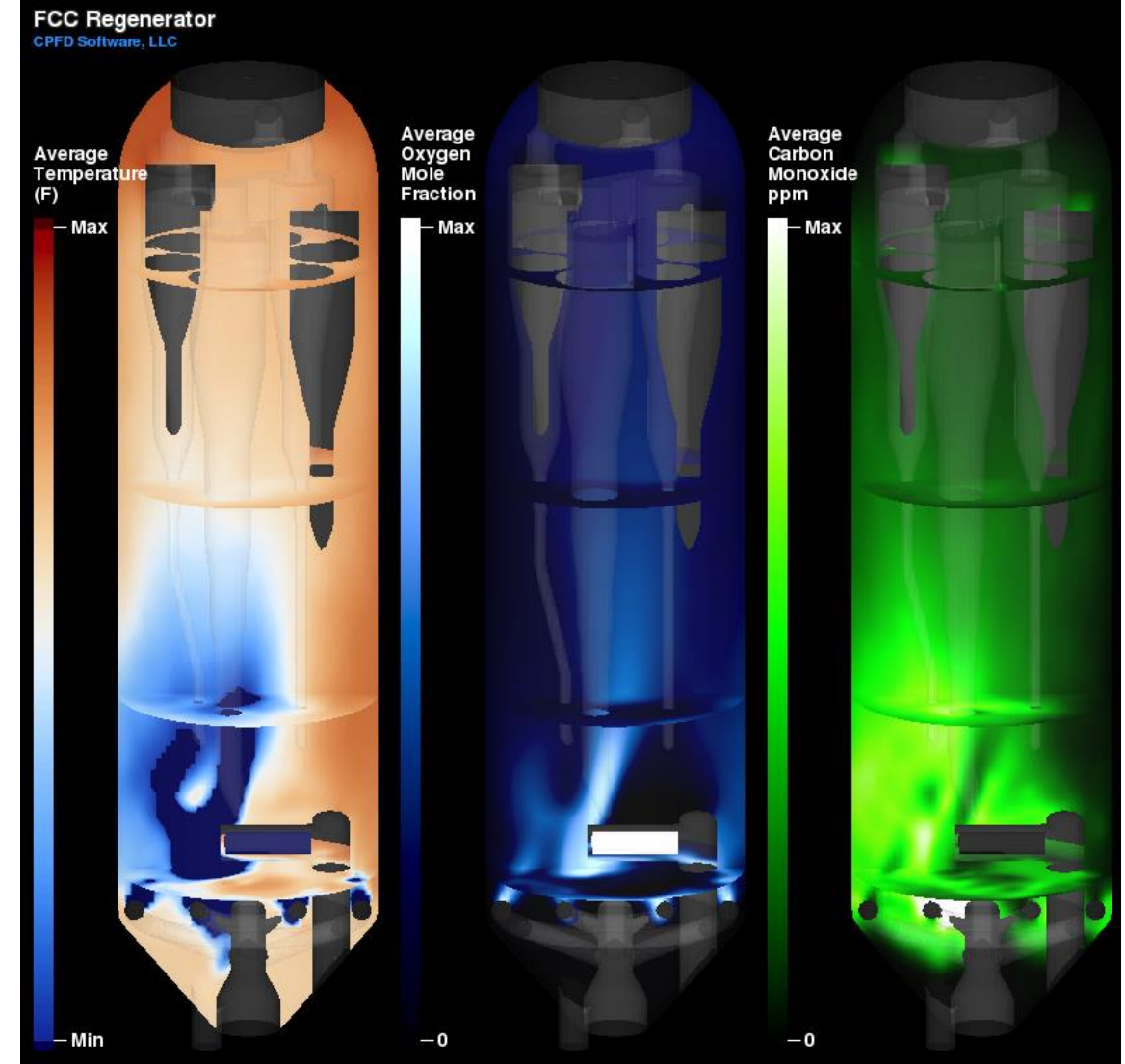
Colormaps

Use colormaps to show results in an intuitive way

- Which color scheme is the most natural for this type of data?
- Could different colors be used to communicate a message?

Several custom colormaps are included in the cpfdHQ directory

- C:\Program Files\CPFD\Barracuda\17.3.0\cpfdHQ\gmv_cmap
- ~/CPFD/Barracuda/17.3.0/cpfdHQ/gmv_cmap



cool-warm.cmap

Colormap Editor

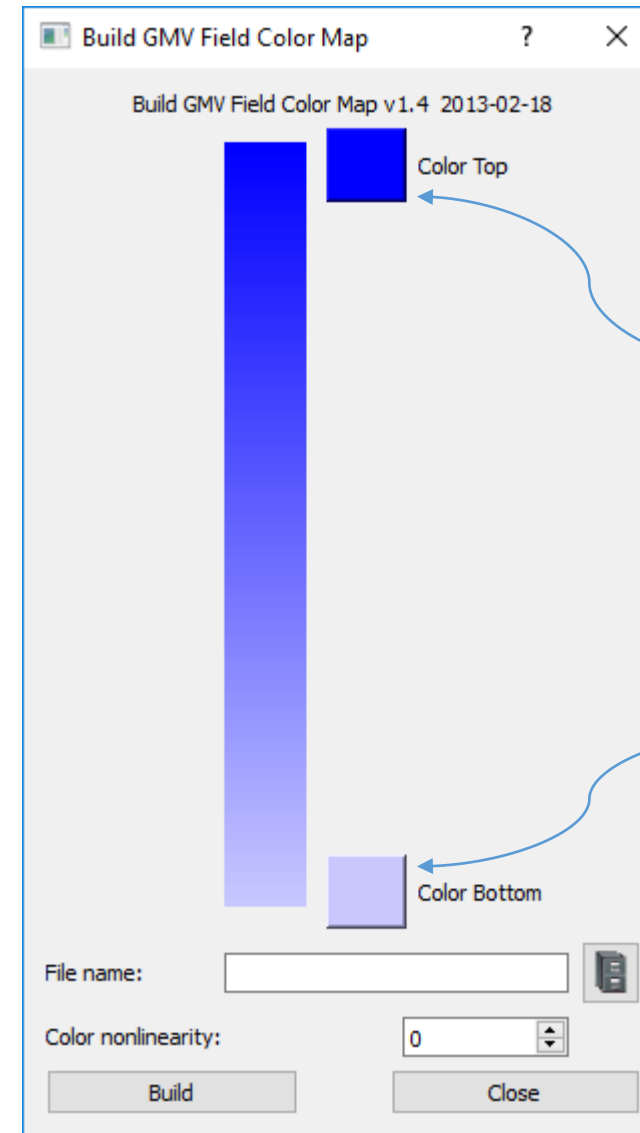
Tool bundled with Virtual Reactor

- *Post-processing, Launch bldcol*

Useful for creating 2-color gradients

- Light-brown to dark-brown for sand
- Dark color to white for gas species

<https://cpfd-software.com/user-manual/post-run#colormap-editor>



Click the top color square to set the "high" scale color

Click the bottom color square to set the "low" scale color

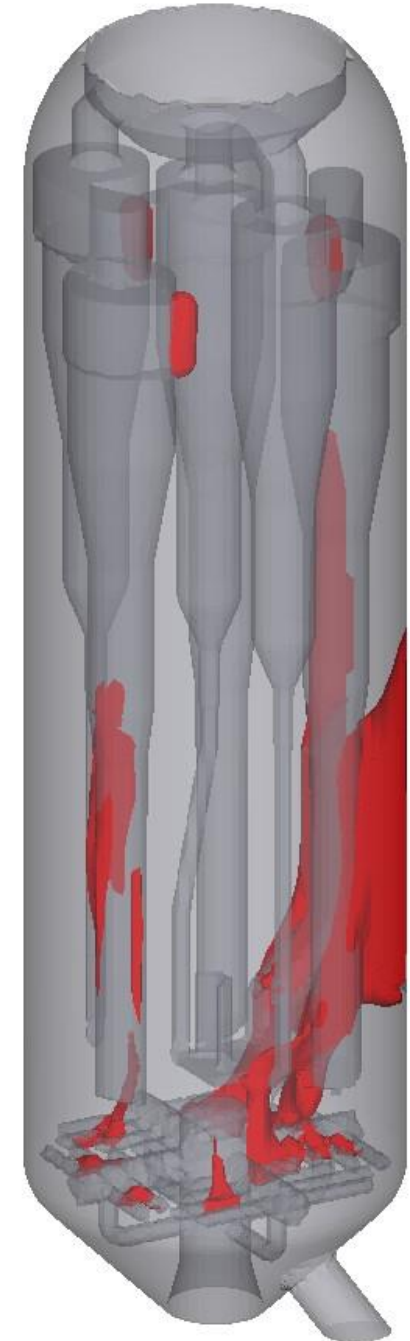
Isovolumes

Show spatial regions meeting specified criteria

- What are high velocity regions?
- Where are particles near close-pack?

General procedure

- Use a *View Particle Data* shortcut in **Post-Run**
- Turn off particles
- Use GMV's dialog *Calculate, Isovolume*
- Use GMV's dialog *Ctl-1, Coloredit, Materials, Isosurfaces, Isovolume* to set constant color



Particle Select

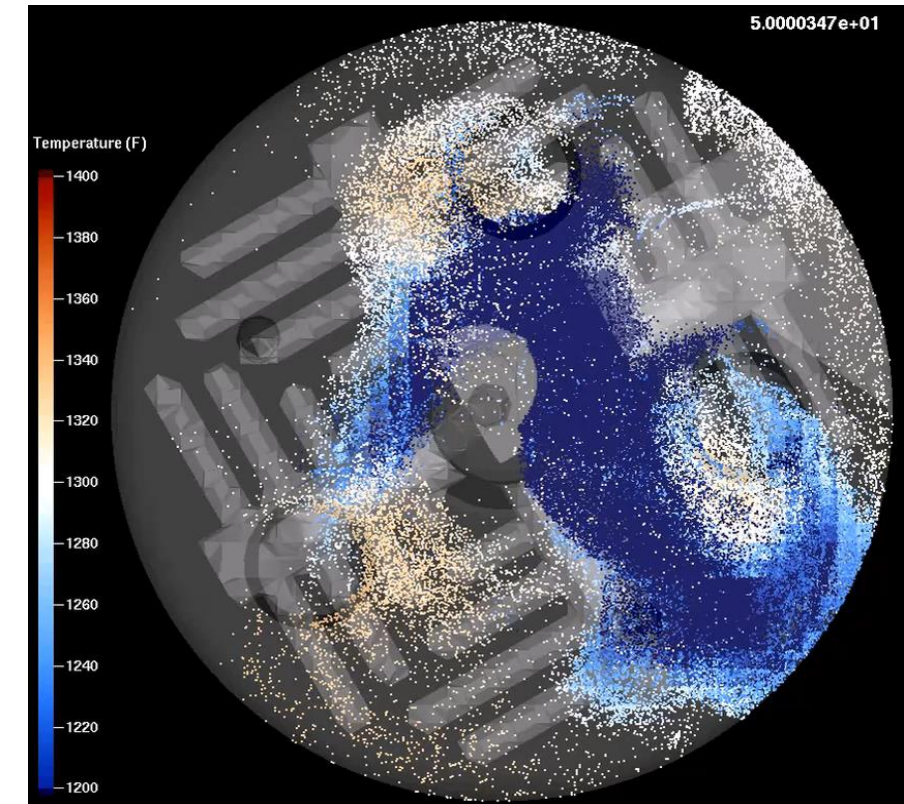
Useful to focus on particles of interest

- Can specify display criteria based on any particle field
- Multiple criteria variables can be used

Can be used in animations

General procedure

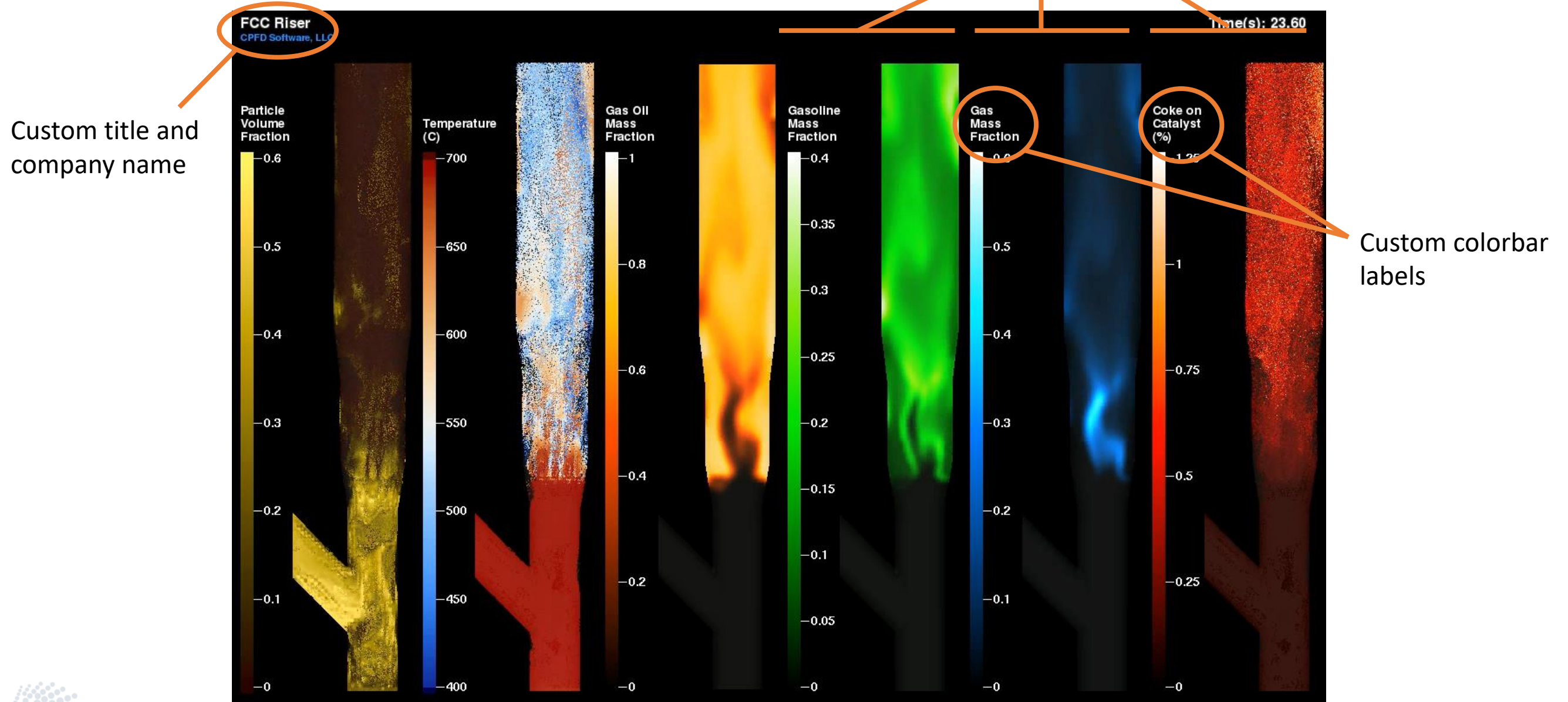
- Use a *View Particle Data* shortcut in **Post-Run**
- Use GMV's dialog *Display, Particles*
- Click *Select* button and specify criteria



Particles selected based on residence time,
 $t \leq 10$ s

Montage animations with masks

Multiple animations side-by-side



Create Individual Animations with BATCHMOVIE.sh

Create GMV attribute files

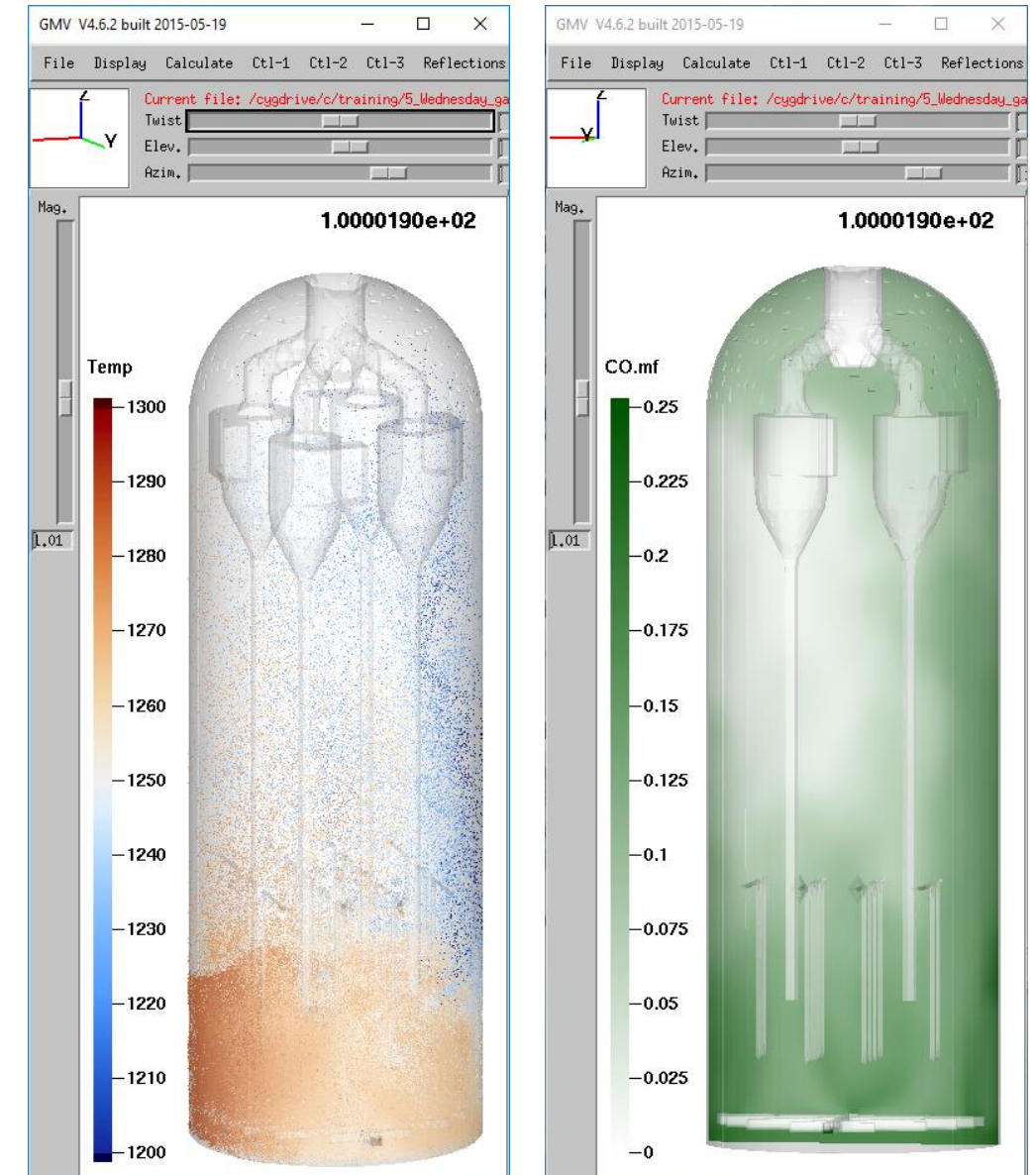
- GMV menu *File, Put Attributes*
- No spaces in file names
- Don't forget ".attr" extension

Use BATCHMOVIE.sh to create all movies

- Use a shell script (MAKE_ANIMATIONS.sh)

```
#!/bin/bash
```

```
BATCHMOVIE.sh particles_temperature.attr  
BATCHMOVIE.sh gas_CO_mass_fraction.attr
```



Side-by-Side Animations: MULTIFRAME.tcl

Add a MULTIFRAME.tcl command to the shell script

```
#!/bin/bash
```

```
BATCHMOVIE.sh particles_temperature.attr  
BATCHMOVIE.sh gas_CO_mass_fraction.attr
```

```
MULTIFRAME.tcl h -sub combined -name combined \  
                particles_temperature \  
                gas_CO_mass_fraction
```

Even if we run the script many times, BATCHMOVIE.sh is smart enough to only make new images if necessary

Backslash is a continuation character so that we can break the long command over multiple lines

When the script is run, a new sub-folder will be created with the combined images

- The subfolder will be named: **combined**

Creating a Transparent Mask with Text: GIMP

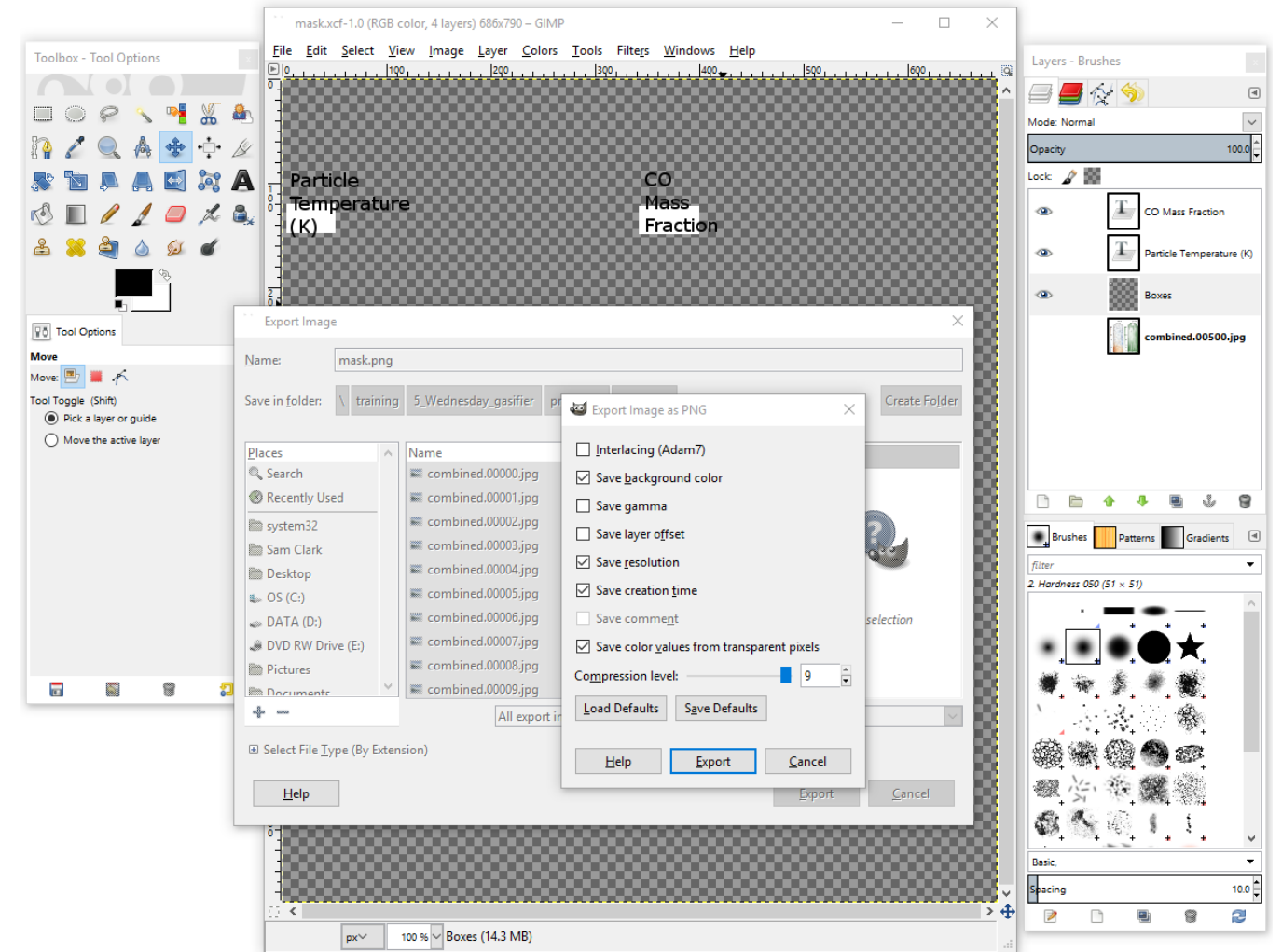
Open one of the combined frames using GIMP

- Other advanced image editors would also work
- GIMP is available at www.gimp.org

Work with Layers to create mask

- Transparent layer for boxes
- Text objects in separate layers
- Final step: hide original image layer

Export mask as PNG with transparency



Putting Mask on Frames: ADDLOGO.tcl

Continuing with the script, use ADDLOGO.tcl to overlay the mask onto the combined images

```
#!/bin/bash
```

```
BATCHMOVIE.sh particles_temperature.attr  
BATCHMOVIE.sh gas_CO_mass_fraction.attr
```

```
MULTIFRAME.tcl h -sub combined -name combined \  
                particles_temperature \  
                gas_CO_mass_fraction
```

```
cd combined  
ADDLOGO.tcl combined*.jpg -logo mask.png noresize  
cd ../
```

Use the “noresize” option since the mask is exactly the same size as the images onto which it is overlaid

Assembling the Final Animation: jpg2mpg / jpg2mp4

Create the final animation file

- mpg format works well on Linux (xanim)
- mp4 format works well on Windows (Media Player)

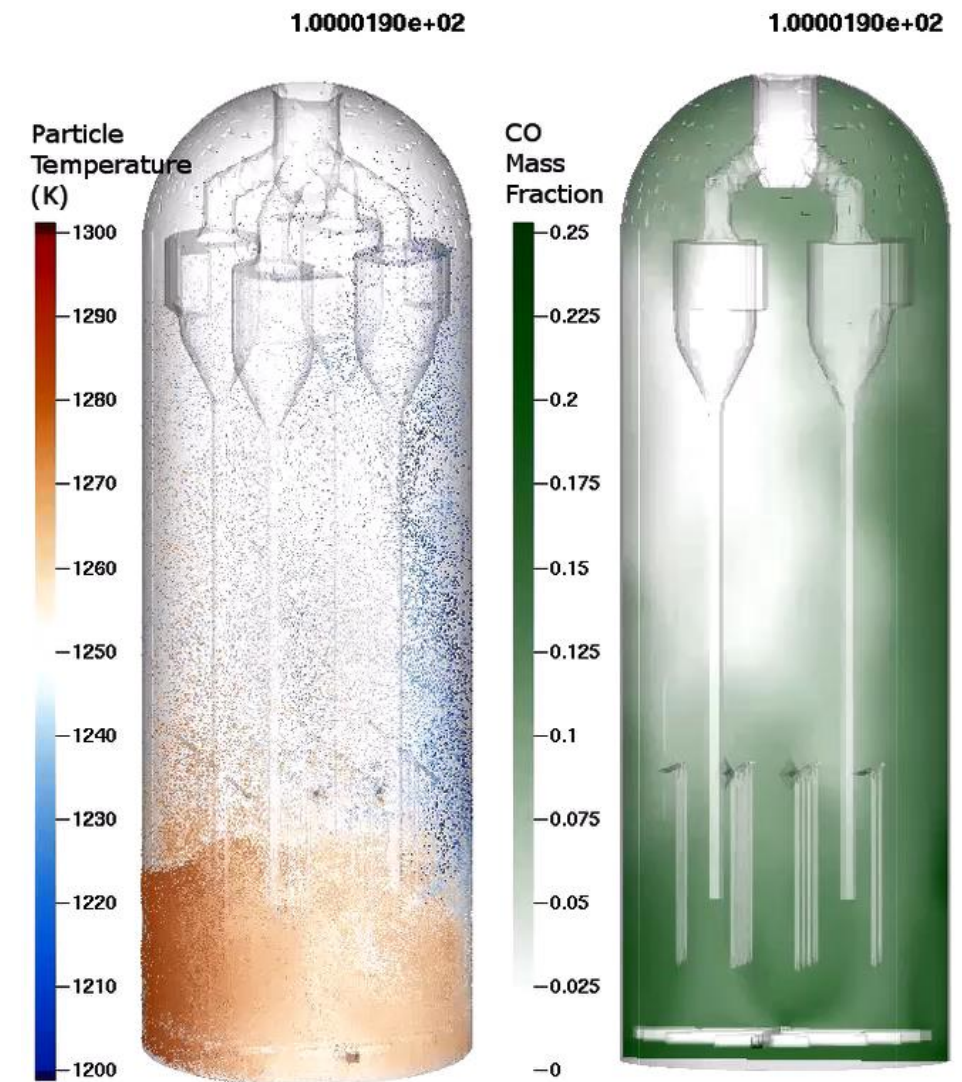
```
#!/bin/bash
```

```
BATCHMOVIE.sh particles_temperature.attr  
BATCHMOVIE.sh gas_CO_mass_fraction.attr
```

```
MULTIFRAME.tcl h -sub combined -name combined \  
                particles_temperature \  
                gas_CO_mass_fraction
```

```
cd combined  
ADDLOGO.tcl combined*jpg -logo mask.png noresize  
cd ../
```

```
jpg2mpg combined/logo_combined*jpg -o side_by_side_montage.mpg  
jpg2mp4 combined/logo_combined*jpg -o side_by_side_montage.mp4
```



Calculating Gas Uniformity Index

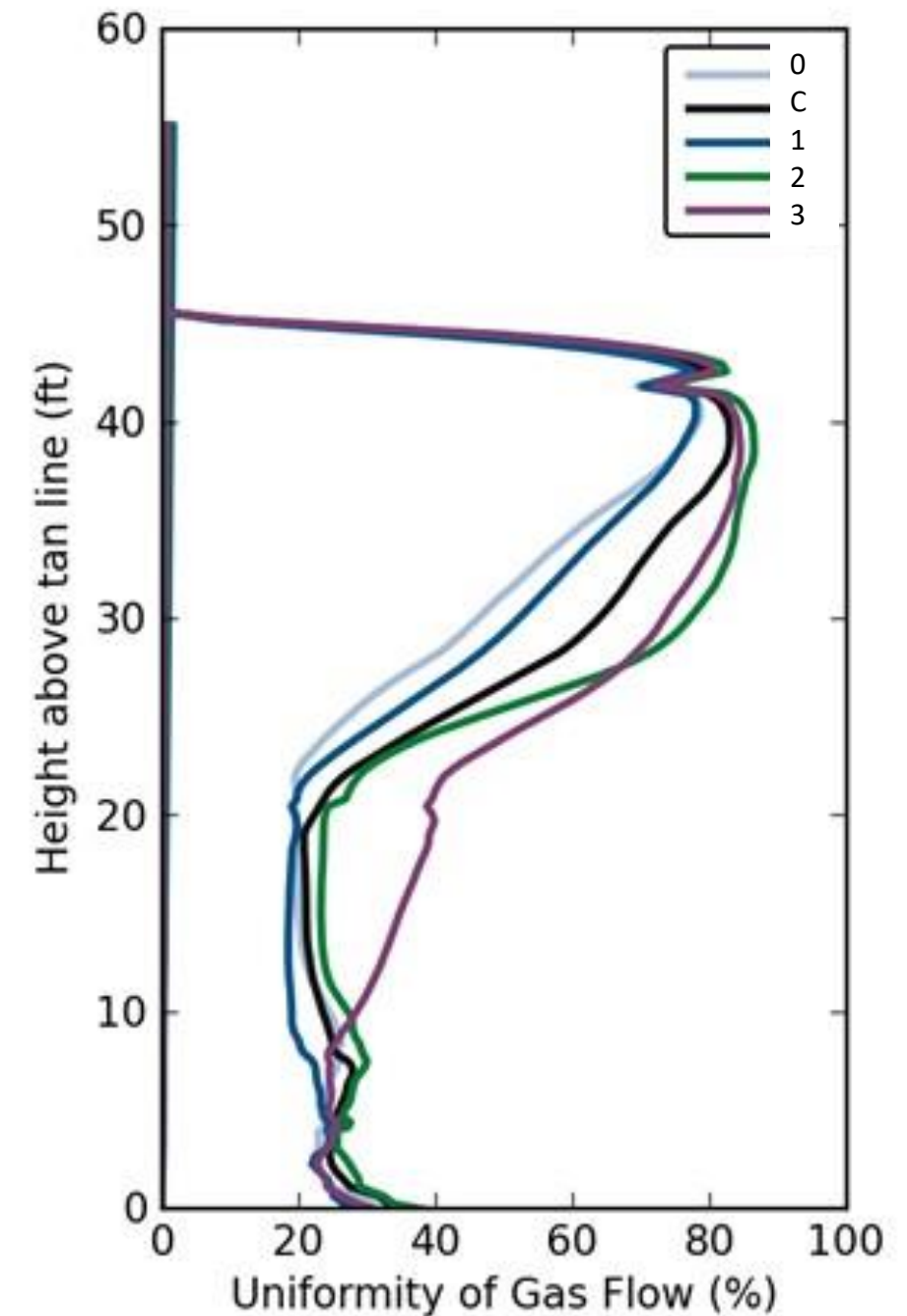
Quantification of time-averaged gas flow shown
(Uniformity Index*)

$$U = \frac{\text{Cross-sectional area being used for gas flow}}{\text{Total cross-sectional area}}$$

Calculated using:

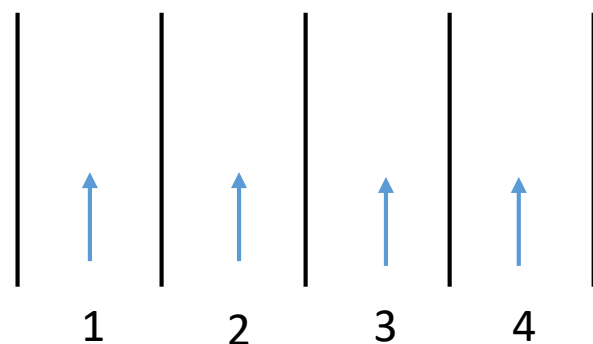
- GMV output data, converted to text format (gmv2txt.py)
- Python (Jupyter notebook)

* See Fletcher, R. et. al., “Identifying the Root Cause of Afterburn in Fluidized Catalytic Crackers”, AFPM 2016 Annual Meeting, AM-16-15.



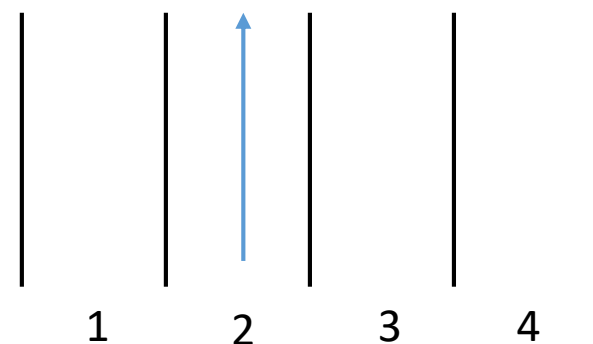
Simple Example of Uniformity Calculation

Consider a very simple system with 4 channels



Channel	Flux	Area	A*F	A*F^2
1	2	1	2	4
2	2	1	2	4
3	2	1	2	4
4	2	1	2	4
Sum		4	8	16
Uniformity =				100%

$$Uniformity = (\text{sum}(A * F))^2 / \text{sum}(A * F^2) / \text{sum}(A)$$



Channel	Flux	Area	A*F	A*F^2
1	0	1	0	0
2	8	1	8	64
3	0	1	0	0
4	0	1	0	0
Sum		4	8	64
Uniformity =				25%

$$Uniformity = (\text{sum}(A * F))^2 / \text{sum}(A * F^2) / \text{sum}(A)$$

Required Data Output Options

To calculate instantaneous flow uniformity, GMV Output Options:

- Cell volume (cellVol)
- Cell indices (i, j, k)
- Fluid mass flux (F_[xyz]Mass)
- Particle volume fraction (p-volFra)

To calculate time-average flow uniformity, Average Data options:

- Particle volume fraction
- Fluid mass flux

General Mesh View Data Output Options

Please select Eulerian and Lagrangian data for export to the General Mesh Viewer (GMV). Only data selected here can be viewed during post-processing. Values inside parenthesis are the **field names** of the variables within GMV.

Output file interval

Plot interval: 0.2 s Number of files produced using current end time of 100s: 501

Eulerian (Cell) Output Data

<input checked="" type="checkbox"/> Particle volume fraction (p-volFra)	<input type="checkbox"/> Particle bulk density (p-dens)	<input type="checkbox"/> dp/dx (dp/dx)
<input checked="" type="checkbox"/> Fluid velocity (U, V, W)	<input type="checkbox"/> Turbulent viscosity (ViscTurb)	<input type="checkbox"/> dp/dy (dp/dy)
<input checked="" type="checkbox"/> Particle velocity (P_[xyz]Vel)	<input checked="" type="checkbox"/> CFL (CFL)	<input checked="" type="checkbox"/> dp/dz (dp/dz)
<input checked="" type="checkbox"/> Pressure (Pressure)	<input type="checkbox"/> Particle species (Species)	<input checked="" type="checkbox"/> Particle mass flux (P_[xyz]Mass)
<input type="checkbox"/> Dynamic pressure (DynPres)	<input checked="" type="checkbox"/> Fluid temperature (F-Temp)	<input checked="" type="checkbox"/> Fluid mass flux (F_[xyz]Mass)
<input checked="" type="checkbox"/> Fluid density (F-dens)	<input checked="" type="checkbox"/> Particle temperature (p-Temp)	<input checked="" type="checkbox"/> Wall heat transfer (wallHeat)
<input checked="" type="checkbox"/> Cell indices (i, j, k)	<input checked="" type="checkbox"/> Cell volume (cellVol)	

Lagrangian (Particle) Output Data

<input checked="" type="checkbox"/> Particle volume fraction (VolFrac)	<input checked="" type="checkbox"/> Particle material (Material)
<input checked="" type="checkbox"/> Particle speed (Speed)	<input type="checkbox"/> Particle density (Density)
<input checked="" type="checkbox"/> Particle radius in microns (rad)	<input checked="" type="checkbox"/> Particle species (Species)
<input type="checkbox"/> Constant color (Particle)	<input checked="" type="checkbox"/> Unique particle ID (pid)
<input type="checkbox"/> Drag (drag)	<input type="checkbox"/> Liquid fraction total (liqFrac)
<input type="checkbox"/> Cloud mass (cldMass)	<input type="checkbox"/> Particles per cloud (npCloud)

Gas Species

<input checked="" type="radio"/> Mass fraction (<species>.mf)	<input type="radio"/> Mole fraction (<species>.nf)
<input type="radio"/> Mass concentration (<species>.mc)	<input type="radio"/> Mole concentration (<species>.nc)

Average Data Output

Averaging start time 80 s

Minimum particle volume fraction 0

GMV Average Data Output

<input checked="" type="checkbox"/> Particle volume fraction
<input type="checkbox"/> Pressure
<input checked="" type="checkbox"/> Fluid velocity
<input checked="" type="checkbox"/> Particle velocity
<input checked="" type="checkbox"/> Solid mass flux (kg/s m ²)
<input checked="" type="checkbox"/> Fluid mass flux (kg/s m ²)
<input checked="" type="checkbox"/> Fluid temperature
<input checked="" type="checkbox"/> Particle temperature
<input type="checkbox"/> dp/dx
<input type="checkbox"/> dp/dy
<input type="checkbox"/> dp/dz
<input type="checkbox"/> Wall heat transfer rate/flux
<input checked="" type="checkbox"/> Gas species

Convert GMV File(s) to Text Format: gmv2txt.py

Text-based data is necessary to calculate uniformity with a script

Use gmv2txt.py to convert one or more GMV files to text

- See this support site post:

<http://cpfd-software.com/customer-support/knowledge-base/data-mining-gmv-files-using-gmv2txt.py>

```
/cygdrive/c/training/5_Wednesday_gasifier/pre_setup
Main Options VT Options VT Fonts

Sam Clark@volta /cygdrive/c/training/5_Wednesday_gasifier/pre_setup
$ python gmv2txt.py -c Gmv.00500
Creating file : cells_Gmv.00500.vars

Sam Clark@volta /cygdrive/c/training/5_Wednesday_gasifier/pre_setup
$
```

Examine the `cells*vars` File Header Information

```
cells_Gmv.00500.vars (C:\training\5_Wednesday_gasifier\pre_setup) - GVIM1
File Edit Tools Syntax Buffers Window Help

^# /cygdrive/c/training/5_Wednesday_gasifier/pre_setup/Gmv.00500
# simulation time = 1.0000190e+02
#1 cell id
#2 i
#3 j
#4 k
#5 cellVol
#6 p-VolFra
#7 vf-Ash
#8 vf-C
#9 Pressure
#10 CFL
#11 f-dens
#12 P_xVel
#13 P_yVel
#14 P_zVel
#15 F_xMass
#16 F_yMass
#17 F_zMass
#18 P_xMass
#19 P_yMass
#20 P_zMass
#21 f-Temp
#22 CH4.mf
#23 CO.mf
#24 CO2.mf
#25 H2.mf
#26 H2O.mf
#27 N2.mf
#28 O2.mf
#29 wallHeat
#30 p-Temp
#31 dp/dz
#32 av_pVolF
#33 avF_xVel
#34 avF_yVel
#35 avF_zVel
#36 avP_xVel
#37 avP_yVel
#38 avP_zVel
#39 av_Tf
#40 av_Tp
#41 avF_xMas
#42 avF_yMas
#43 avF_zMas
#44 avP_xMas
#45 avP_yMas
#46 avP_zMas
#47 av_CH4.mf
#48 av_CO.mf
#49 av_CO2.mf
#50 av_H2.mf
#51 av_H2O.mf
#52 av_N2.mf
#53 av_O2.mf
#54 x-velocity
#55 y-velocity
#56 z-velocity
#57 x-center
#58 y-center
#59 z-center

cells_Gmv.00500.vars 1,1 Top cells_Gmv.00500.vars 34,1 0%
```

Use Jupyter Notebook

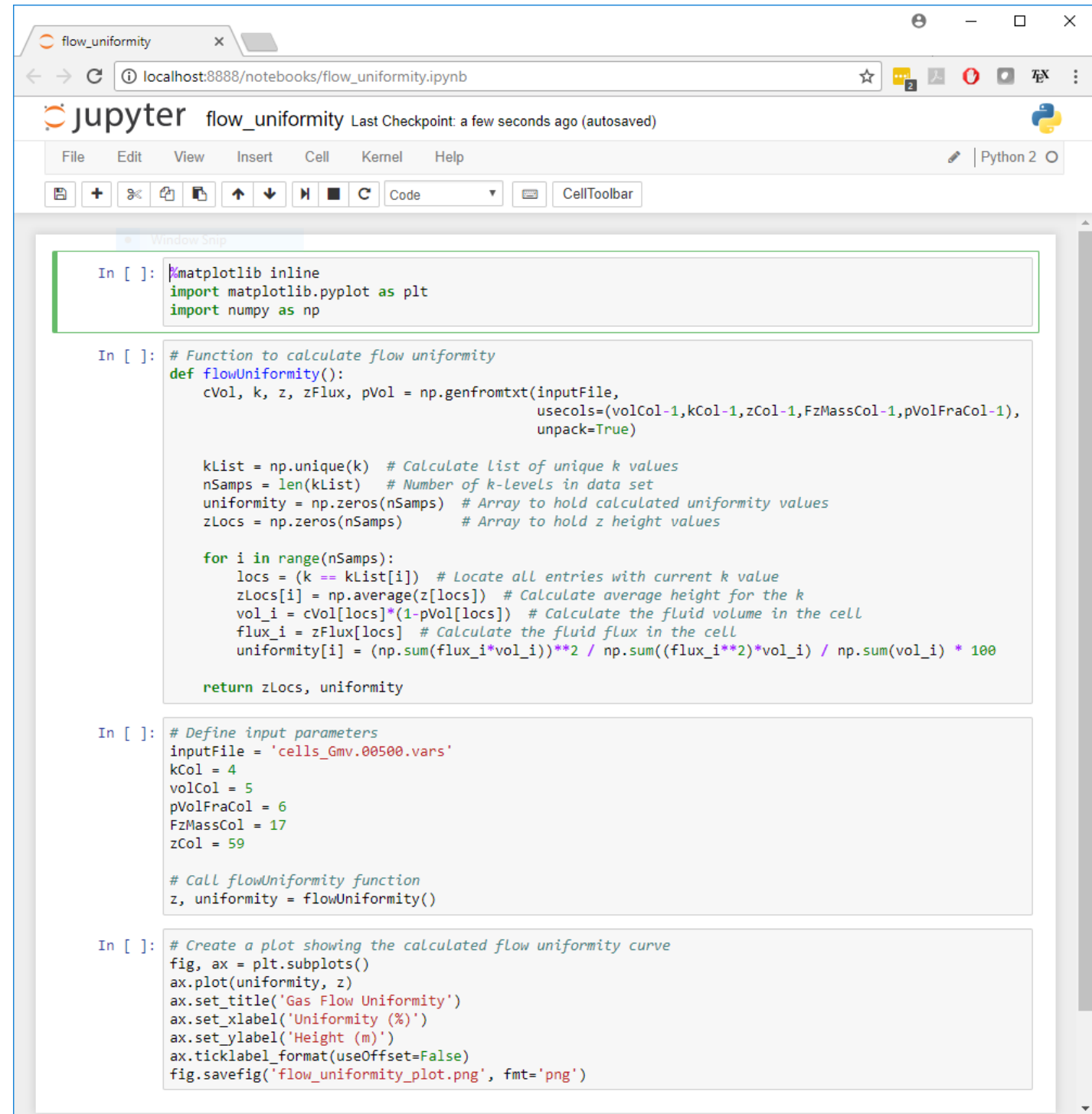
Notebook supplied on USB stick

- `flow_uniformity.ipynb`

For information on Python and the Jupyter notebook, see:

<http://cpfd-software.com/customer-support/knowledge-base/installing-the-anaconda-python-distribution>

<http://cpfd-software.com/customer-support/knowledge-base/advanced-post-processing-presented-by-sam-clark>



```
In [ ]: %matplotlib inline
import matplotlib.pyplot as plt
import numpy as np

In [ ]: # Function to calculate flow uniformity
def flowUniformity():
    cVol, k, z, zFlux, pVol = np.genfromtxt(inputFile,
                                           usecols=(volCol-1, kCol-1, zCol-1, FzMassCol-1, pVolFraCol-1),
                                           unpack=True)

    kList = np.unique(k) # Calculate list of unique k values
    nSamps = len(kList) # Number of k-levels in data set
    uniformity = np.zeros(nSamps) # Array to hold calculated uniformity values
    zLocs = np.zeros(nSamps) # Array to hold z height values

    for i in range(nSamps):
        locs = (k == kList[i]) # Locate all entries with current k value
        zLocs[i] = np.average(z[locs]) # Calculate average height for the k
        vol_i = cVol[locs]*(1-pVol[locs]) # Calculate the fluid volume in the cell
        flux_i = zFlux[locs] # Calculate the fluid flux in the cell
        uniformity[i] = (np.sum(flux_i*vol_i)**2 / np.sum((flux_i**2)*vol_i) / np.sum(vol_i) * 100

    return zLocs, uniformity

In [ ]: # Define input parameters
inputFile = 'cells_Gmv.00500.vars'
kCol = 4
volCol = 5
pVolFraCol = 6
FzMassCol = 17
zCol = 59

# Call flowUniformity function
z, uniformity = flowUniformity()

In [ ]: # Create a plot showing the calculated flow uniformity curve
fig, ax = plt.subplots()
ax.plot(uniformity, z)
ax.set_title('Gas Flow Uniformity')
ax.set_xlabel('Uniformity (%)')
ax.set_ylabel('Height (m)')
ax.ticklabel_format(useOffset=False)
fig.savefig('flow_uniformity_plot.png', fmt='png')
```

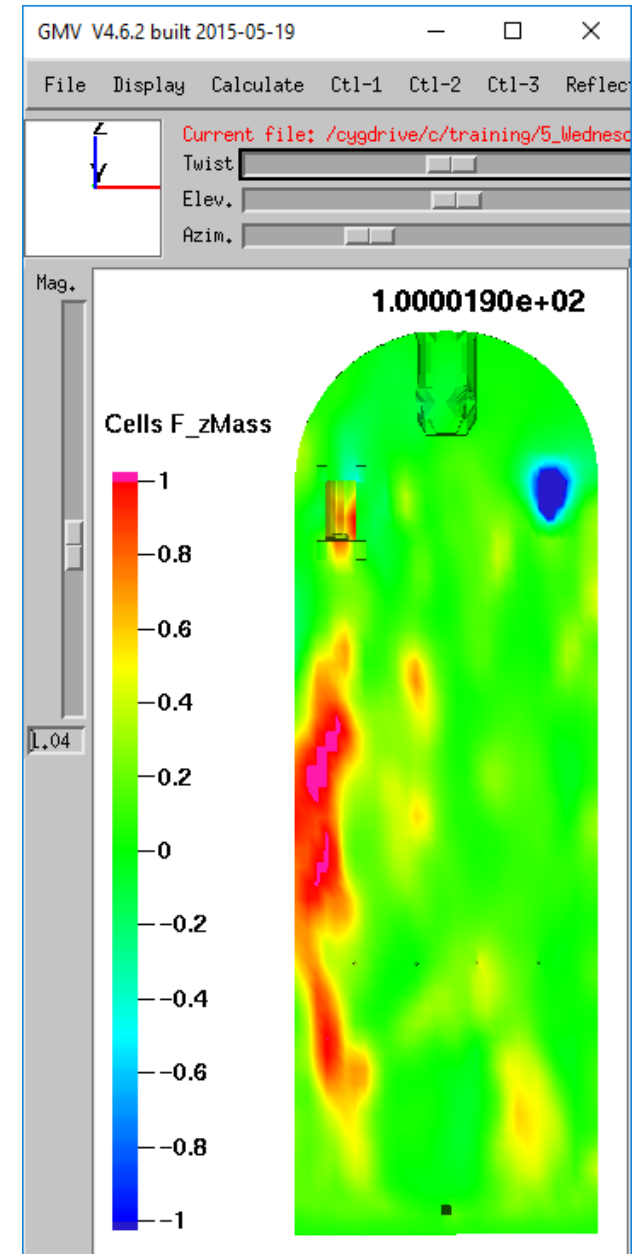
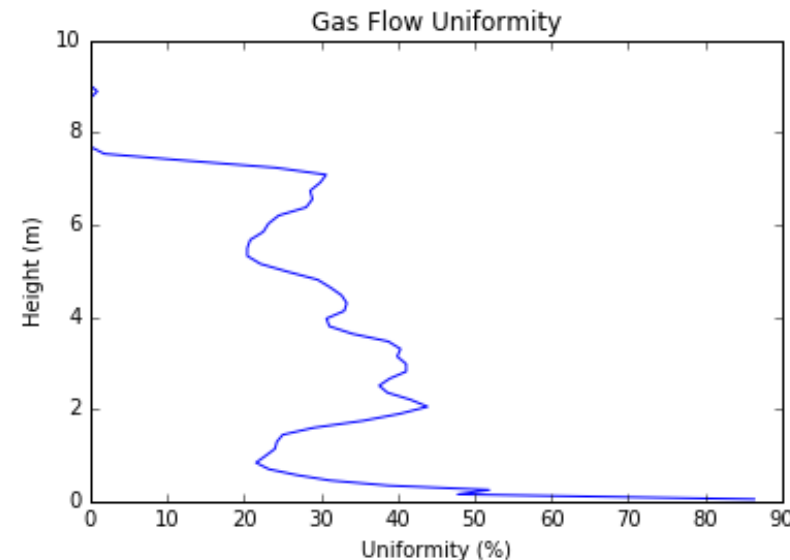

Run the Jupyter Notebook to Plot Uniformity

Uniformity plot is shown at right

- The flow in this system is not very uniform. Why?

Look at GMV to gain insight

- The side particle feed is reducing uniformity
- Fresh coal is devolatilizing and producing high quantities of gas



Questions

Thank you for your attention

Questions?

