# Coupling a sub-grid scale plume model for biomass burns with adaptive grid CMAQ: part 2

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# Motivation

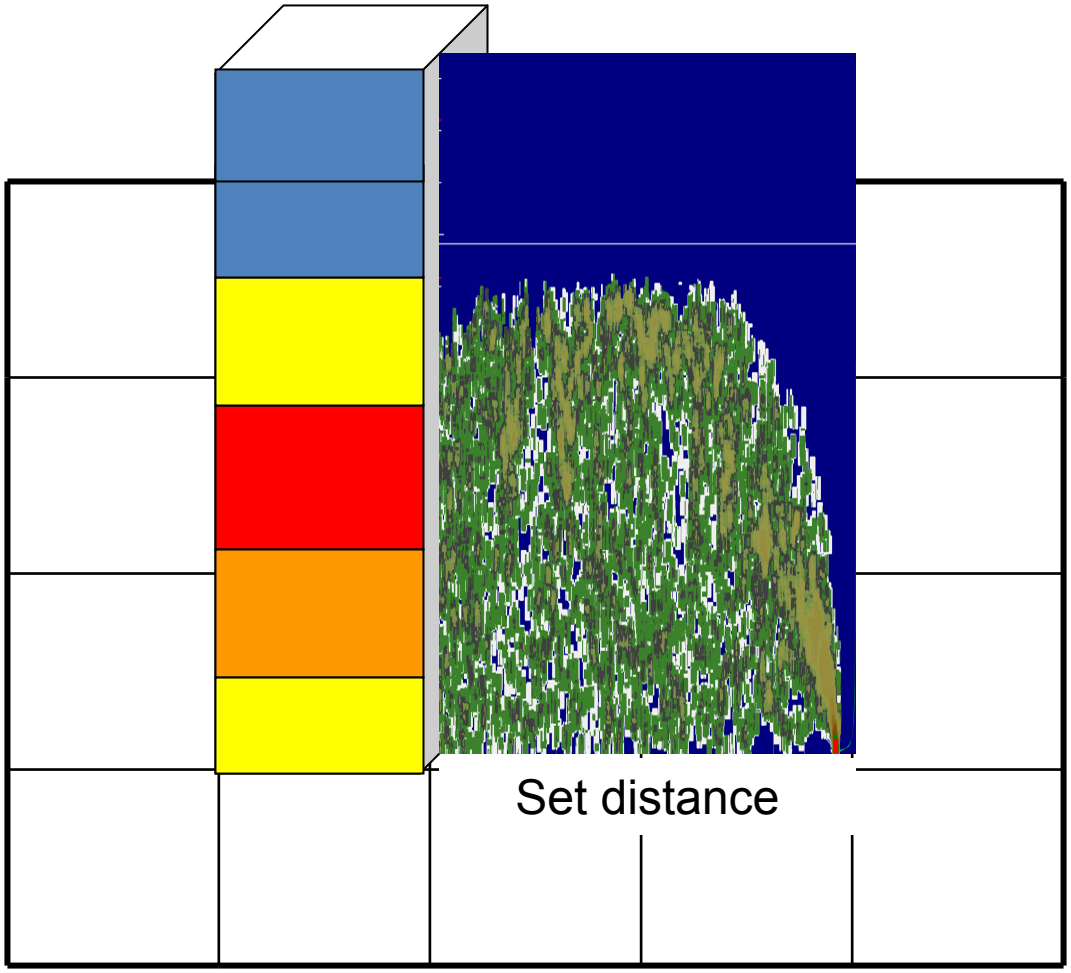
- U.S. EPA lists prescribed burning as the 3rd largest source of fine particulate matter.
- Smoke plume must be preserved in order to predict downwind concentration accurately in CMAQ
- Use of sub grid model and adaptive grid can help resolve smoke plume in CMAQ

# Objective

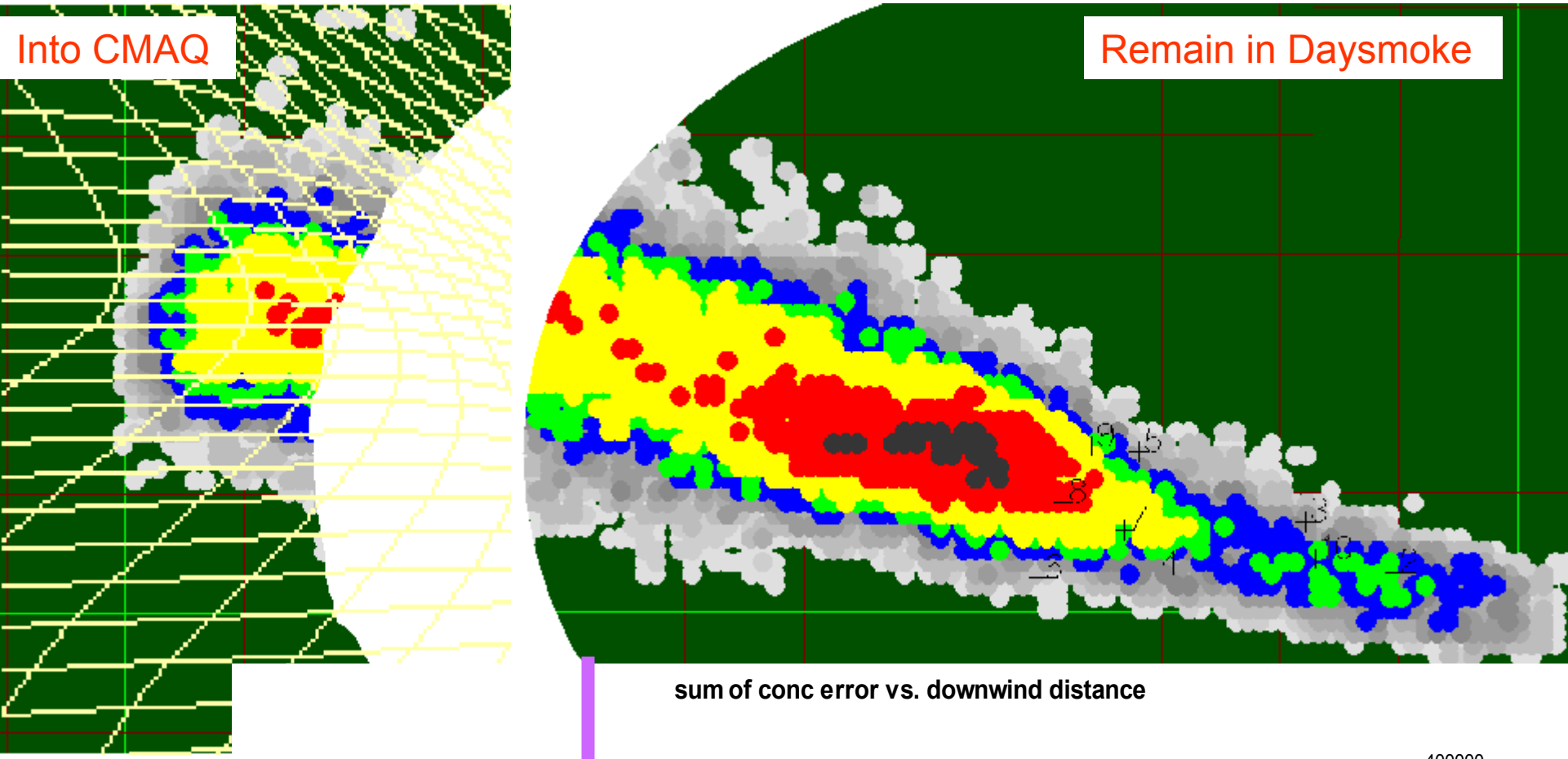
**Find out the ideal relationship between sub-grid model coupling and grid adaptation for burn plumes.**

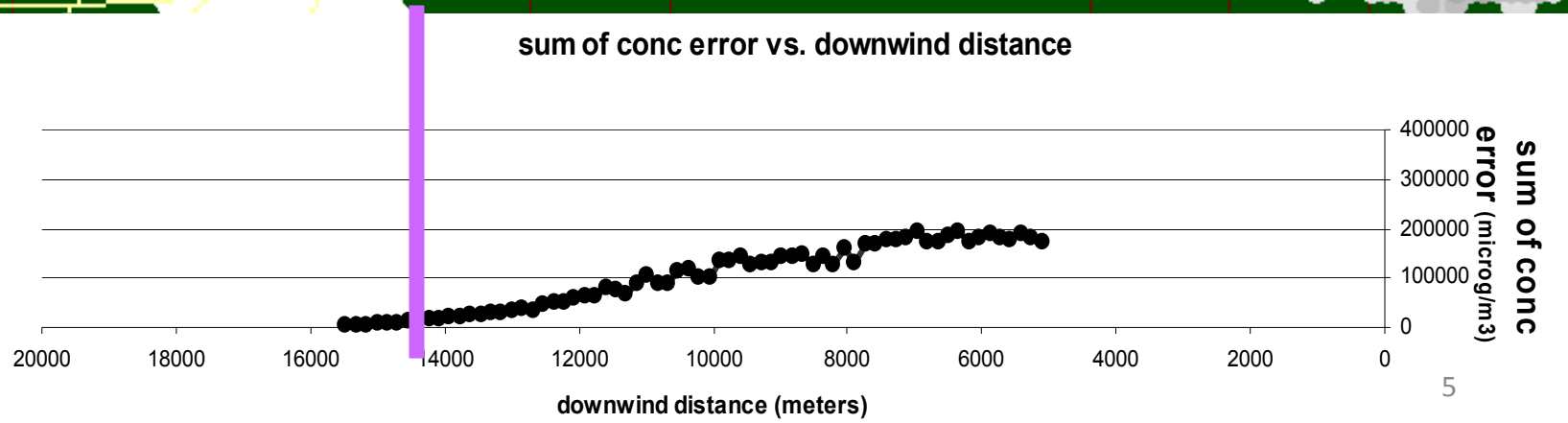
1. Effectiveness of the coupling method, handover, on both uniform and adaptive grid.
2. Different methods of inserting smoke emissions
3. Ground level concentration vs. all vertical layer concentration adaptation (adapt in 2D)
4. Adaptive weighting function parameters
5. Frequency of tracer/wall analysis

# Column Injection

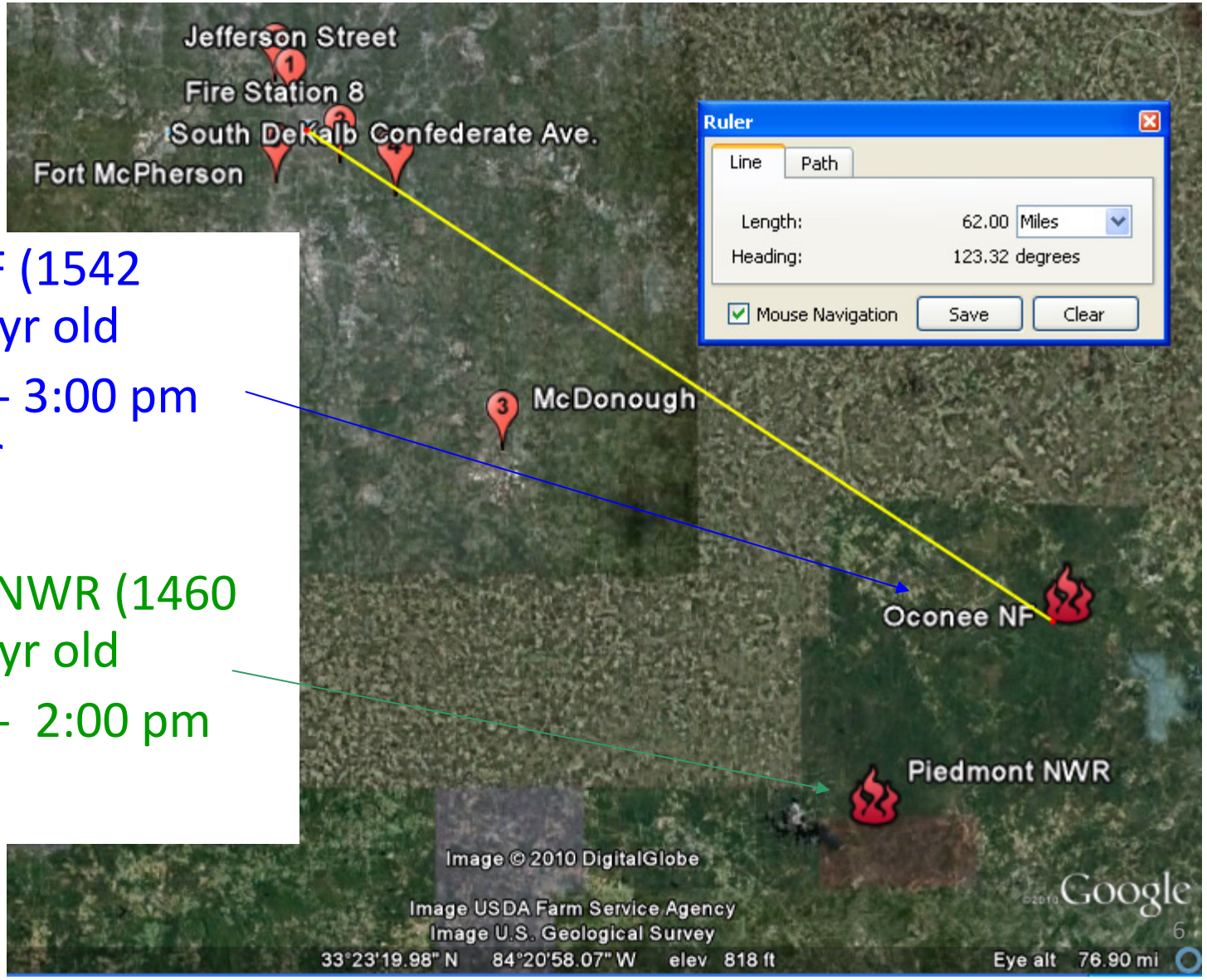


# Handover


Into CMAQ
Remain in Daysmoke


sum of conc error vs. downwind distance
400000
300000
200000
100000
0
sum of conc error (microg/m3)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
downwind distance (meters)

# Atlanta Smoke Case
# Feb. 28 2007




Oconee NF (1542 acres) 5 yr old

10:00 am - 3:00 pm

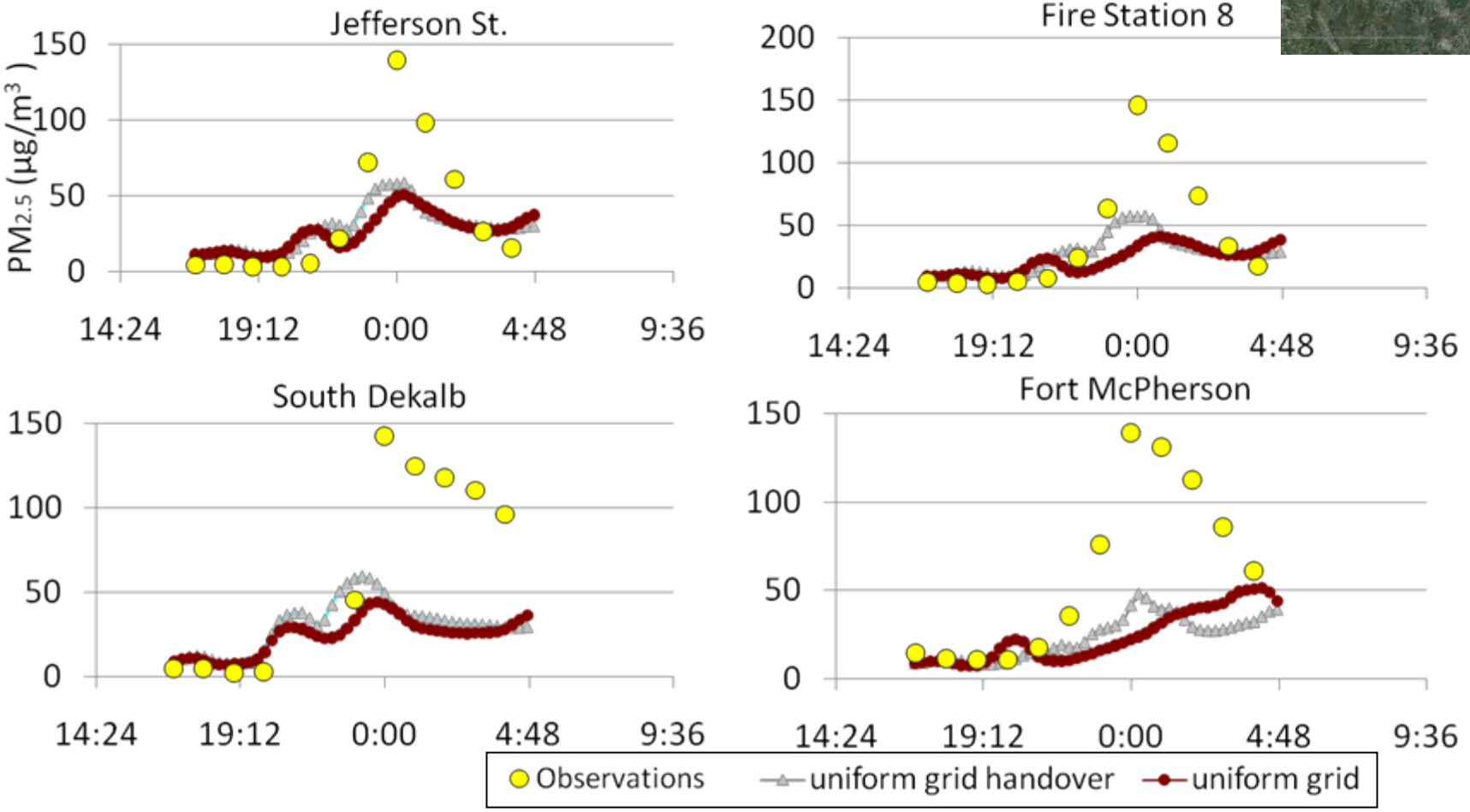
total 5hr

Piedmont NWR (1460 acres) 1 yr old

11:00 am - 2:00 pm

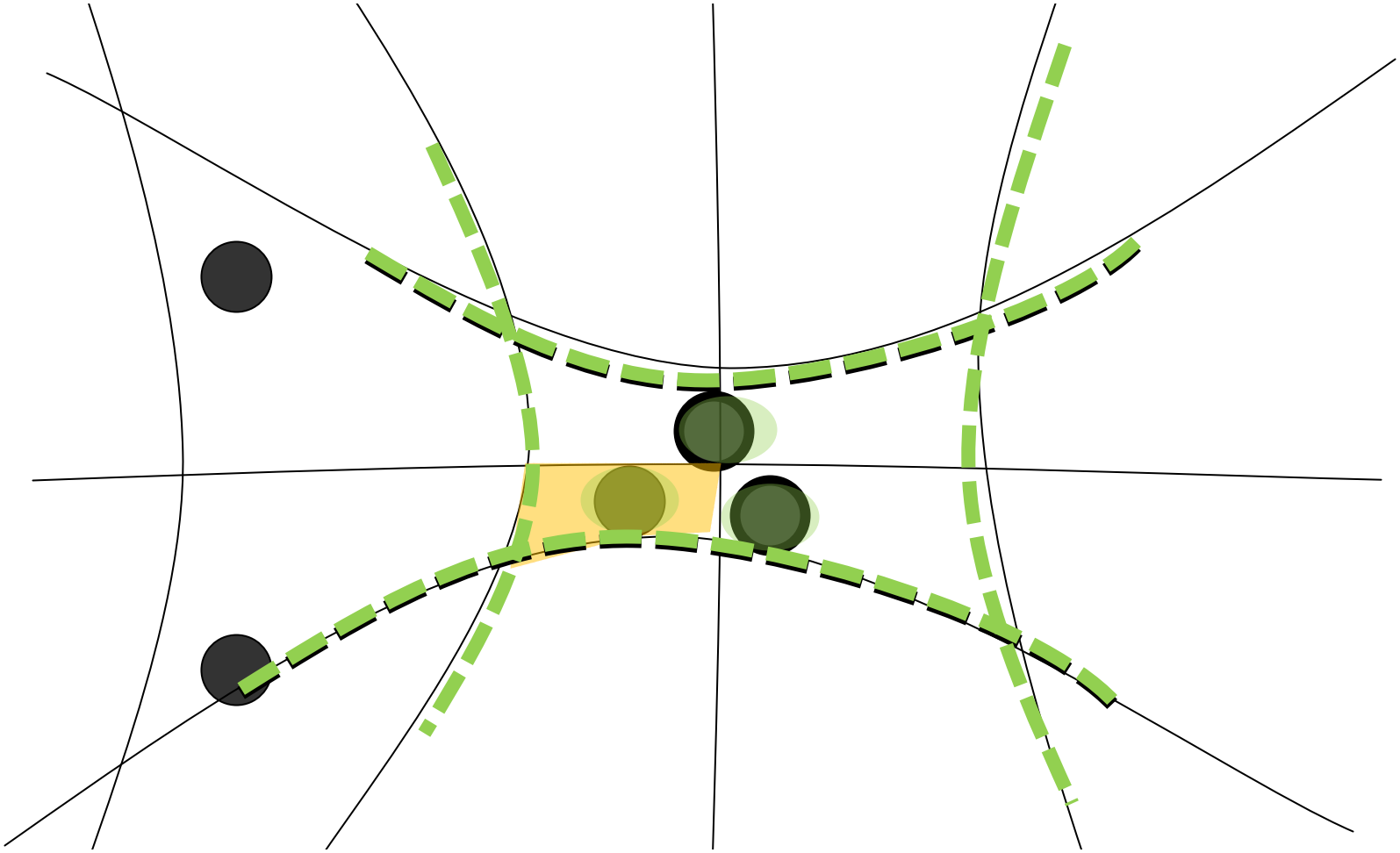
total 3hr

# Handover with uniform grid

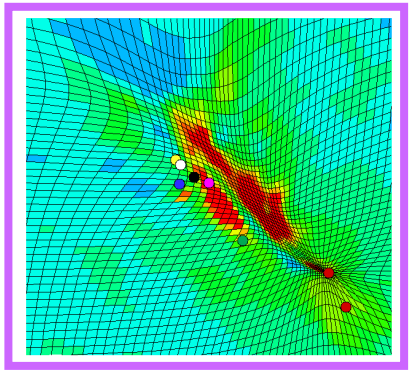

| | uniform CMAQ | uniform handover CMAQ |
|---|---|---|
| **Mean fractional error** | 76.27% | 69.35% |

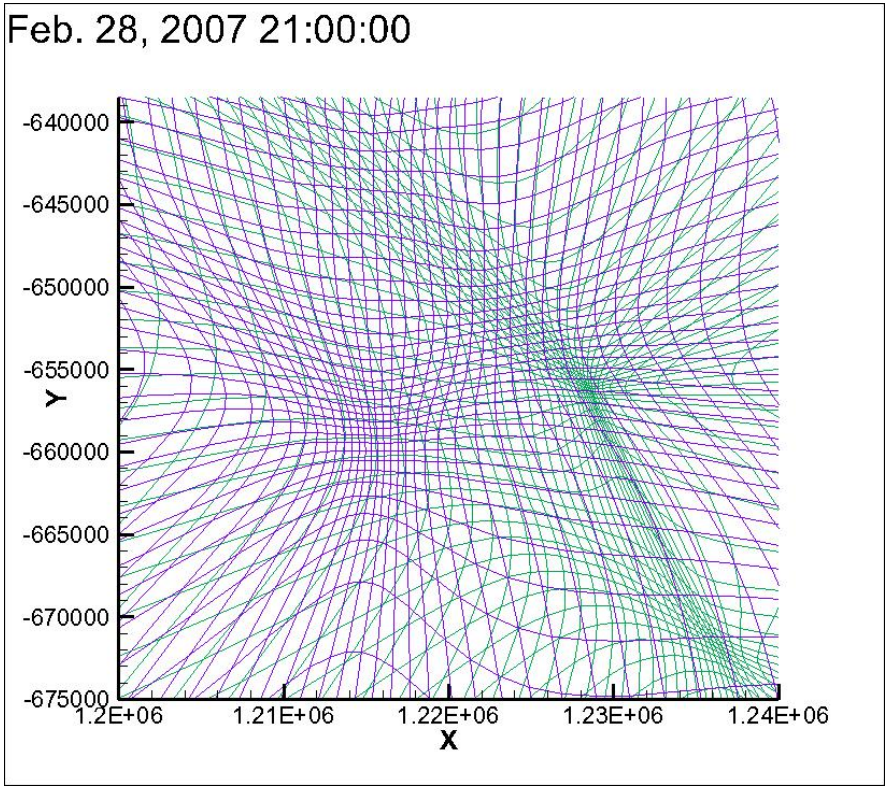
# Adaptive grid weighting function

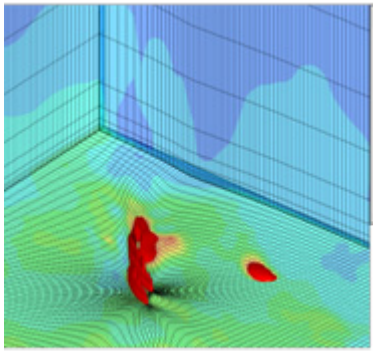


$$w_o = V_o^{1+e_1} \left| \sum_l (\Delta^2 \phi_l)_o + w_{\min} \right|, \quad \phi_l = c_l \left( \frac{V}{V_o} \right)^{e_2},$$

# Surface only vs. all layers concentration adaptation



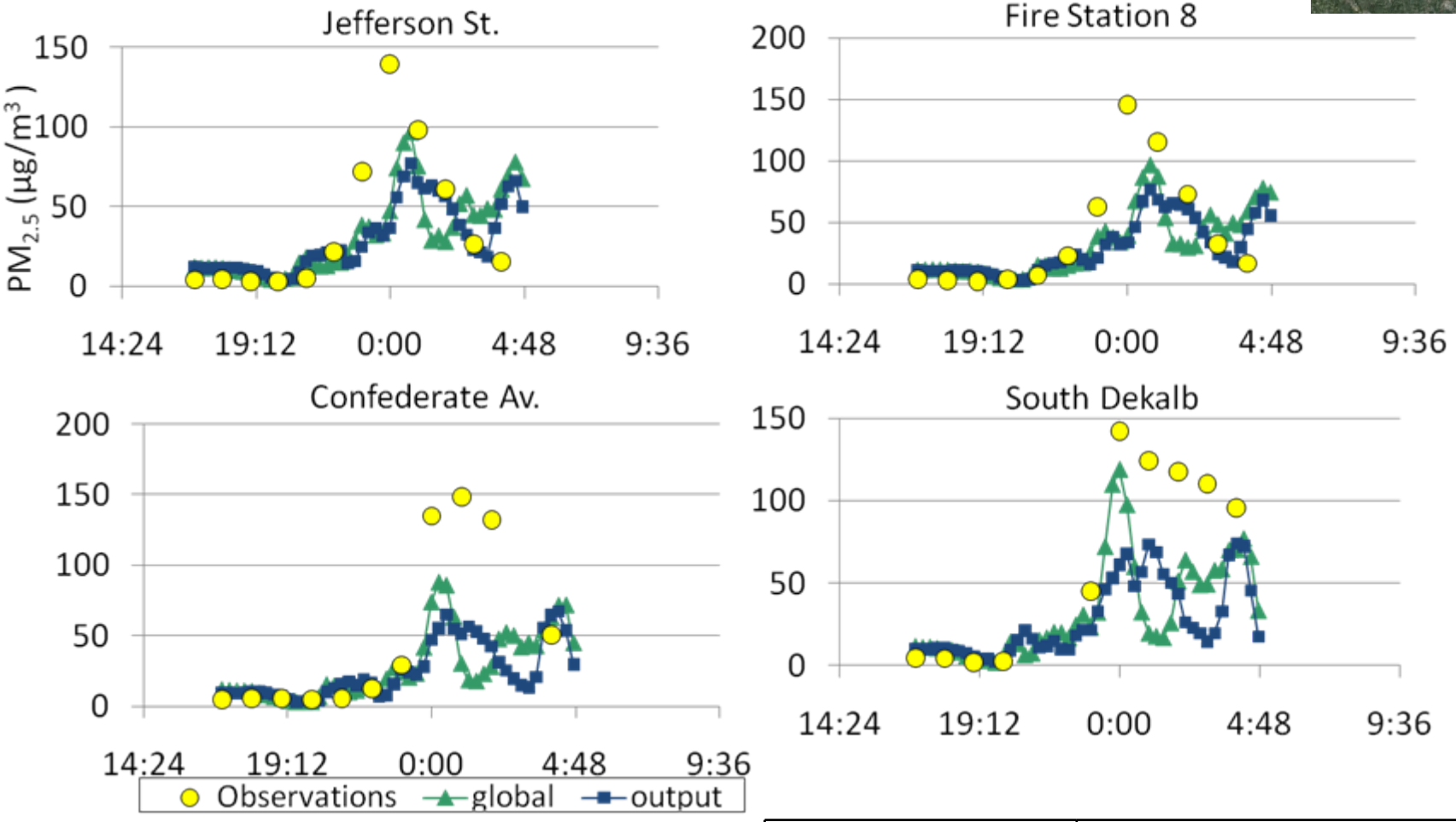


| | surface adaptation | all layer adaptation |
|---|---|---|
| Mean fractional error | 80.47% | 76.82% |

3.6% improvement

# Global vs. Output time step handover analysis


| global handover | handover per output |
|---|---|
| 65.08% | 65.19% |

Mean fractional error

# Plume modeling criteria

Uniform vs Adaptive grid

All layer adaption vs Surface layer adaption

Colum Injection vs Handover

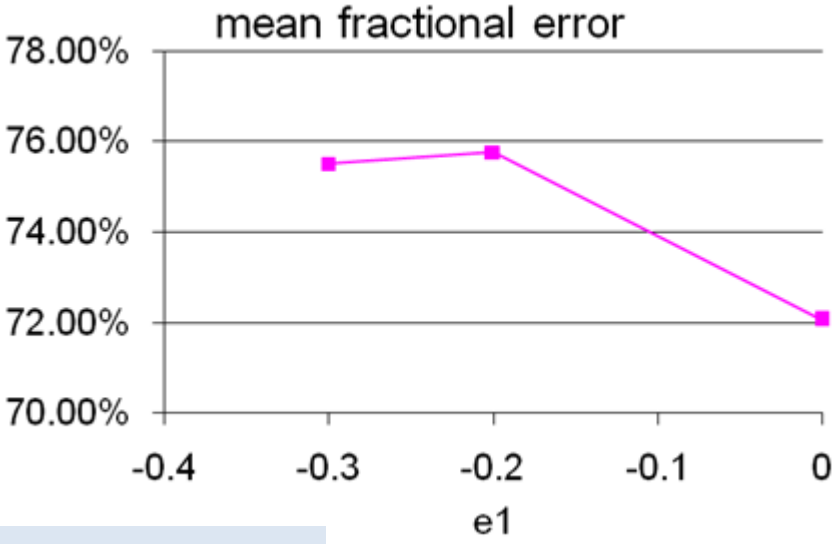
Global time step handover vs Output time step handover

# Adaptive grid weight function

$$w_o = V_o^{1+e_1}\left|\sum_l (\Delta^2\phi_l)_o + w_{\min}\right|, \quad \phi_l = c_l\left(\frac{V}{V_o}\right)^{e_2},$$

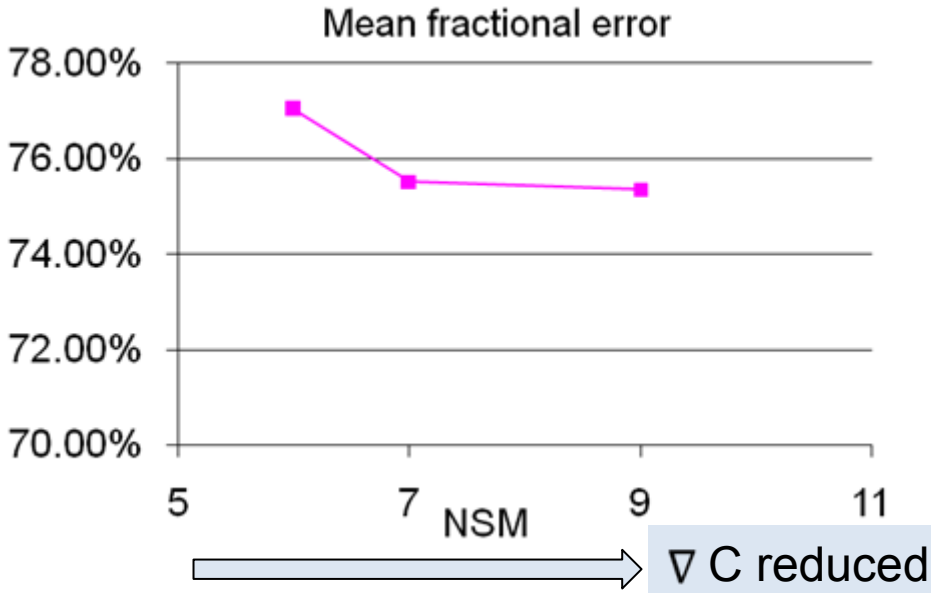
$$\sum_l (\Delta^2\phi_l)_{i,j}^{\text{norm}}.$$

# Areal adaptation: e1



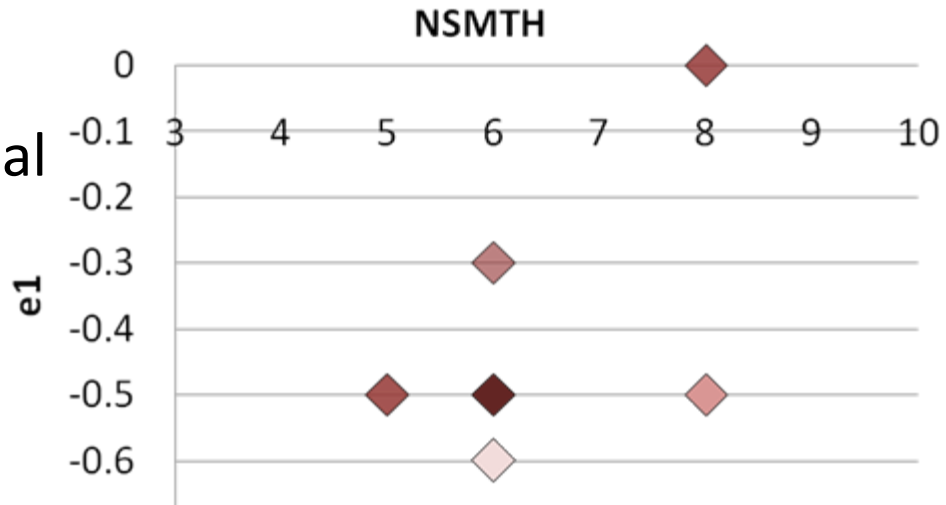

Smaller cells weighted more

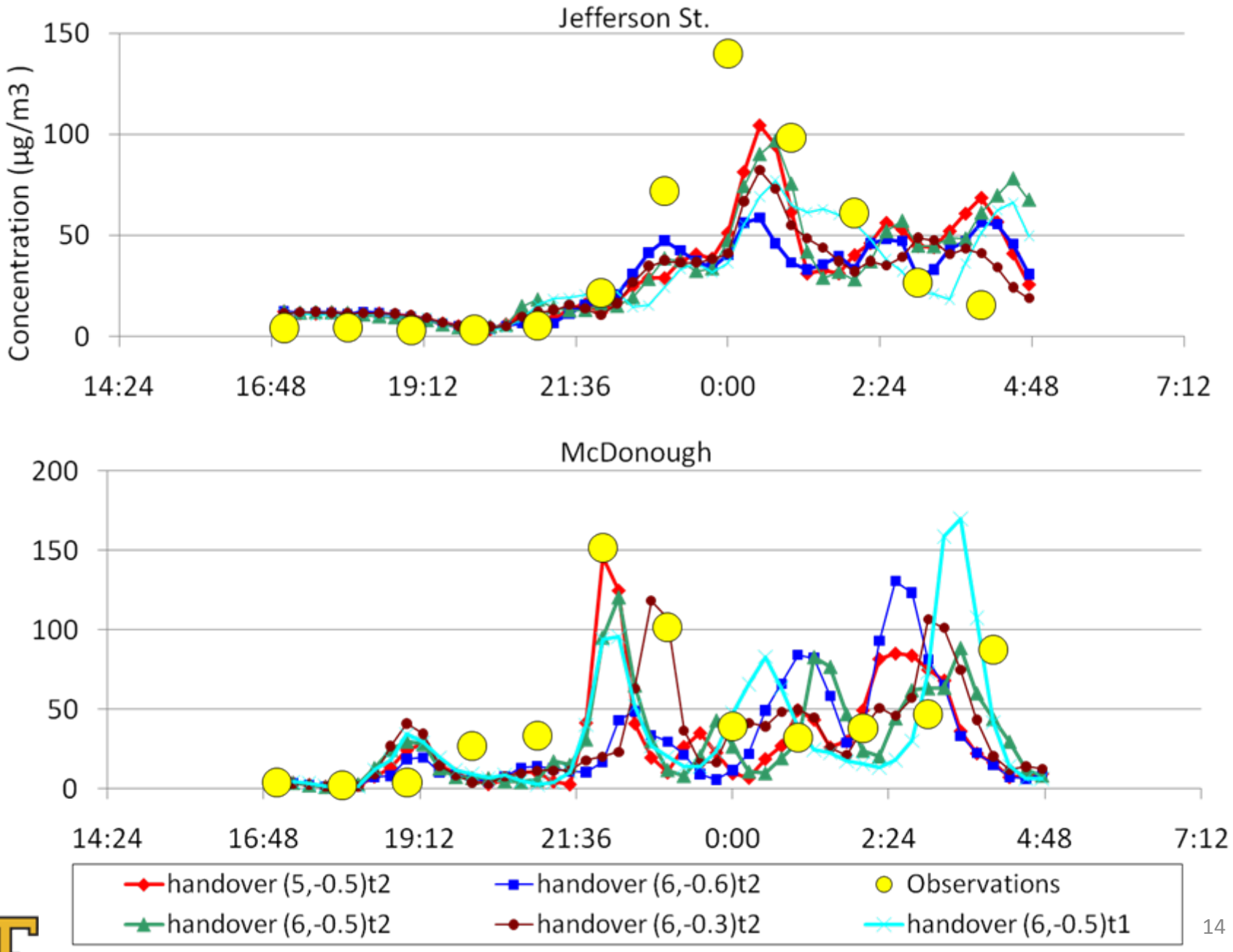
# Smoothing factor: NSMTH




∇ C reduced

Mean Fractional Error




Jefferson St.
Concentration (µg/m3 )
150
100
50
0
14:24
16:48
19:12
21:36
0:00
2:24
4:48
7:12
McDonough
200
150
100
50
0
14:24
16:48
19:12
21:36
0:00
2:24
4:48
7:12
handover (5,-0.5)t2
handover (6,-0.6)t2
Observations
handover (6,-0.5)t2
handover (6,-0.3)t2
handover (6,-0.5)t1

# Judging criteria

Normalized Mean Error (%)

$$NME = \frac{\sum_{i=1}^{N} |m_i - o_i|}{\sum_{i=1}^{N} o_i}$$

Mean Fractional Error (%)

$$MFE = \frac{1}{N} \sum_{i=1}^{N} \frac{|m_i - o_i|}{\left(\frac{m_i + o_i}{2}\right)}$$

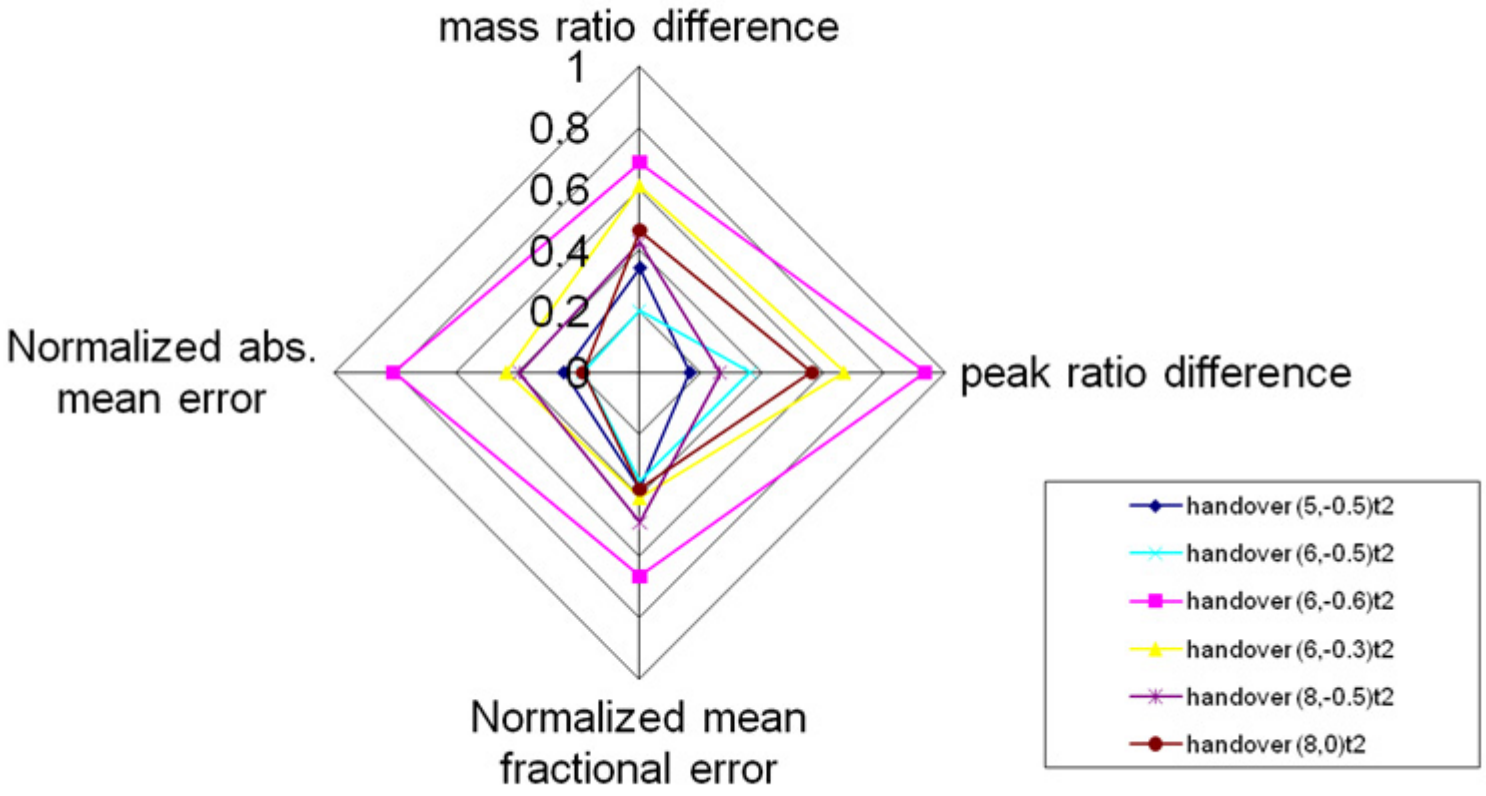
Peak Ratio (%)

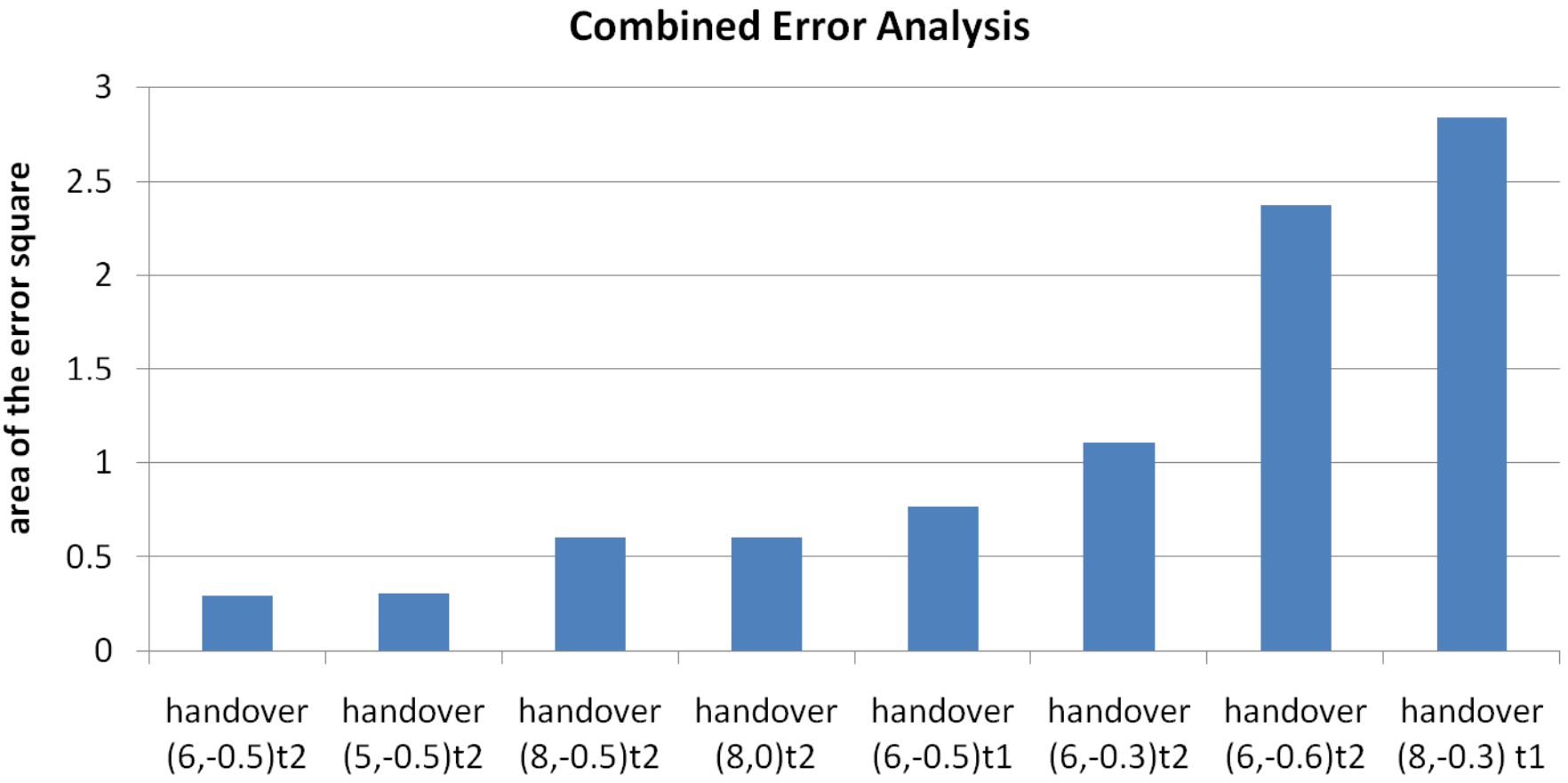
$$PR = \frac{1}{M} \sum \frac{m_{max}}{o_{max}}$$

Mass Ratio (%)

$$MR = \frac{1}{M} \frac{\sum_{i=1}^{N} m_i}{\sum_{i=1}^{N} o_i}$$

# Error analysis (NSMTH,e1)






NSMTH=6, e1=-0.5 using global time step handover analysis with adaptive grid CMAQ models this burn case plume the best.

# Summary

- Boundary between sub grid model to CMAQ should be determined by analysis on error due to unresolved plume concentration
- Optimal parameters for grid adaptation were determined for prescribed burning plumes
- Similar analysis to be done for other burn cases

# Acknowledgements


- Strategic Environmental Research and Development Program
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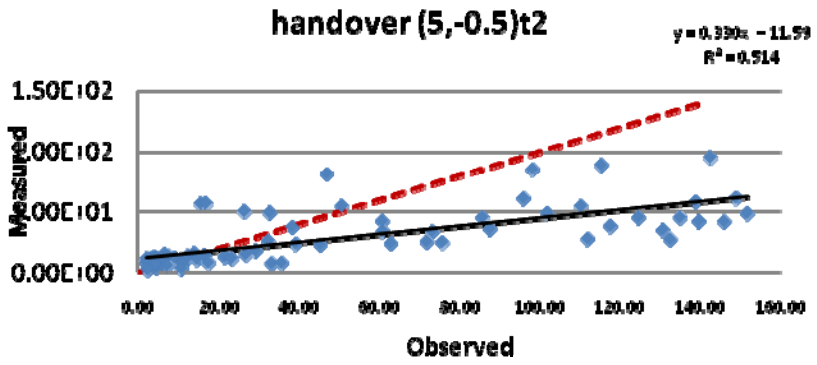
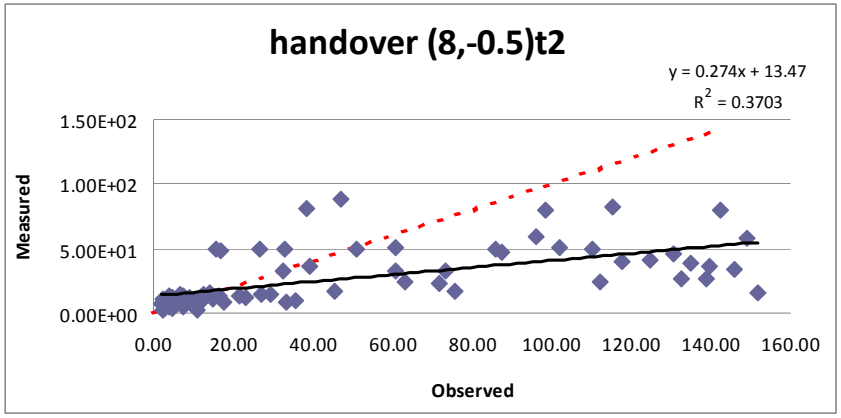
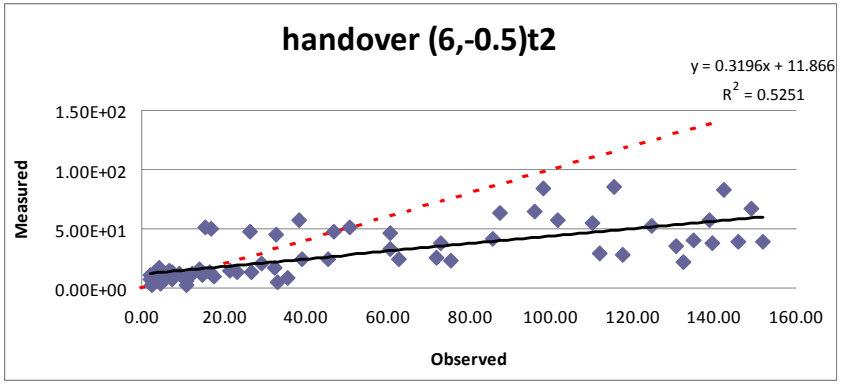
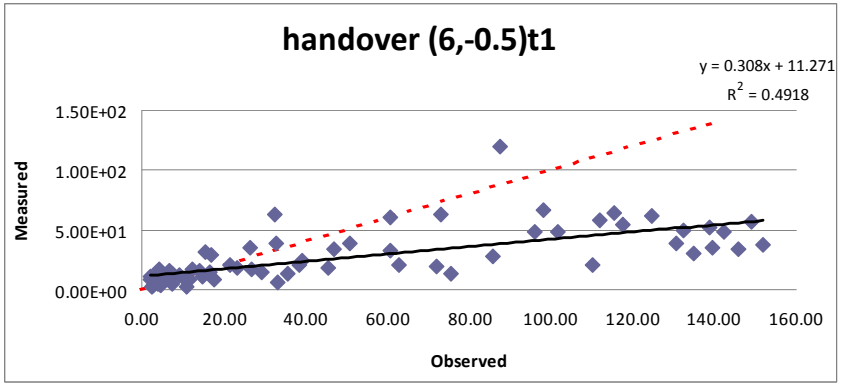
- Georgia Department of Natural Resources, Environmental Protection Division
- US Forest Service, Southern Research Station


handover (5,-0.5)t2
y = 0.330x - 11.59
R² = 0.514
1.50E+02
1.00E+02
5.00E+01
0.00E+00
Measured
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Observed


handover (8,-0.5)t2
y = 0.274x + 13.47
R² = 0.3703
1.50E+02
1.00E+02
5.00E+01
0.00E+00
Measured
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Observed


handover (6,-0.5)t2
y = 0.3196x + 11.866
R² = 0.5251
1.50E+02
1.00E+02
5.00E+01
0.00E+00
Measured
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Observed


handover (6,-0.5)t1
y = 0.308x + 11.271
R² = 0.4918
1.50E+02
1.00E+02
5.00E+01
0.00E+00
Measured
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Observed

# Adaptive Grid