A High-Resolution Modeling System for Regional Carbonaceous Aerosols

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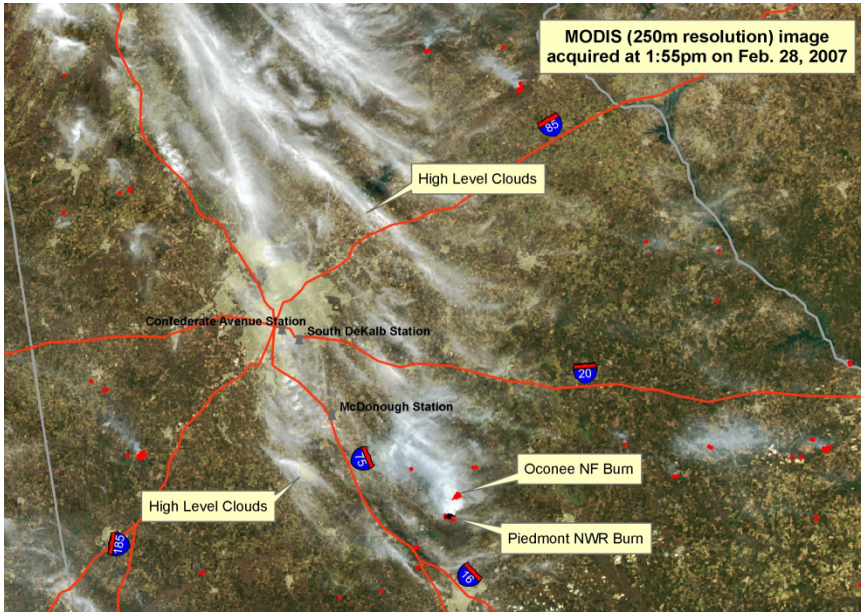
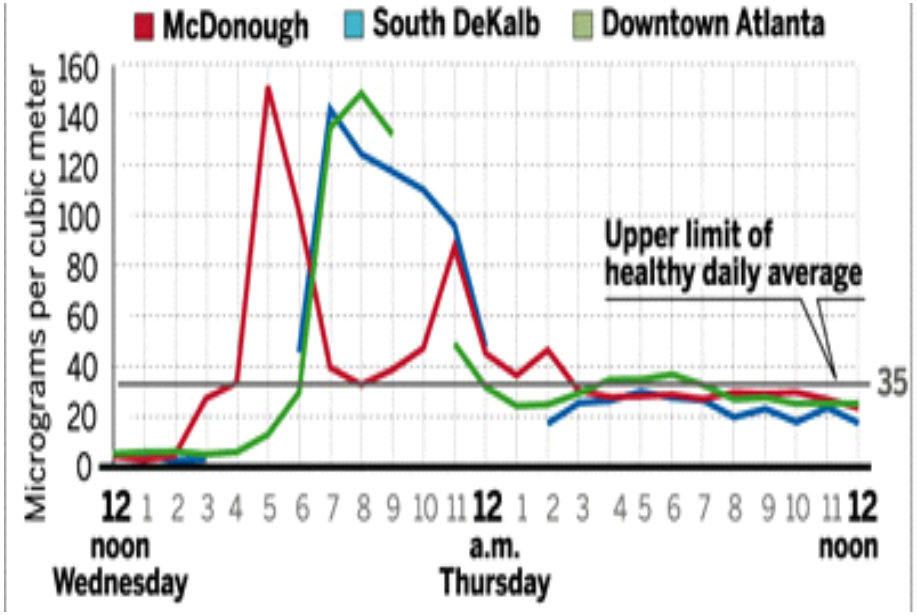
Carbonaceous Aerosols in the Southeastern United States

- Biomass burning is the premier source of fine organic carbon (OC) in the Southeast.
  - 25−40% of OC is from biomass burning (Zheng et al, 2006)
- Fireplaces and woodstoves are significant in winter.
- Early spring is the prescribed (Rx) burning season.
- Residential wood burning emissions are more uniformly distributed while Rx-burn emissions are scattered and each burn is a relatively larger source.
- Rx-burns do not behave like typical point sources or area sources

Feb. 28, 2007 Atlanta Smoke Event

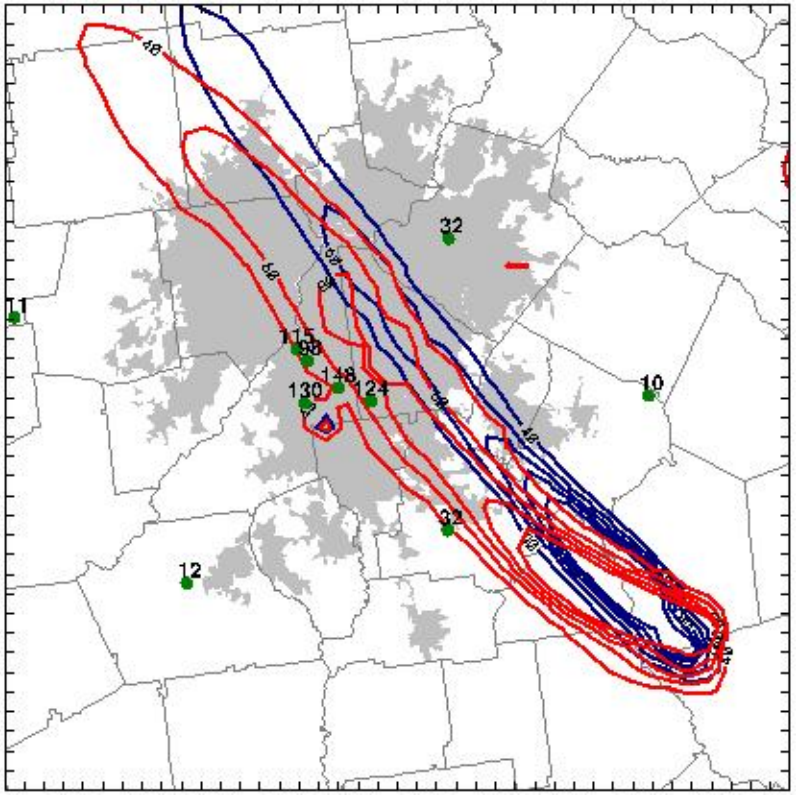
- Two fires, one in Oconee National Forest (1550 acres, 5 year old rough) and another in Piedmont Wildlife Refuge (1450 acres, 1 year old rough) were started in the morning under northeasterly winds.
- The winds shifted to southeasterly and started to blow the smoke directly to Atlanta. By late afternoon, $PM_{2.5}$ levels of 150 $\mu g/m^3$ were recorded at several Atlanta monitors.





State of Regional-Scale Models
(focusing on weaknesses)

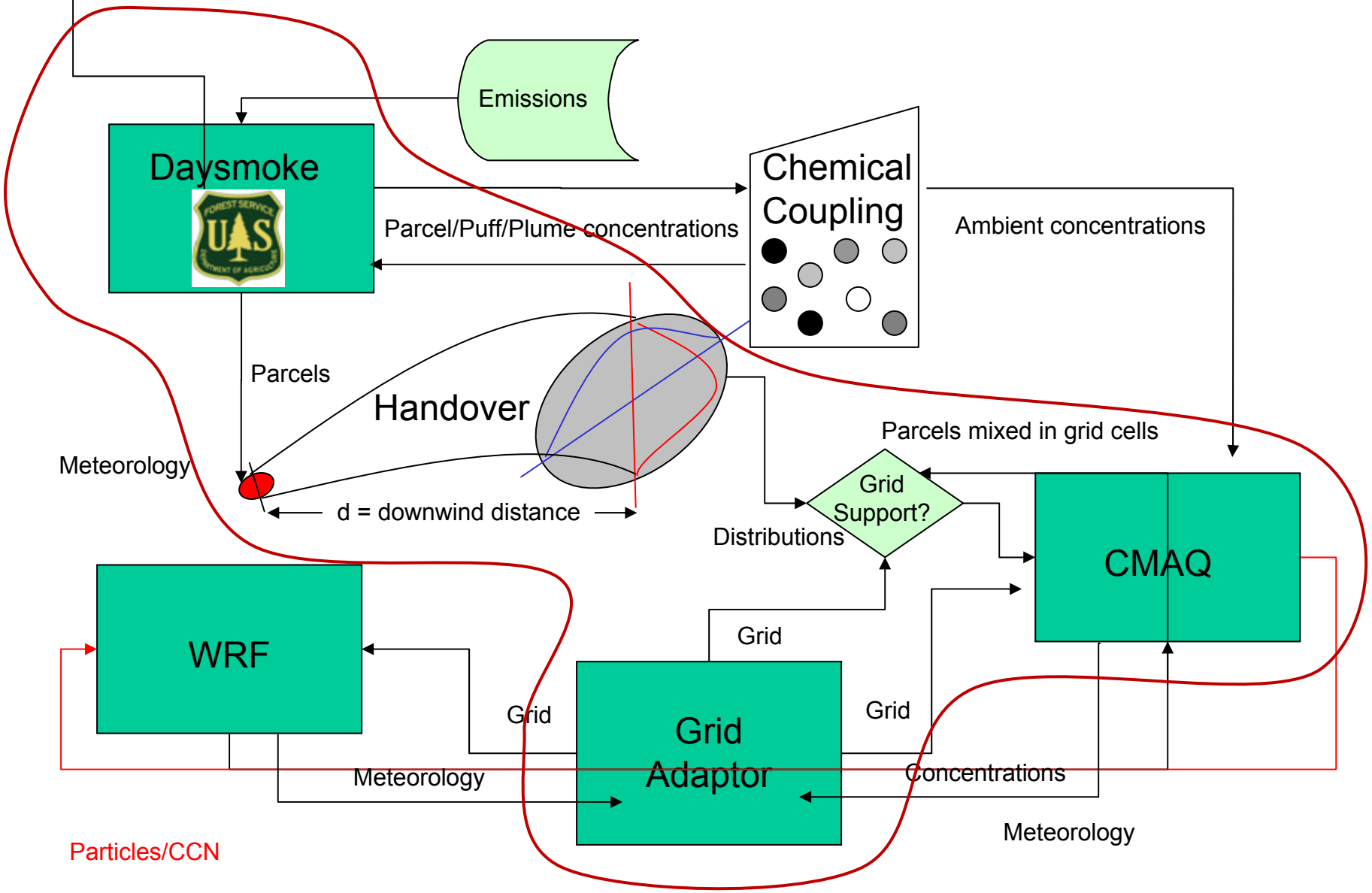
First Modeling Attempt
with WRF / CMAQ



Hu, et al. (2008): Simulation of air quality impacts from prescribed fires on an urban area, *Environ. Sci. Technol.*, **42**, 3676-3682.

- Uncertainty in emissions
  - Fuel loads, consumption & emission factors are uncertain
  - Fire-induced emissions (from non-burning trees) are not estimated
- Insufficient resolution
  - 4-km horizontal grid resolution is considered fine resolution
- Lack of adequate plume dynamics / chemistry
  - No special plume treatment
  - SOA formation is largely underestimated
- Lack of plume feedback on meteorology
  - First WRF then CMAQ

Smoke Impact Prediction System

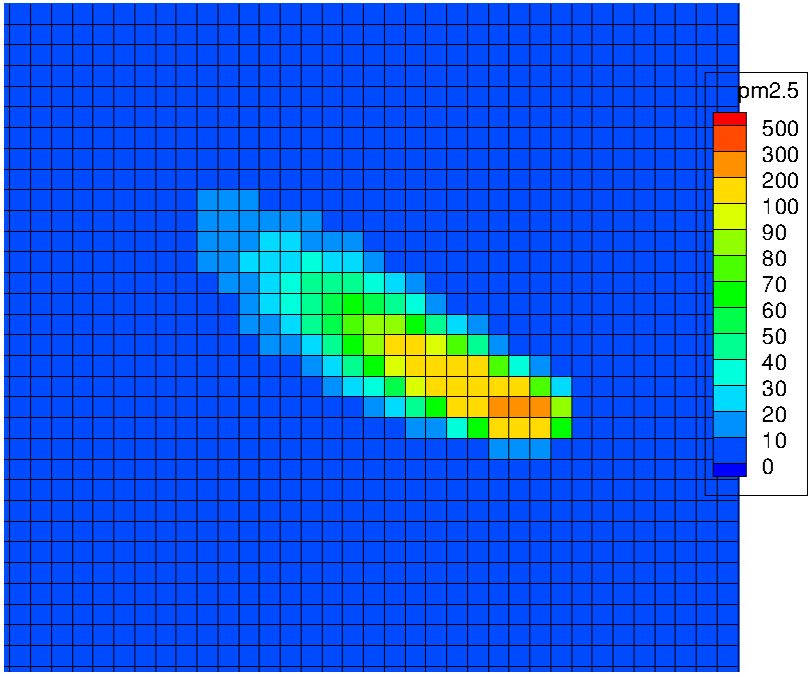


Adaptive Grid (AG-) CMAQ

- Grid adaptor refines the grid around the plumes. As a result the plumes are more concentrated and less diffused.

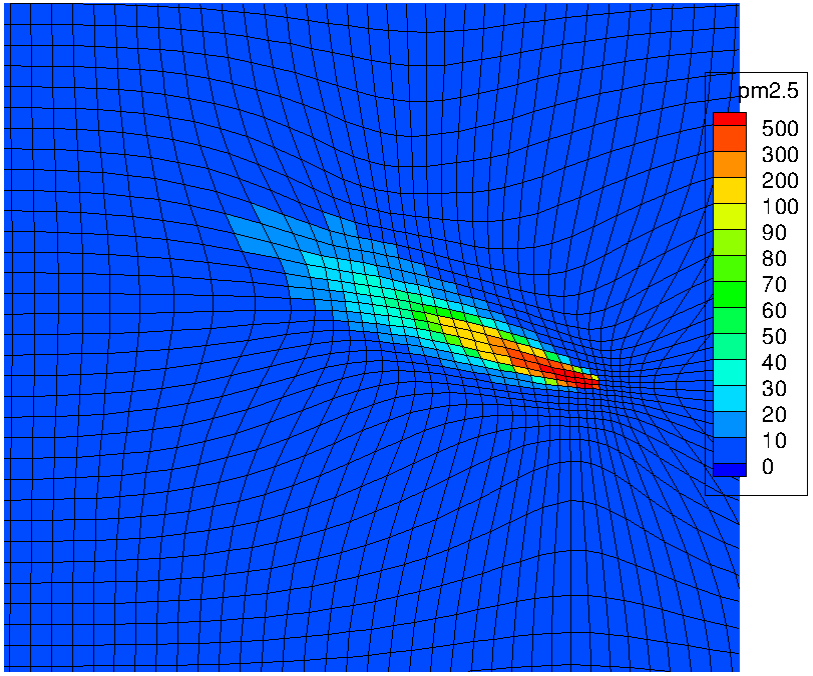
CMAQ

1.33 km grid



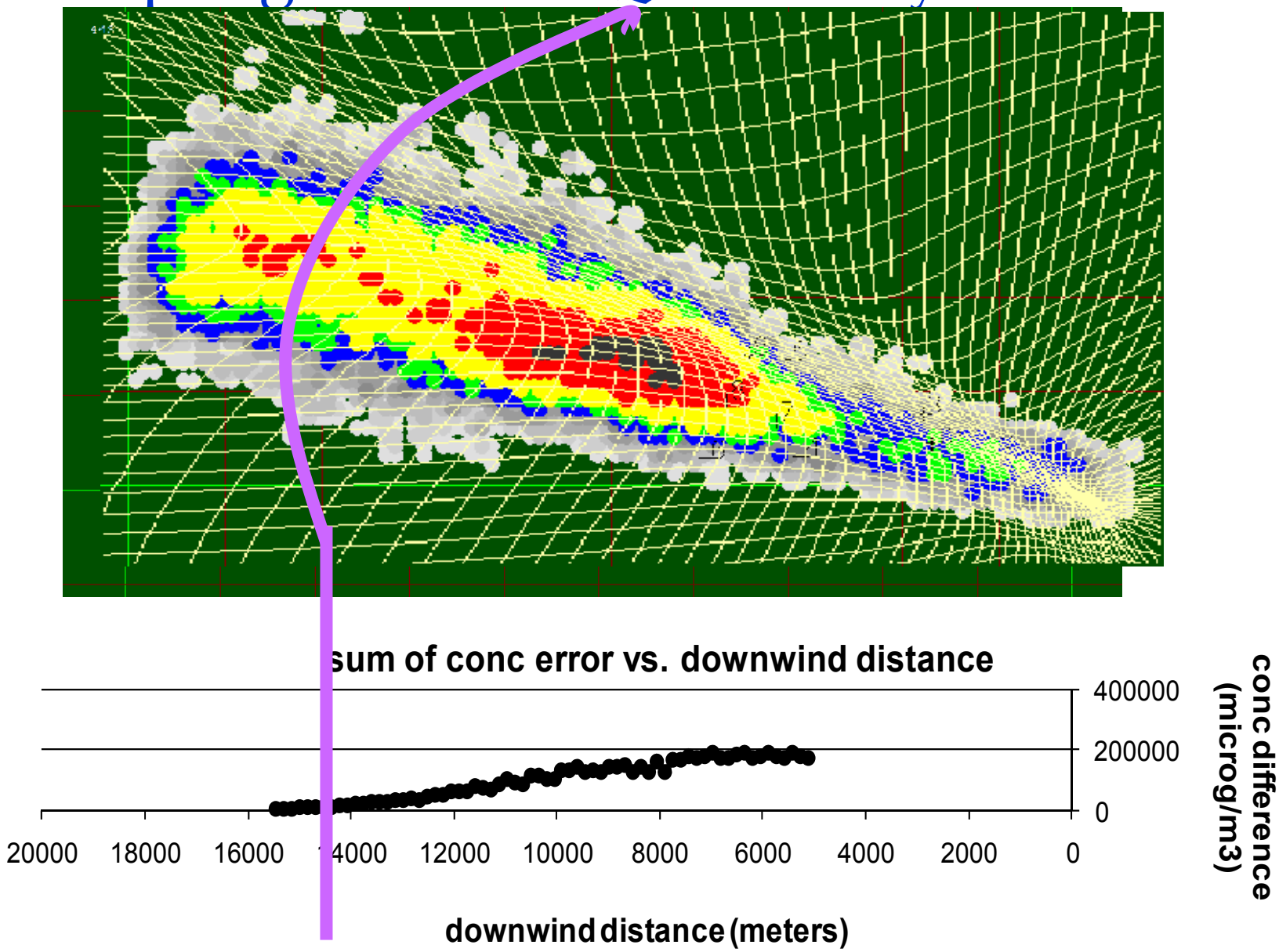
AG-CMAQ

~ 100 m grid



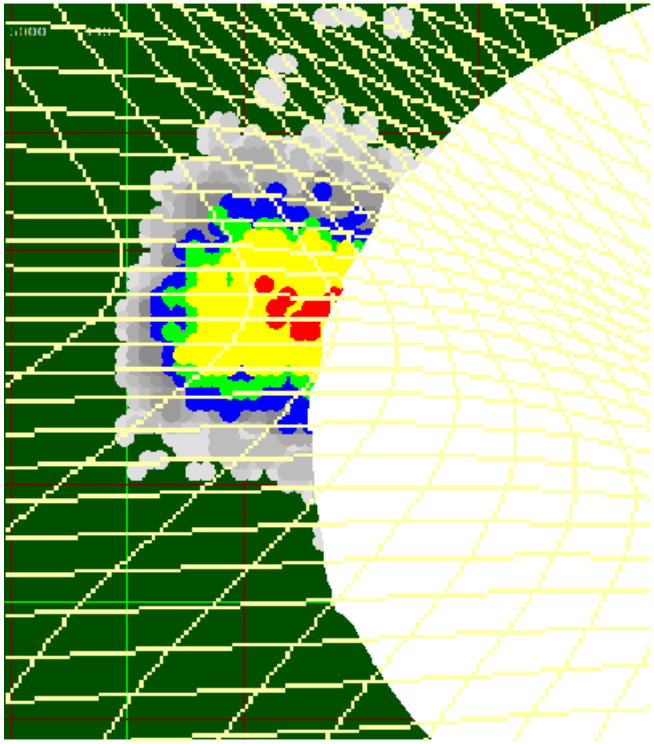
Garcia-Menendez, et al. (2010): An Adaptive Grid Version of CMAQ for Improving the Resolution of Plumes, *Atmos. Pol. Res.*, **1**, 239-249

Coupling AG-CMAQ with Daysmoke

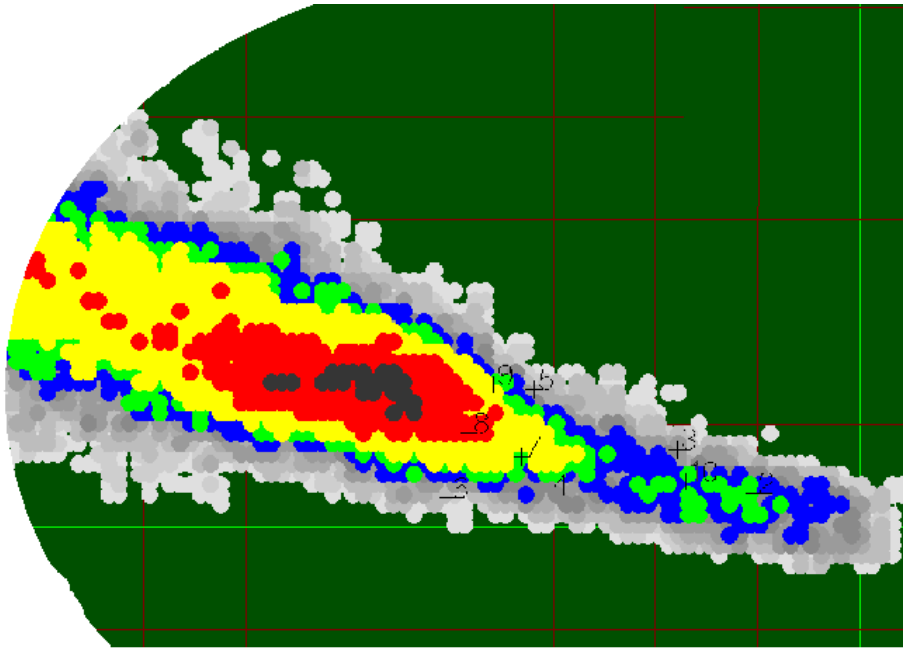


Plume Handover

AG-CMAQ



Daysmoke



New SOA Module

(Poster 2C.22 by Baek et al., Improving SOA in CMAQ using Aged Aerosol)

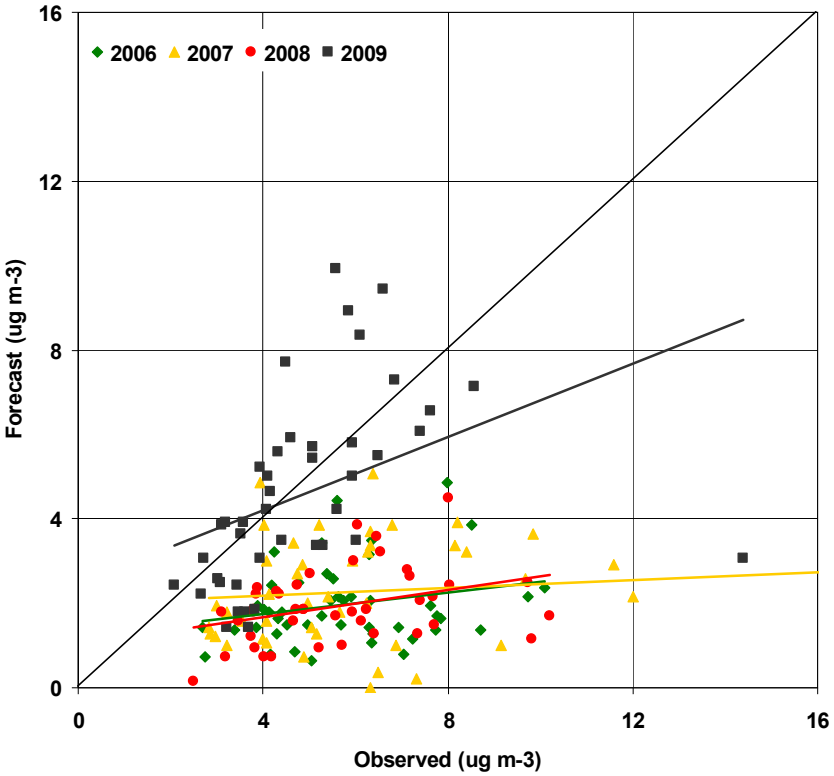
Pre-existing SOA Processes:

- SOA partitioned from anthropogenic VOCs' oxidations (8 SVOCs)
- From monoterpenes (2 SVOCs)

Added SOA Processes:

- **From isoprene (2 SVOCs)**
- **From sesquiterpenes (1 SVOC; gas phase oxidation reactions added for α-caryphyllene, β-humulene, and other sesquiterpenes)**
- **Aging of all SVOCs**

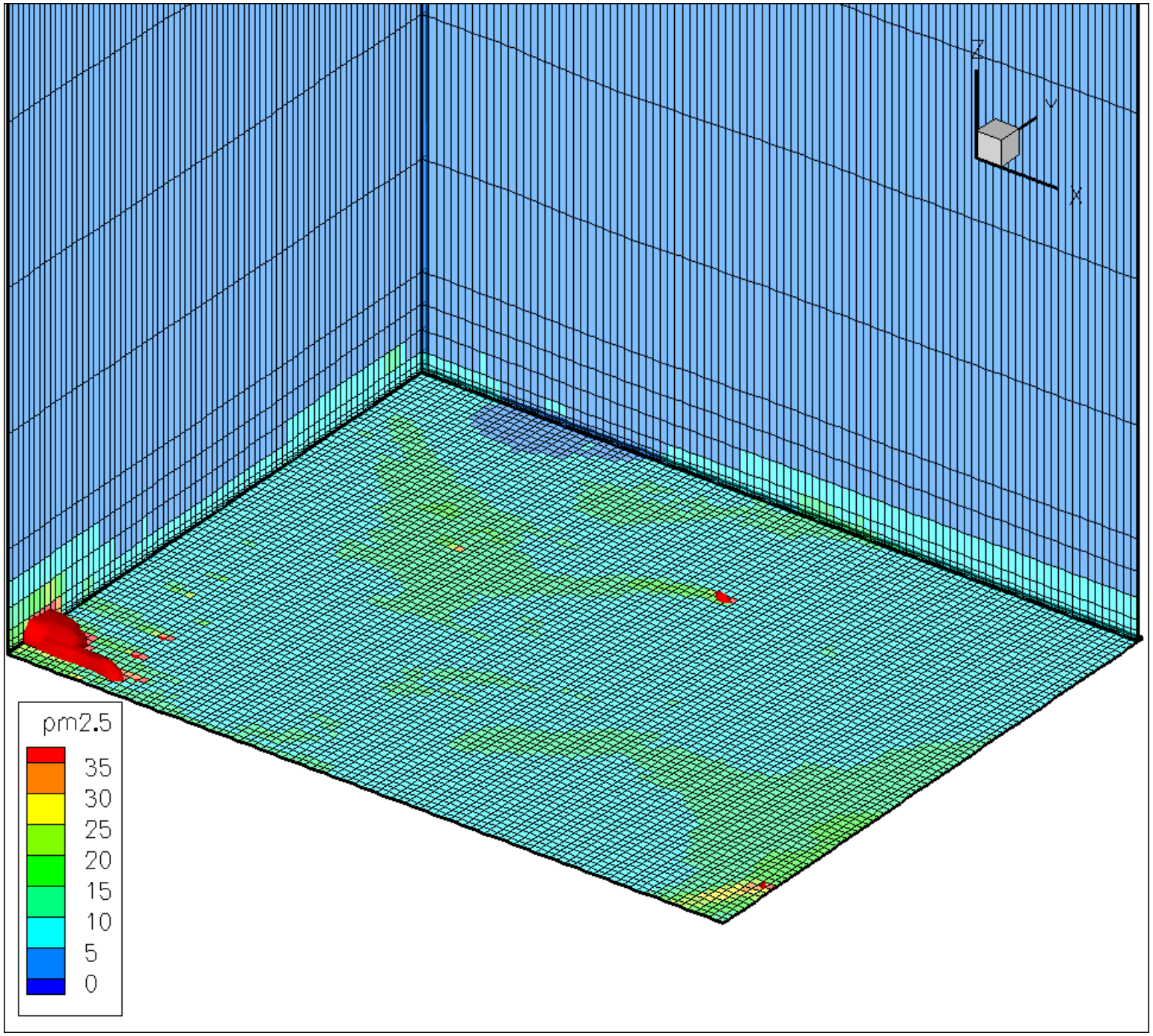
OC in Atlanta

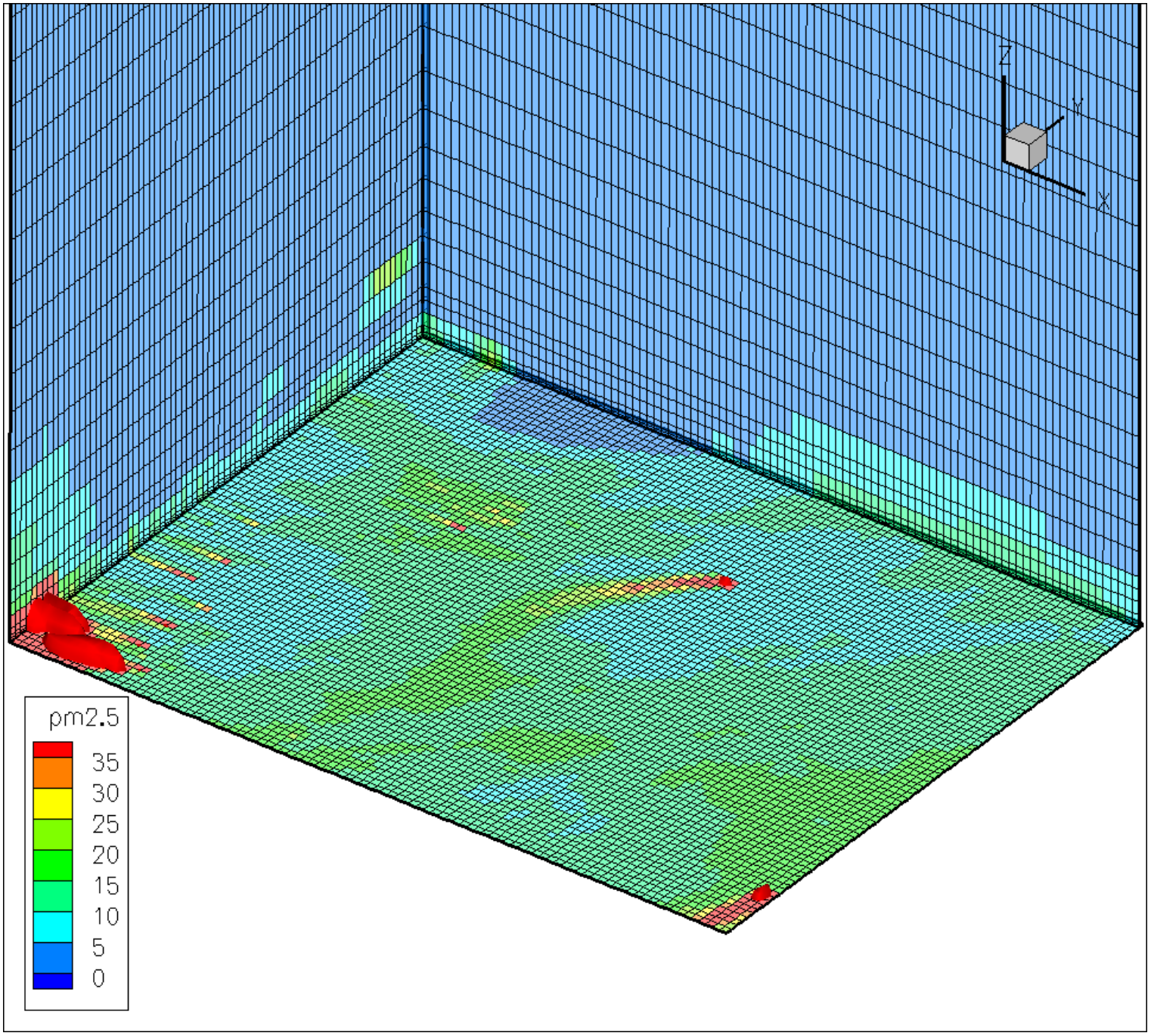


Aging process: HSVOC $\xrightarrow{+OH,+O_3}$ LSVOC $\xrightarrow{+OH,+O_3}$ SOA

(Responsible for 40-80% of all SOA)

Simulation of Feb. 28, 2007 Atlanta Smoke Event


Z
Y
X
pm2.5
35
30
25
20
15
10
5
0


Z
Y
X
pm2.5
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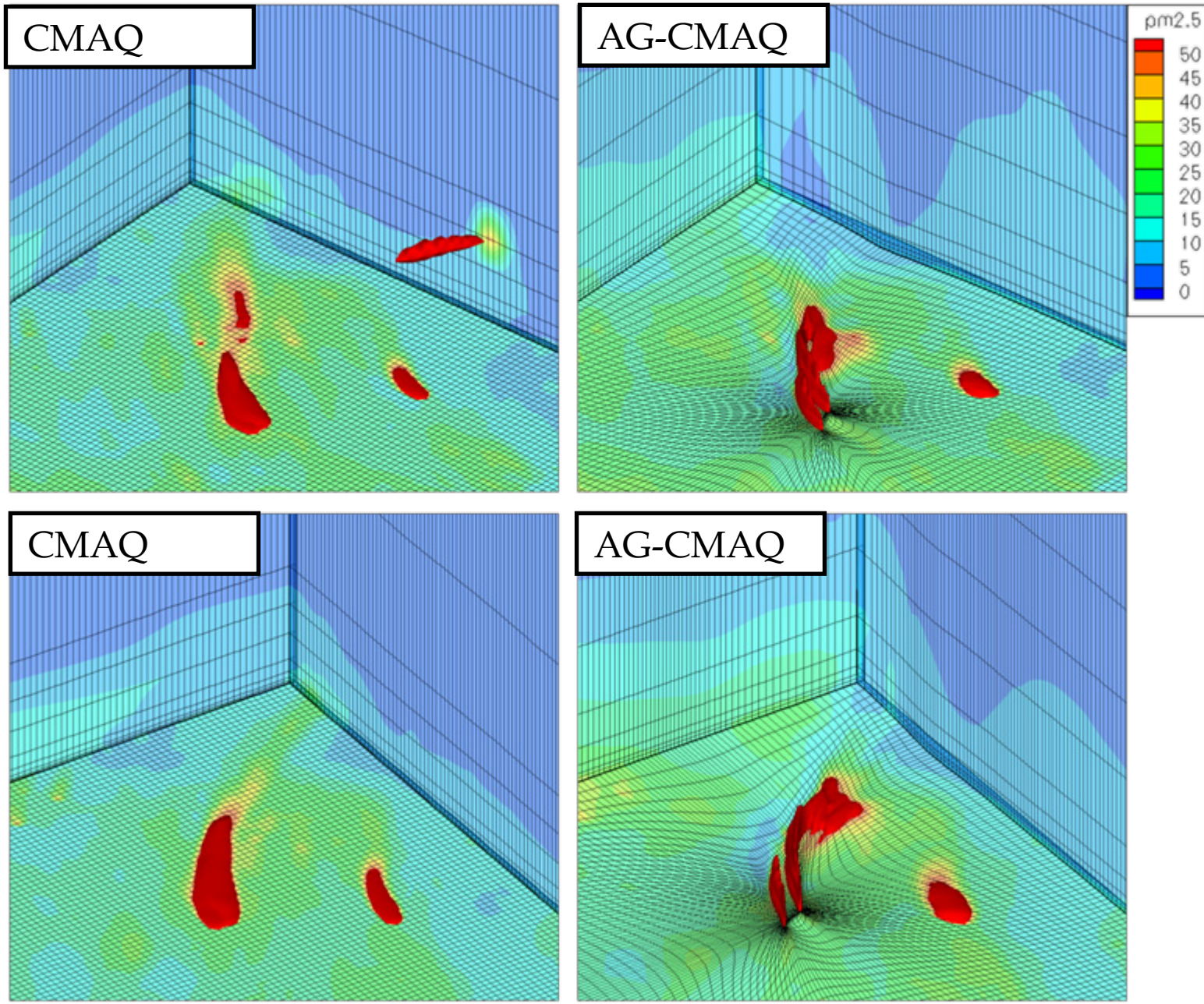
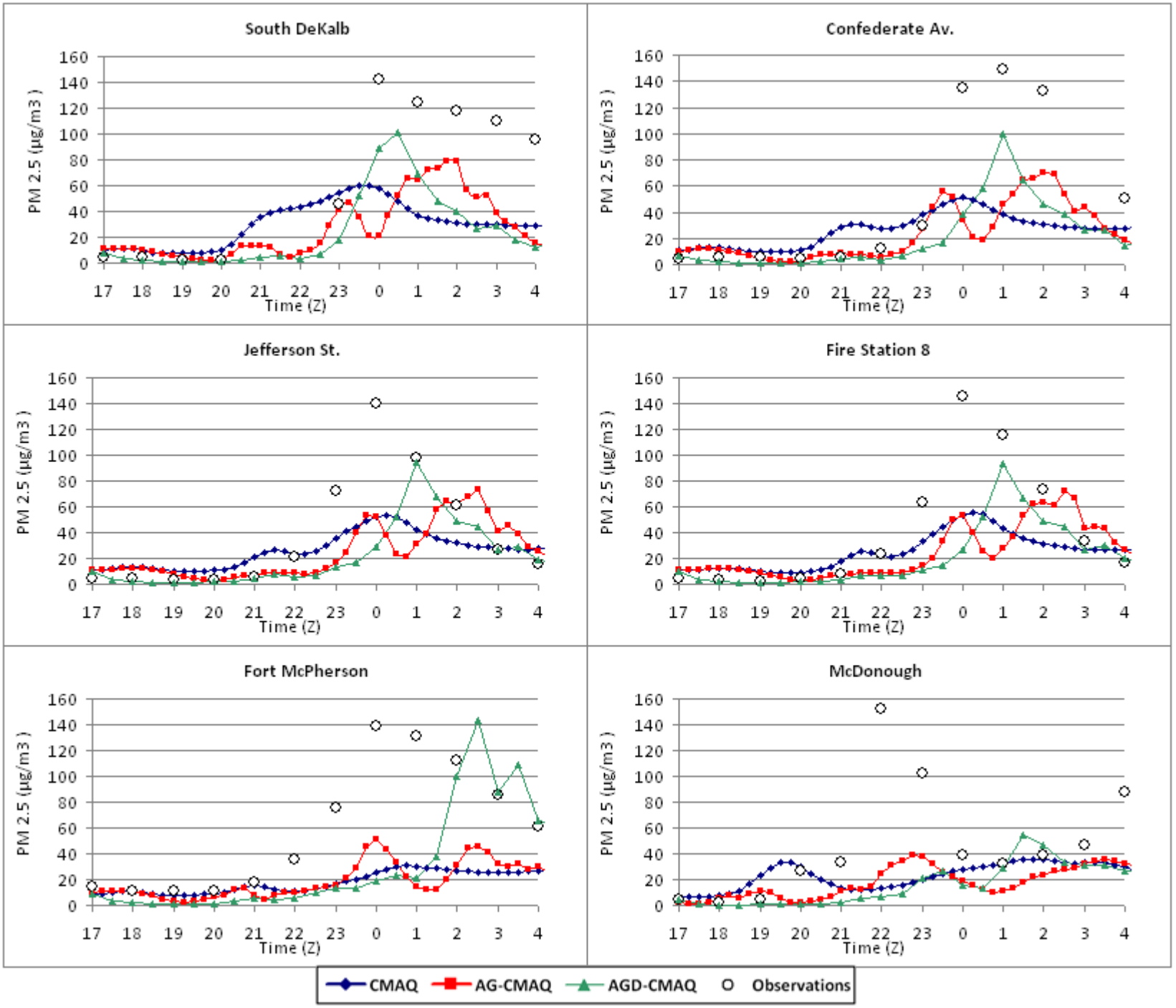
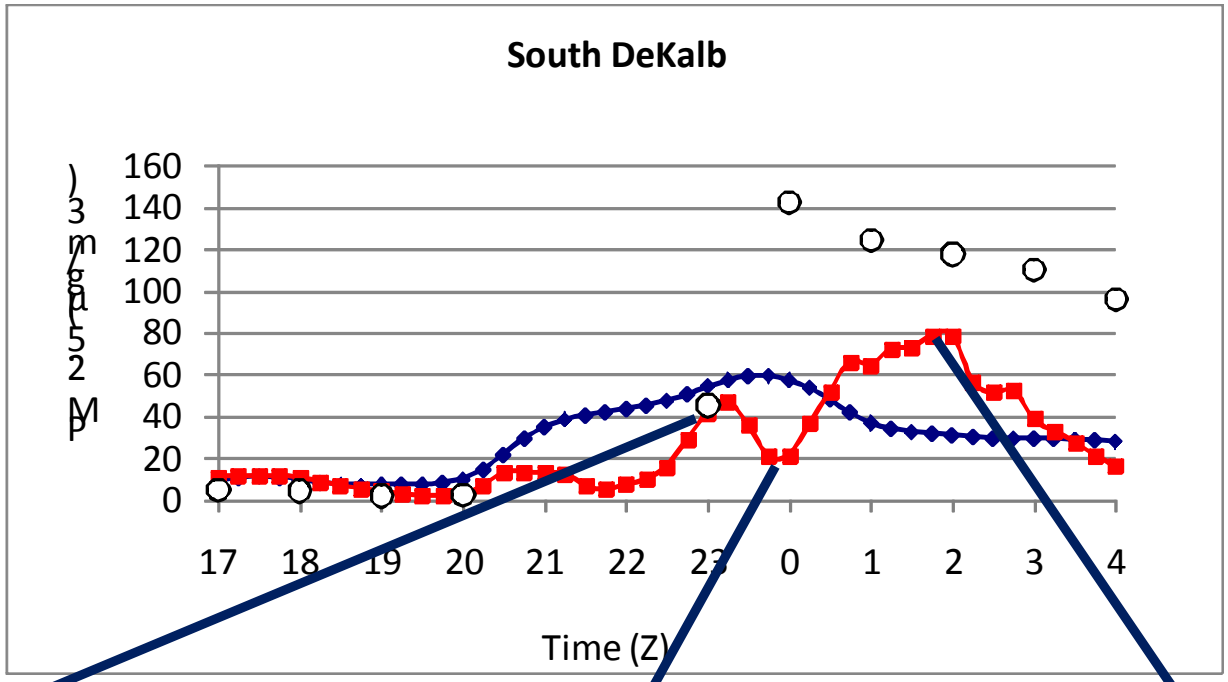
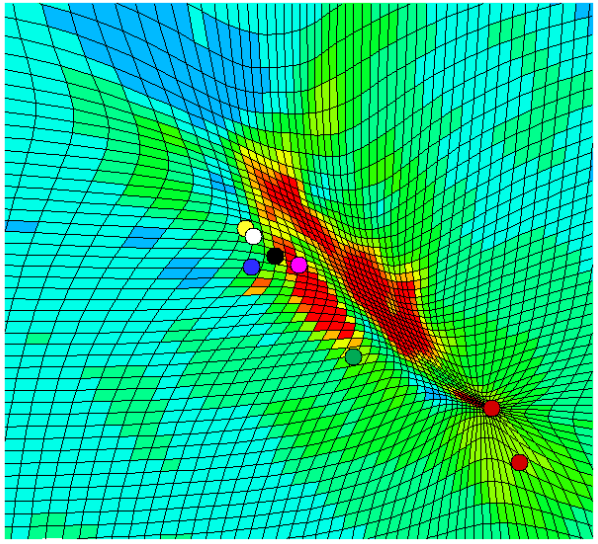
Mar. 1, 2007
00:30 Z

Mar. 1, 2007
02:15 Z




South DeKalb
Confederate Av.
Jefferson St.
Fire Station 8
Fort McPherson
McDonough
PM 2.5 (µg/m3)
Time (Z)
0
20
40
60
80
100
120
140
160
17
18
19
20
21
22
23
0
1
2
3
4
CMAQ
AG-CMAQ
AGD-CMAQ
Observations





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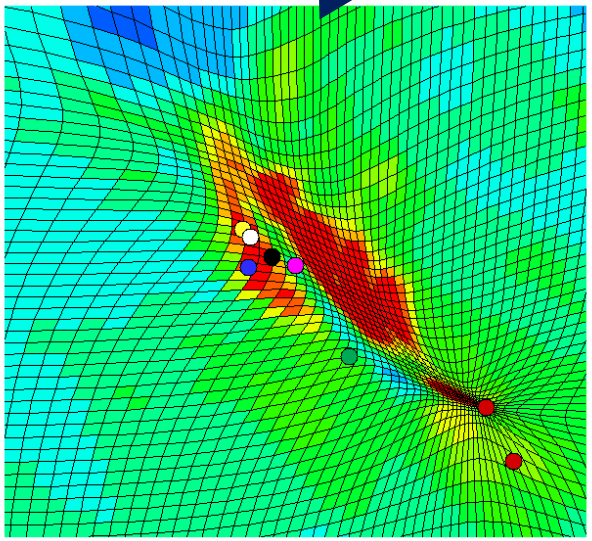

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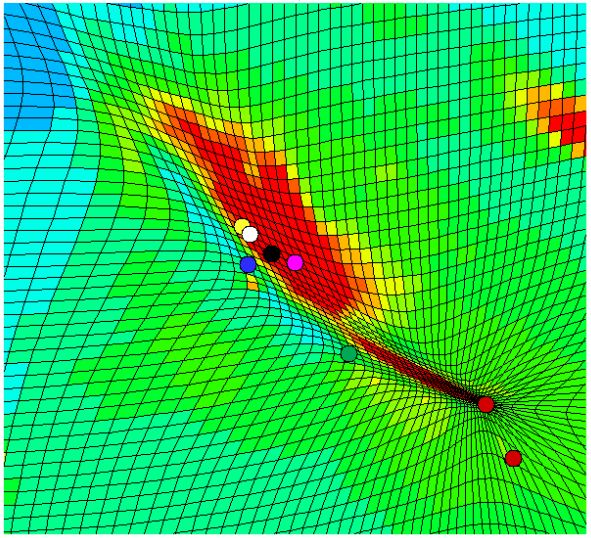

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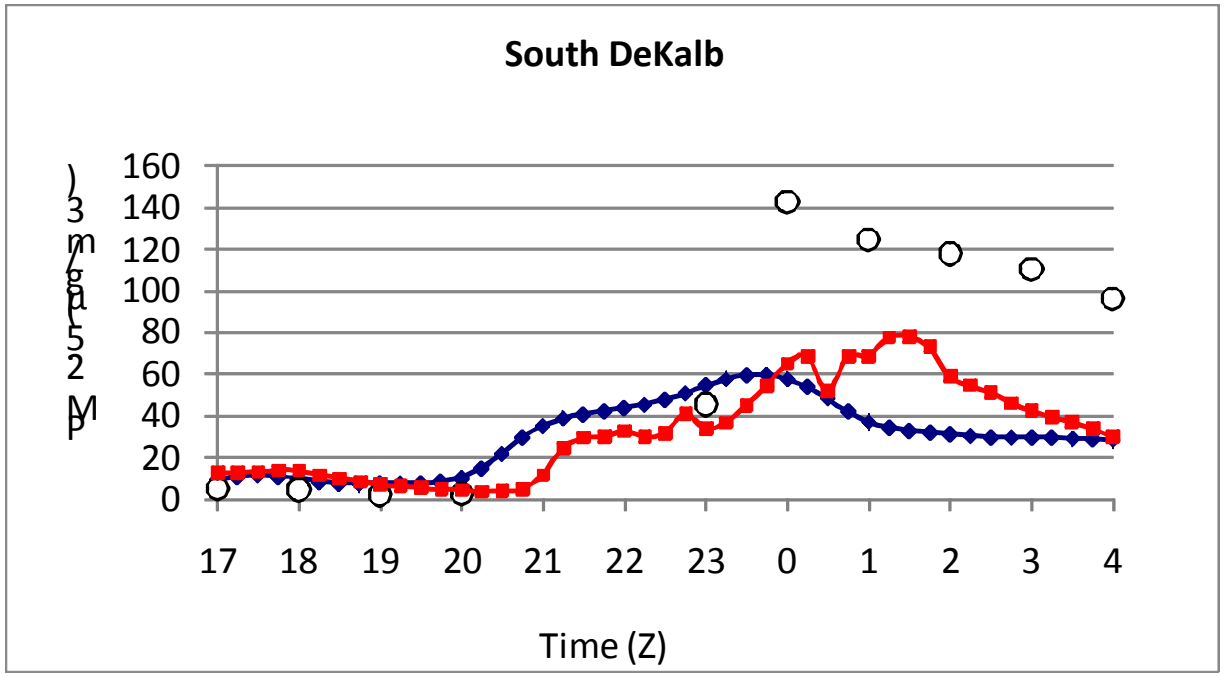
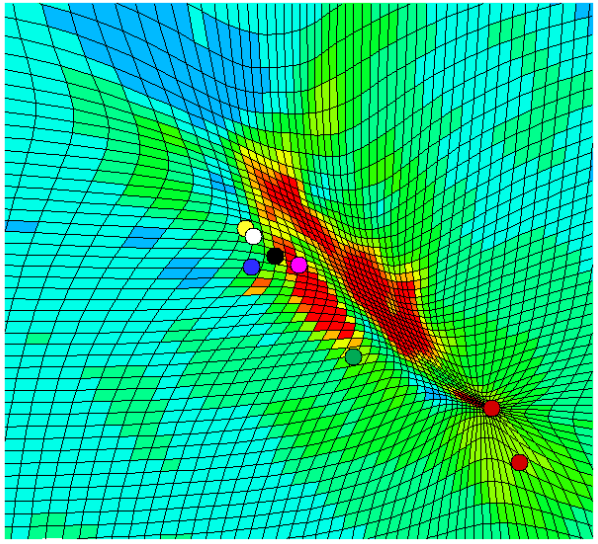
5° Degree Shift in Wind Field





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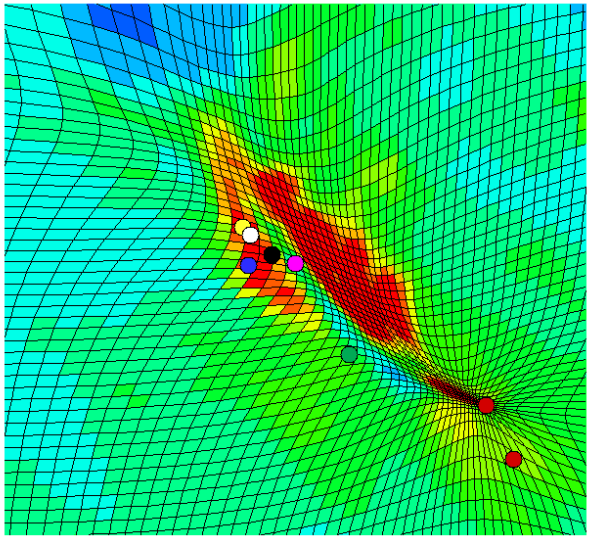

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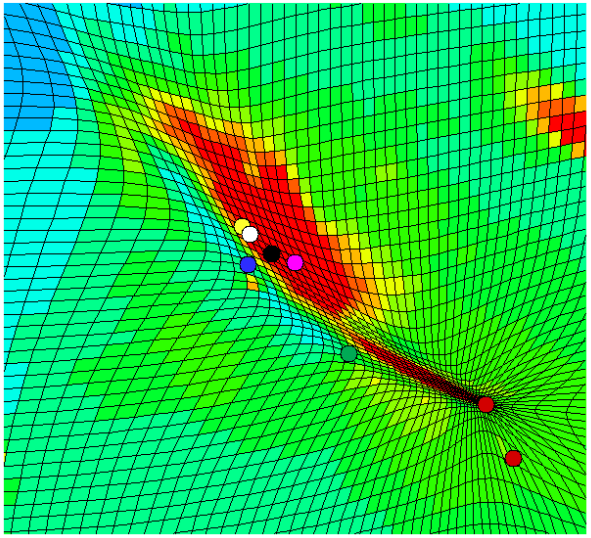

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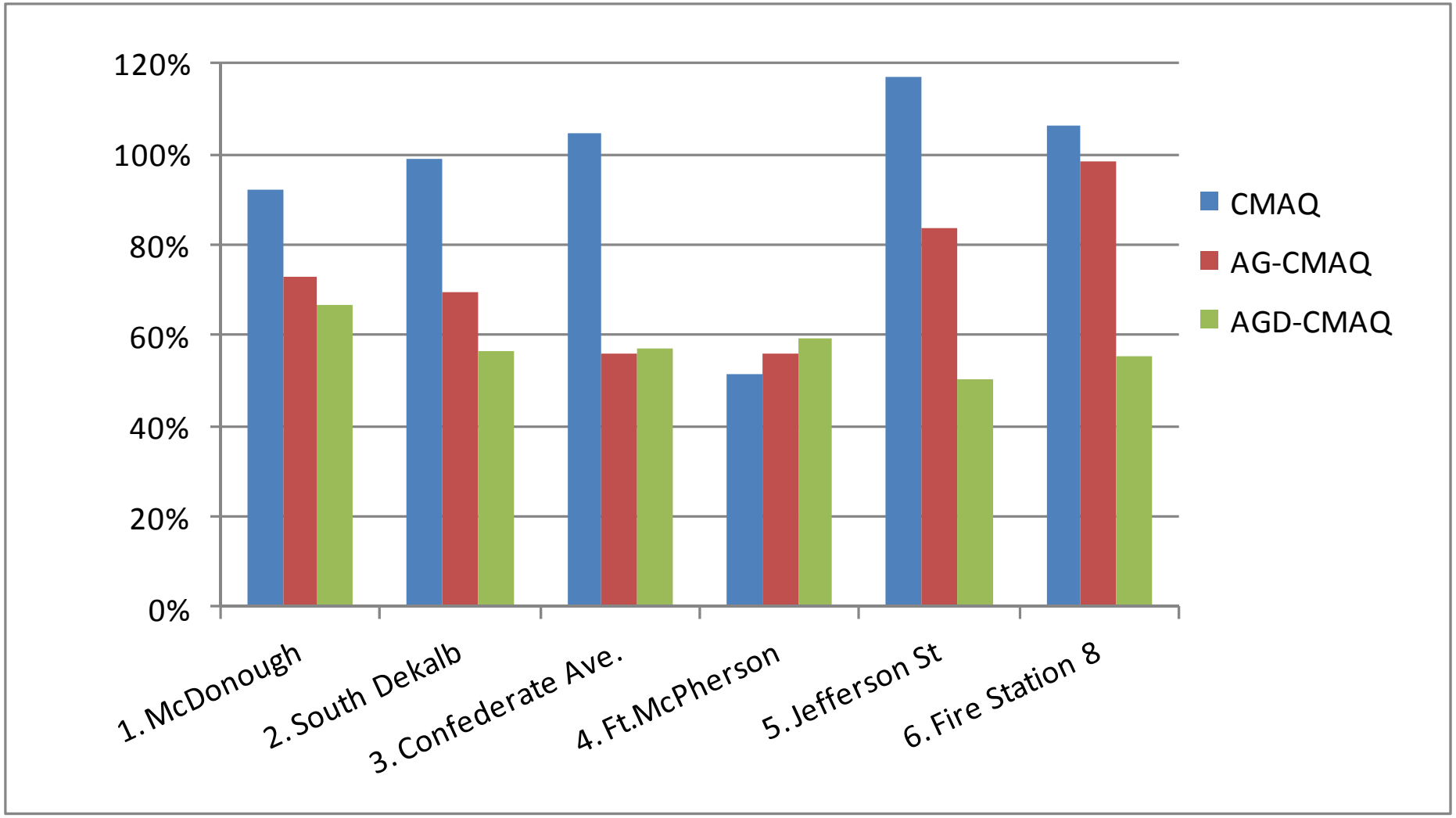
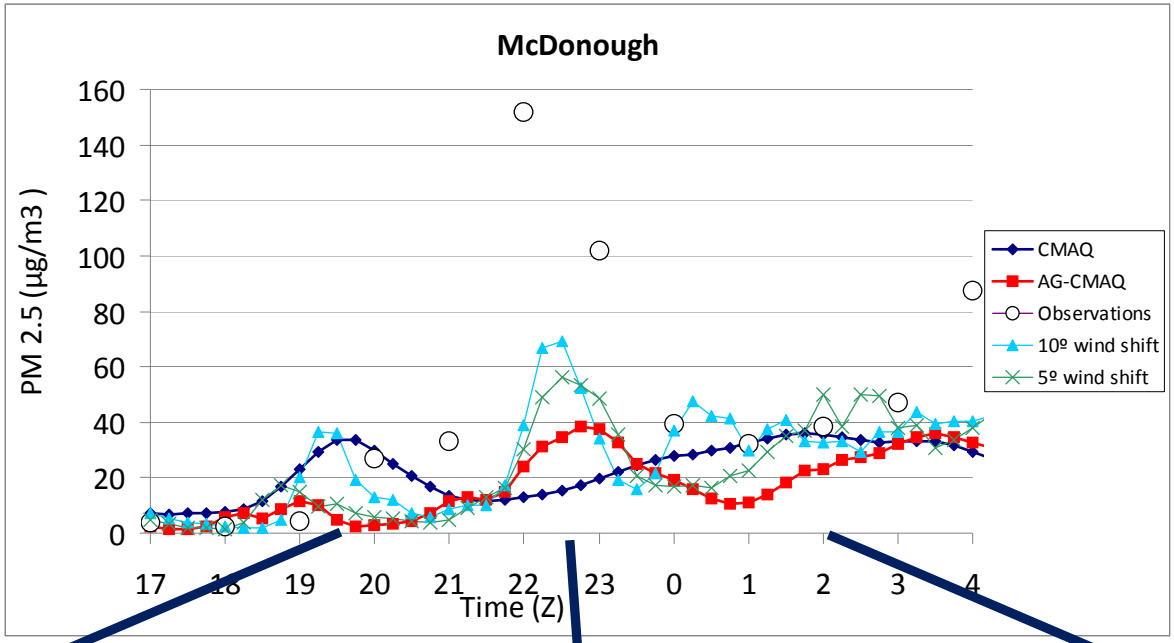
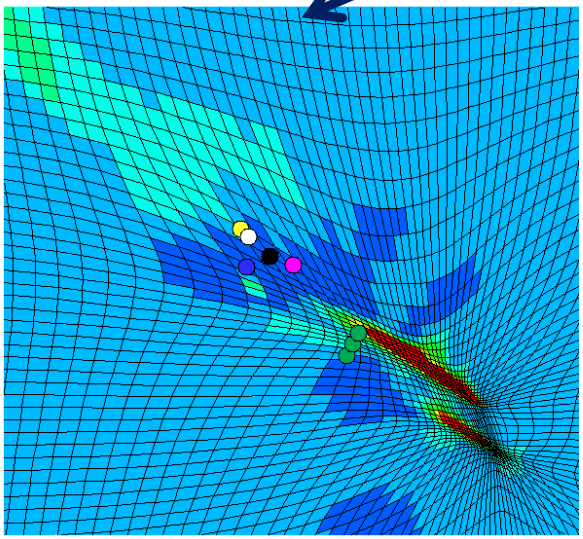
Mean Normalized Error







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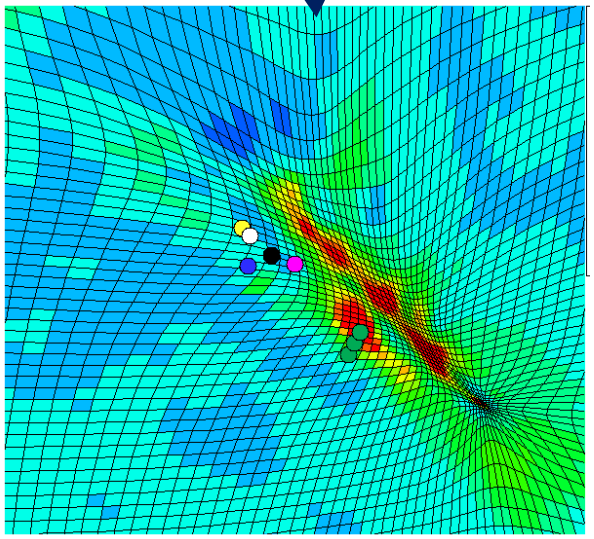

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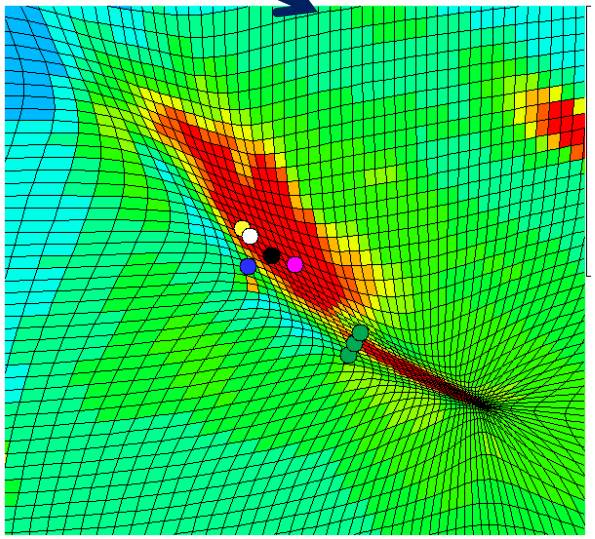

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Summary and Future Work

- A modeling system is being developed to predict the impacts of prescribed burns on regional air quality.
- An adaptive grid version of CMAQ has been developed. AG-CMAQ produces more accurate results than standard CMAQ.
- AG-CMAQ has been coupled with Daysmoke, a sub-grid scale plume model. AGD-CMAQ produces yet more accurate results than AG-CMAQ.
- An improved SOA module has been incorporated.
- An adaptive grid version of WRF is under development for fine resolution meteorology.
- Fully interactive coupling of AGD-CMAQ with AG-WRF will be the final step.

Acknowledgements

- Strategic Environmental Research and Development Program (SERDP)
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- Environmental Protection Agency (EPA)

Thank you!
Questions?