Development of a Modeling System for Prescribed Burn Emissions and Air Quality Impacts

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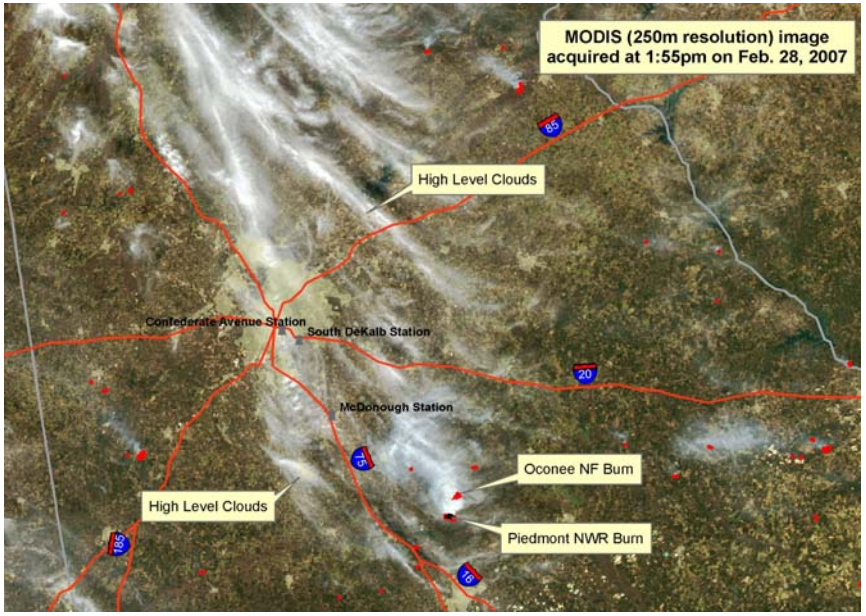
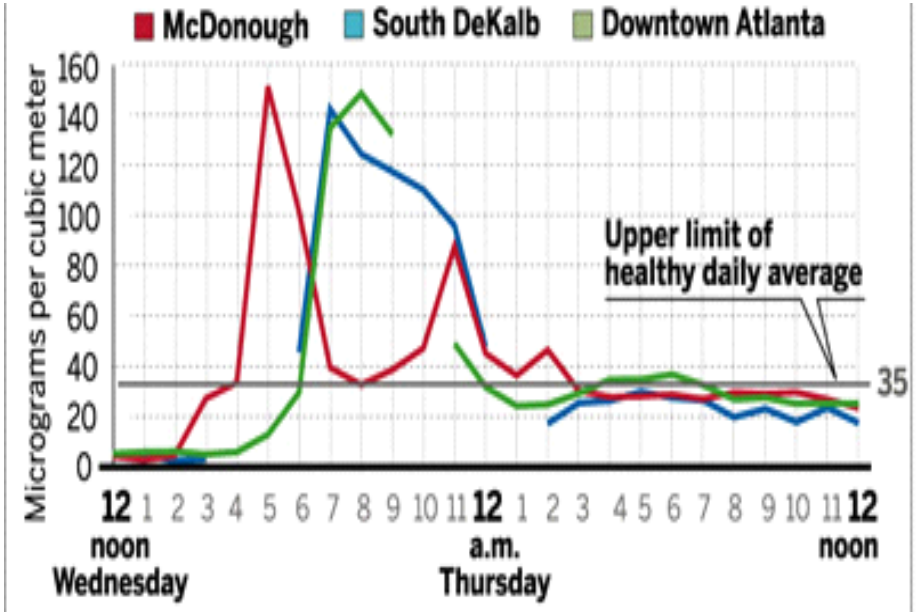
Air Quality Impacts of Prescribed Burns

- Prescribed burning is an economical way of maintaining and improving the forest ecosystem, and reducing wildfire risk.
- However, pollutants emitted from the fires may be transported long distances, mix with emissions from other sources, and contribute to air quality problems in downwind urban areas.

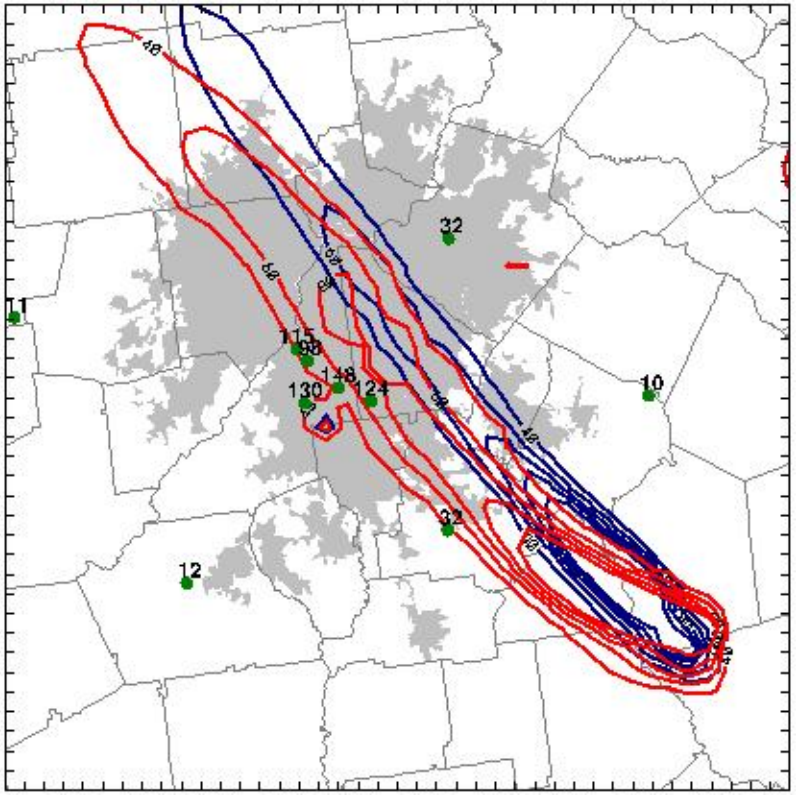
Feb. 28, 2007 Atlanta Smoke Event





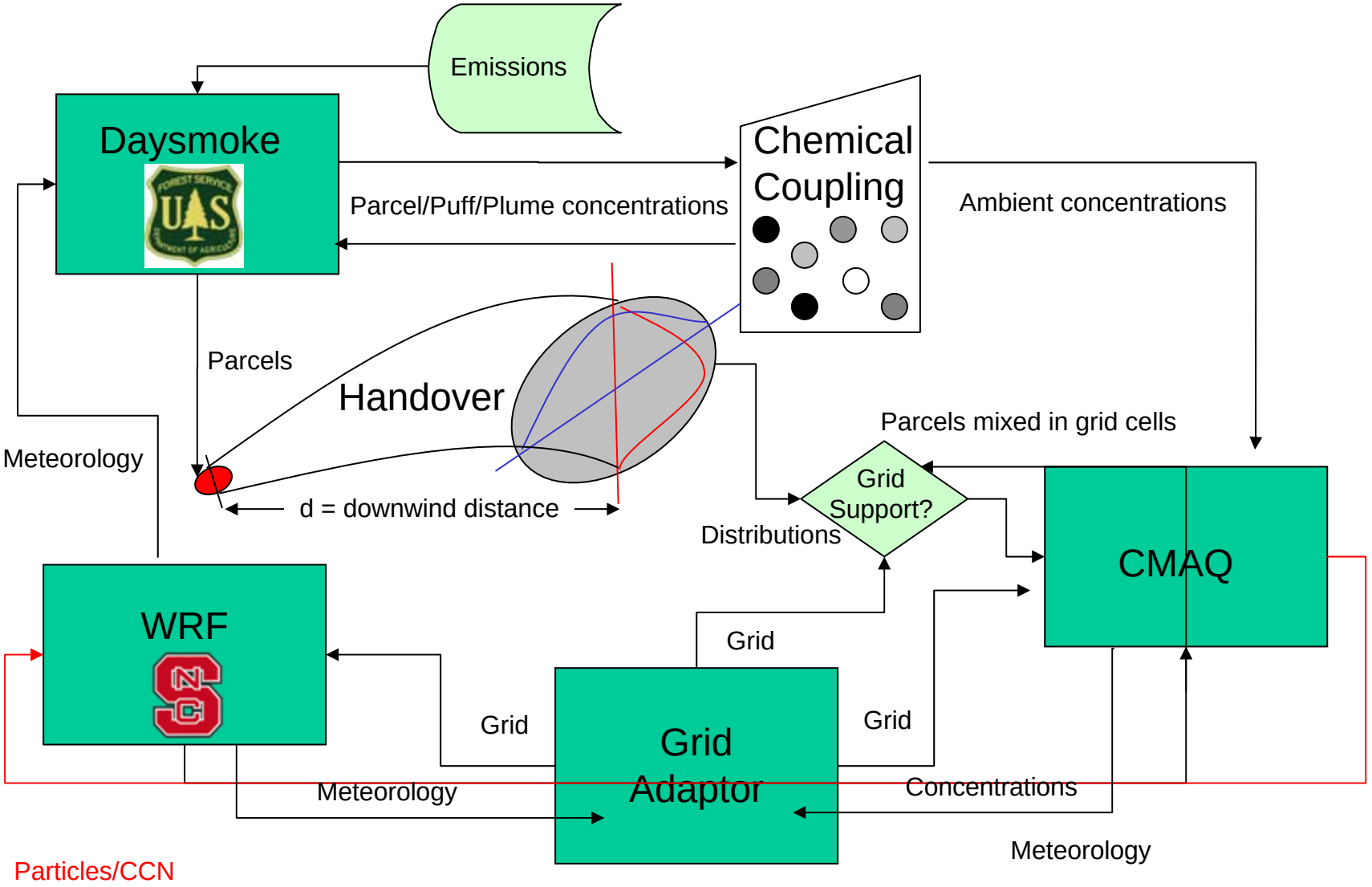
State of the Models (weaknesses)

First Modeling Attempts
with WRF / CMAQ



- Uncertainty in emissions
  - Fuel loads, consumption & emission factors
  - Fire-induced emissions (from non-burning trees)
- Lack of adequate plume dynamics / chemistry
  - No plume-in-grid treatment
  - PB plume different from power plant plumes or area sources
- Lack of plume feedback on meteorology
  - First WRF then CMAQ
- Insufficient resolution
  - 4-km horizontal grid

Smoke Impact Simulation System



Adaptive Grid CMAQ

- AG-CMAQ incorporates the products of our adaptive grid research in CMAQ (v. 4.5)
  - Adaptive Grid Algorithm (1997-2001)
  - Adaptive Grid Air Quality Model (2001-2004)
  - Variable Time Step Algorithm (2004-2007)
- Governing equations in CMAQ are transformed from (x,y,σ) to (ξ,η,σ) space :

$$\frac{\partial(Jc_n)}{\partial t}+\frac{\partial\left(Jv^{\xi}c_n\right)}{\partial\xi}+\frac{\partial\left(Jv^{\eta}c_n\right)}{\partial\eta}+\frac{\partial\left(Jv^{\sigma}c_n\right)}{\partial\sigma}+\frac{\partial}{\partial\xi}\left(JK^{\xi\xi}\frac{\partial c_n}{\partial\xi}\right)$$

$$+\frac{\partial}{\partial\eta}\left(JK^{\eta\eta}\frac{\partial c_n}{\partial\eta}\right)+\frac{\partial}{\partial\sigma}\left(JK^{\sigma\sigma}\frac{\partial c_n}{\partial\sigma}\right)=JR_n+JS_n$$

  - J is the Jacobian of the transformation

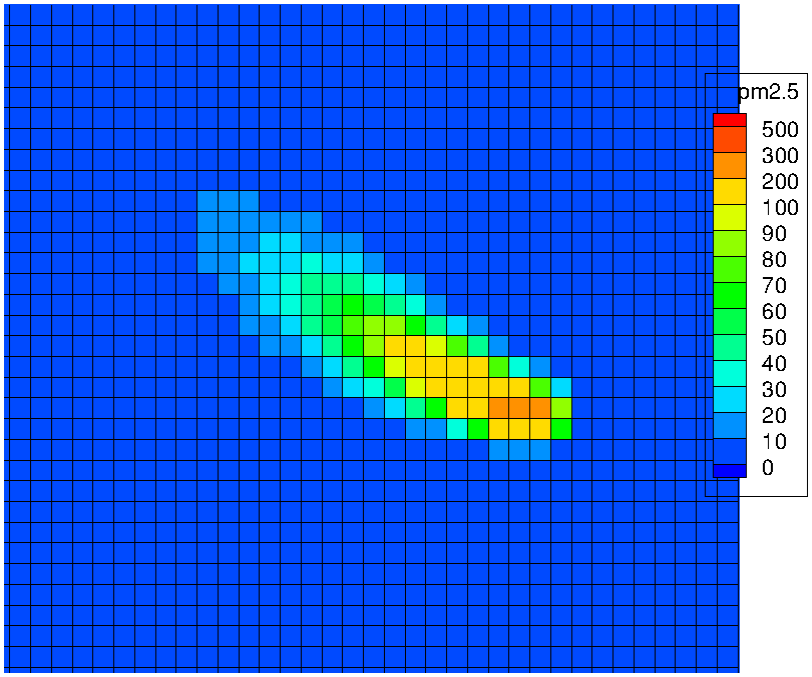
$$J=\frac{1}{m^2}\frac{\partial z}{\partial\sigma}\left(\frac{\partial x}{\partial\xi}\frac{\partial y}{\partial\eta}-\frac{\partial y}{\partial\xi}\frac{\partial x}{\partial\eta}\right)$$

Verification of AG-CMAQ Code

- Non adapting AG-CMAQ produces the same results as CMAQ
- Grid adaptor refines the grid around the plumes (as it should) and AG-CMAQ produces a more accurate solution.

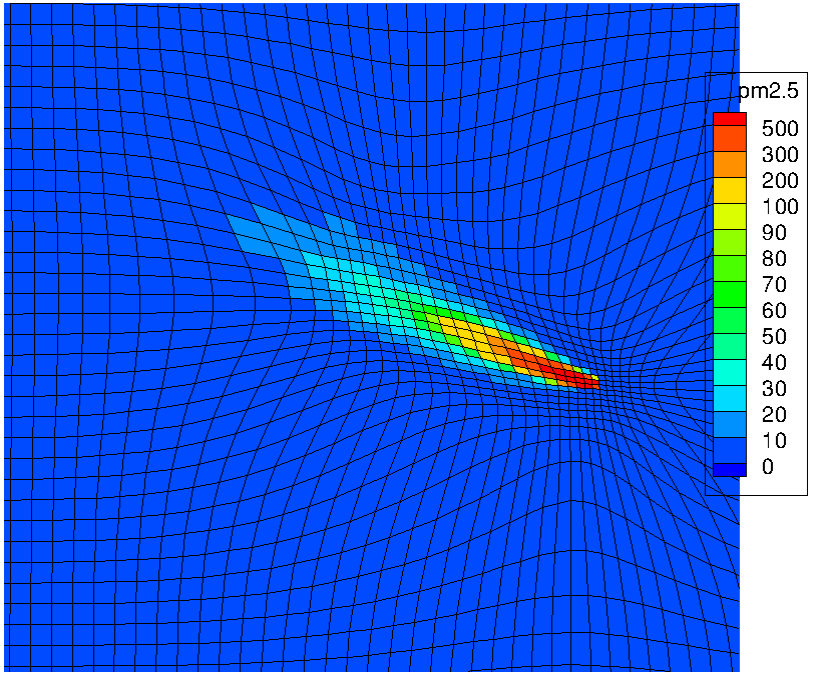
CMAQ

1.33 km grid



AG-CMAQ

~ 100 m grid

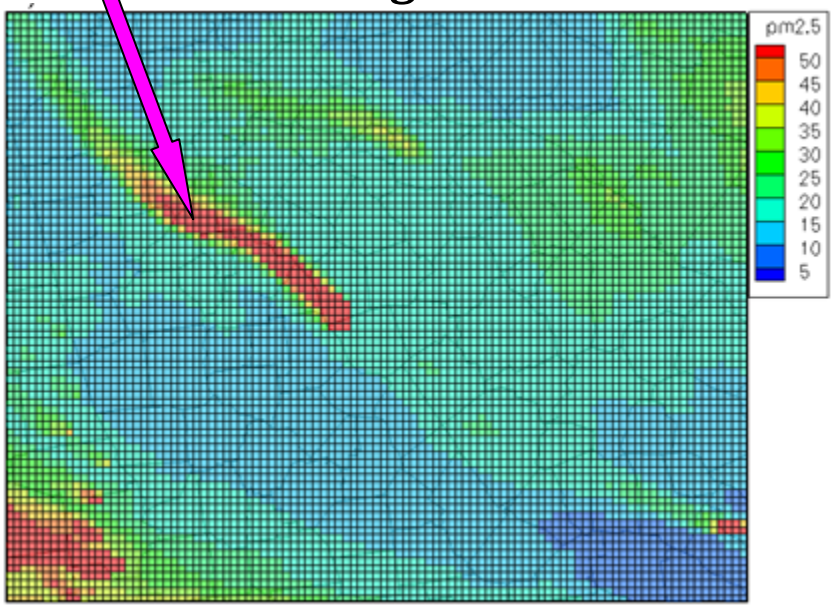


Model Evaluation: Feb. 28, 2007
Atlanta Smoke Event

Atlanta

CMAQ

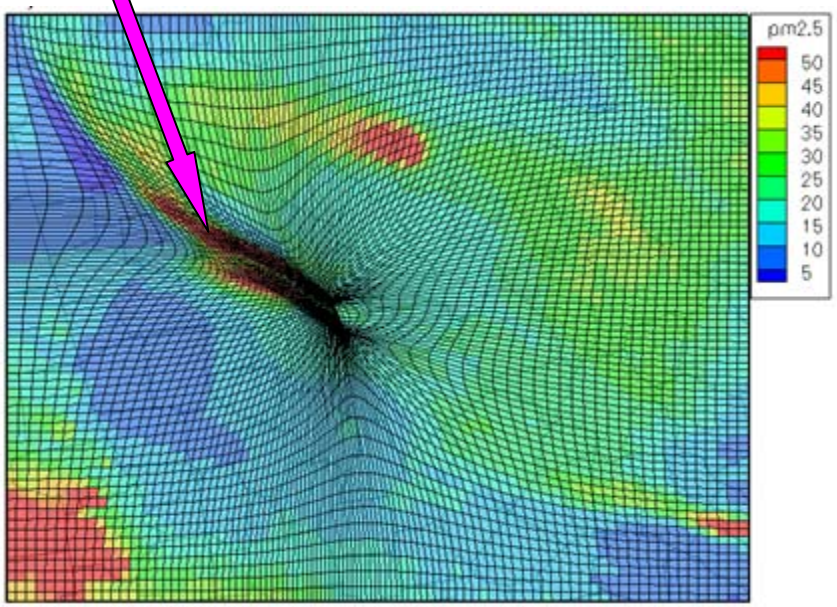
4 km grid



Atlanta

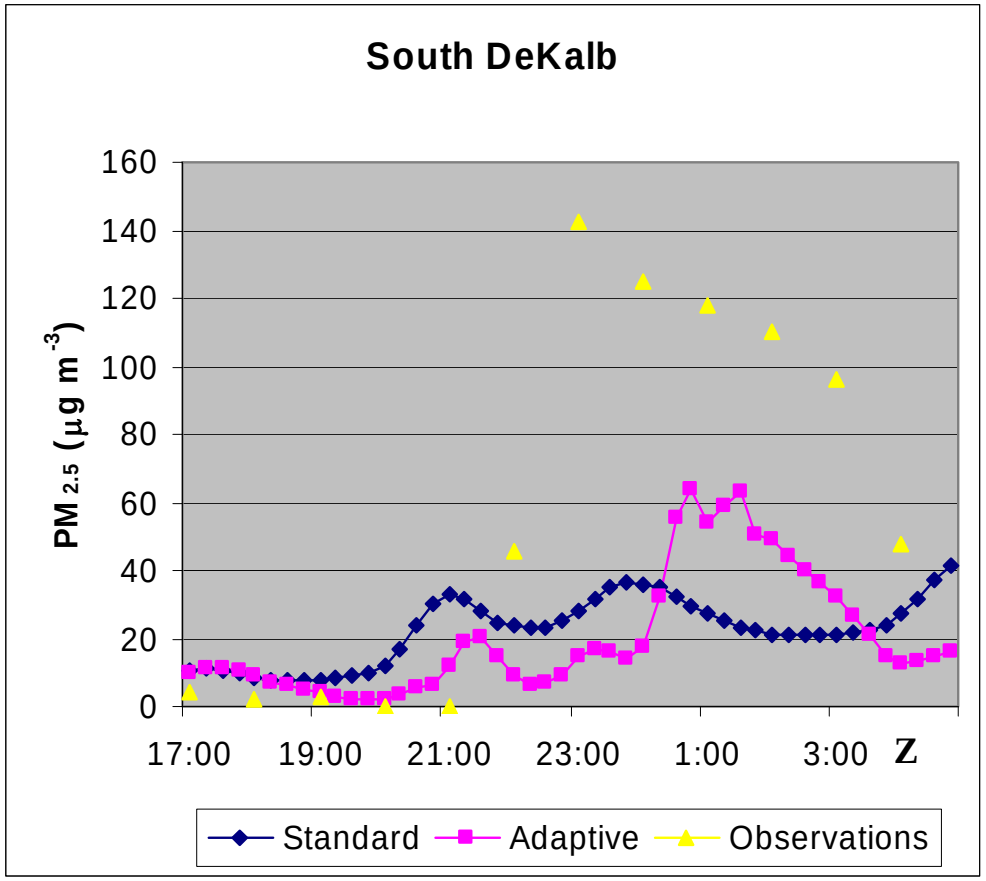
AG-CMAQ

~ 100 m grid

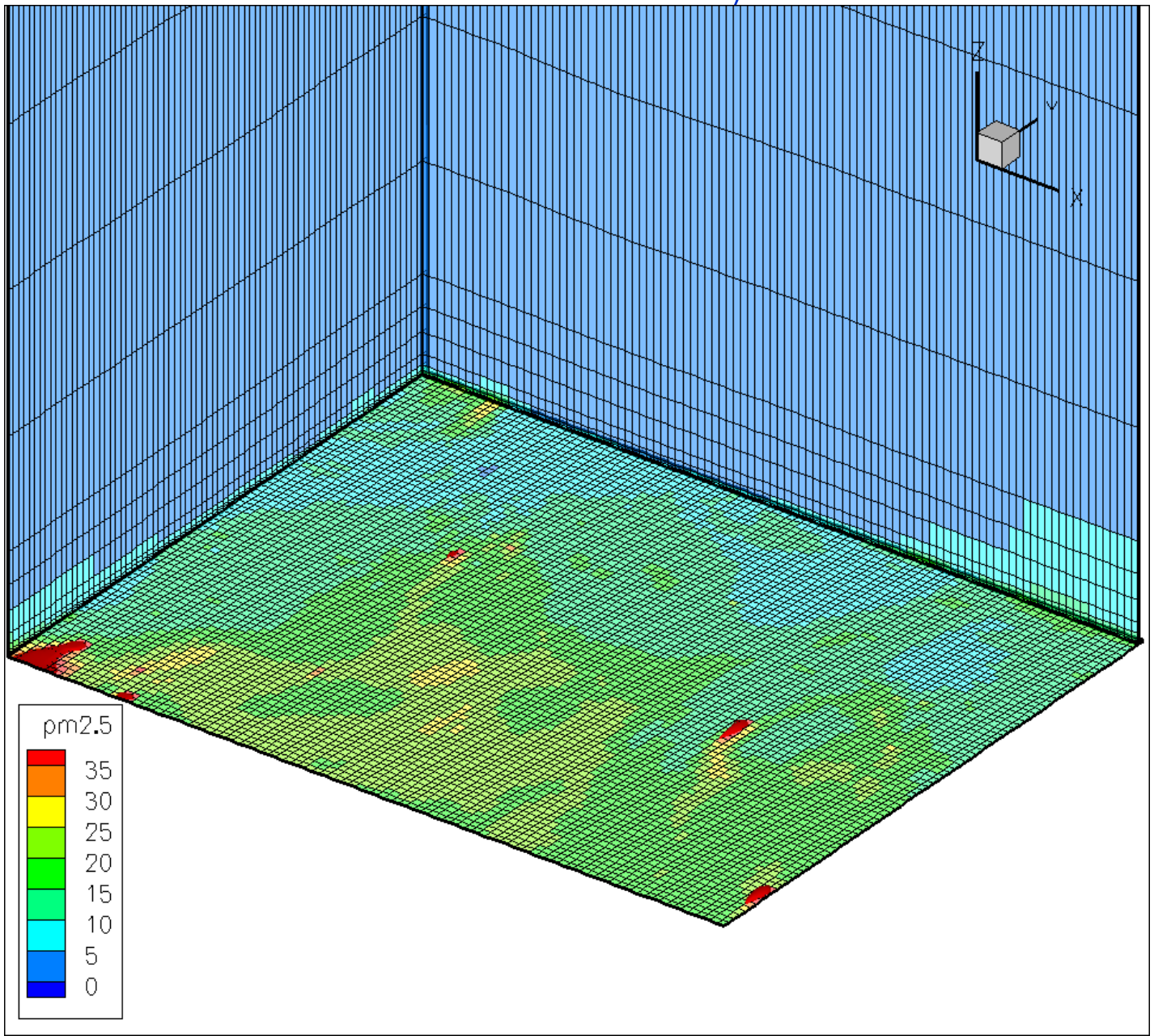


Comparison to Observations:

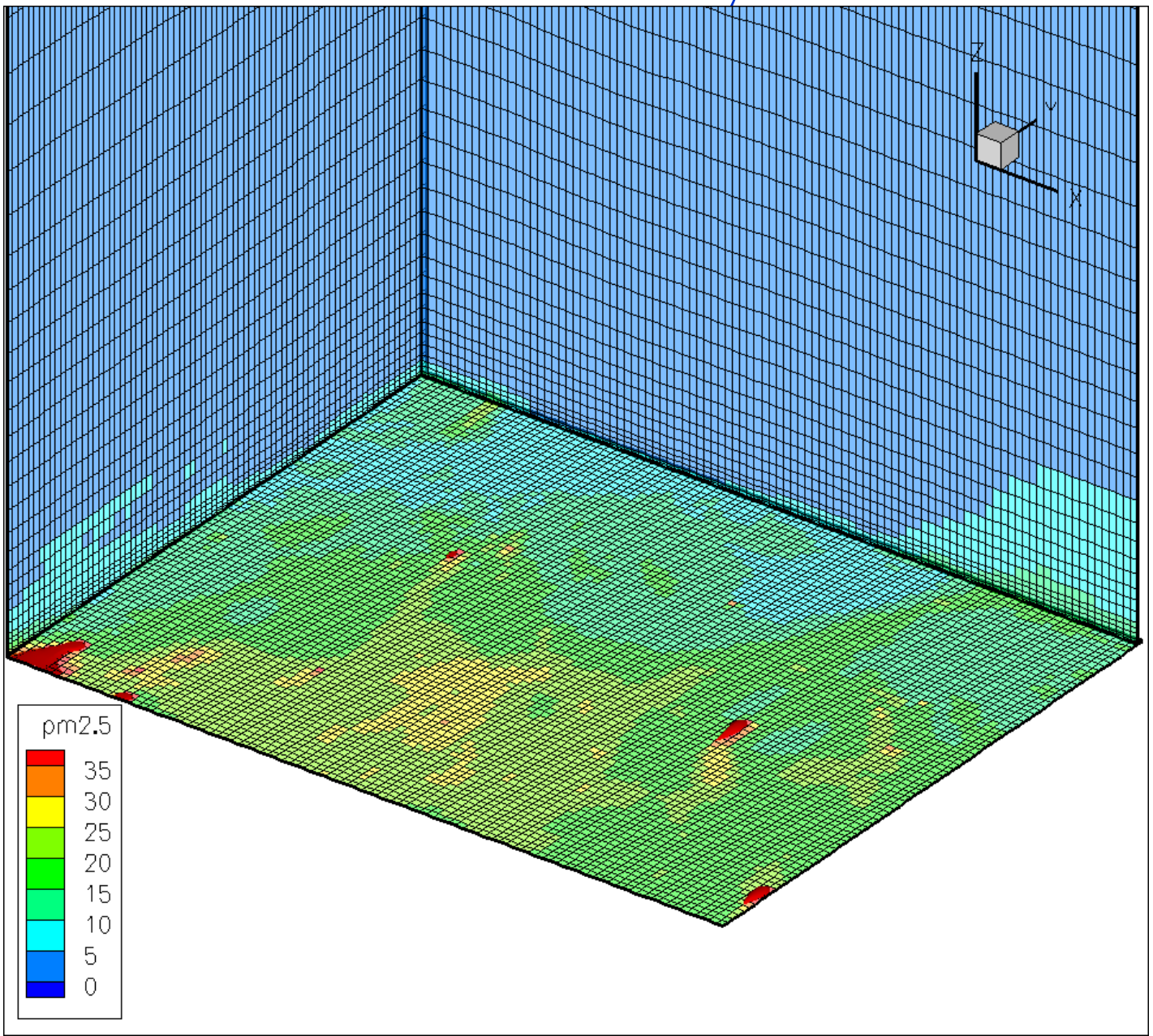
CMAQ vs AG-CMAQ



13 Vertical Layers

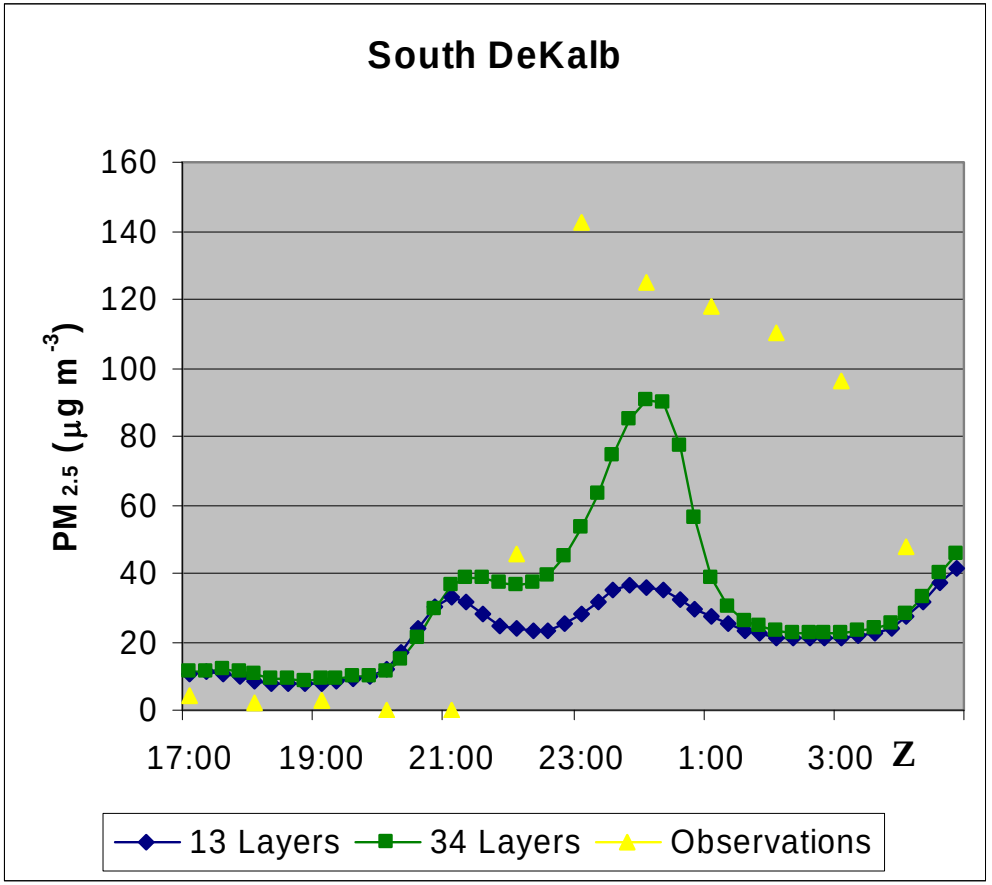


34 Vertical Layers

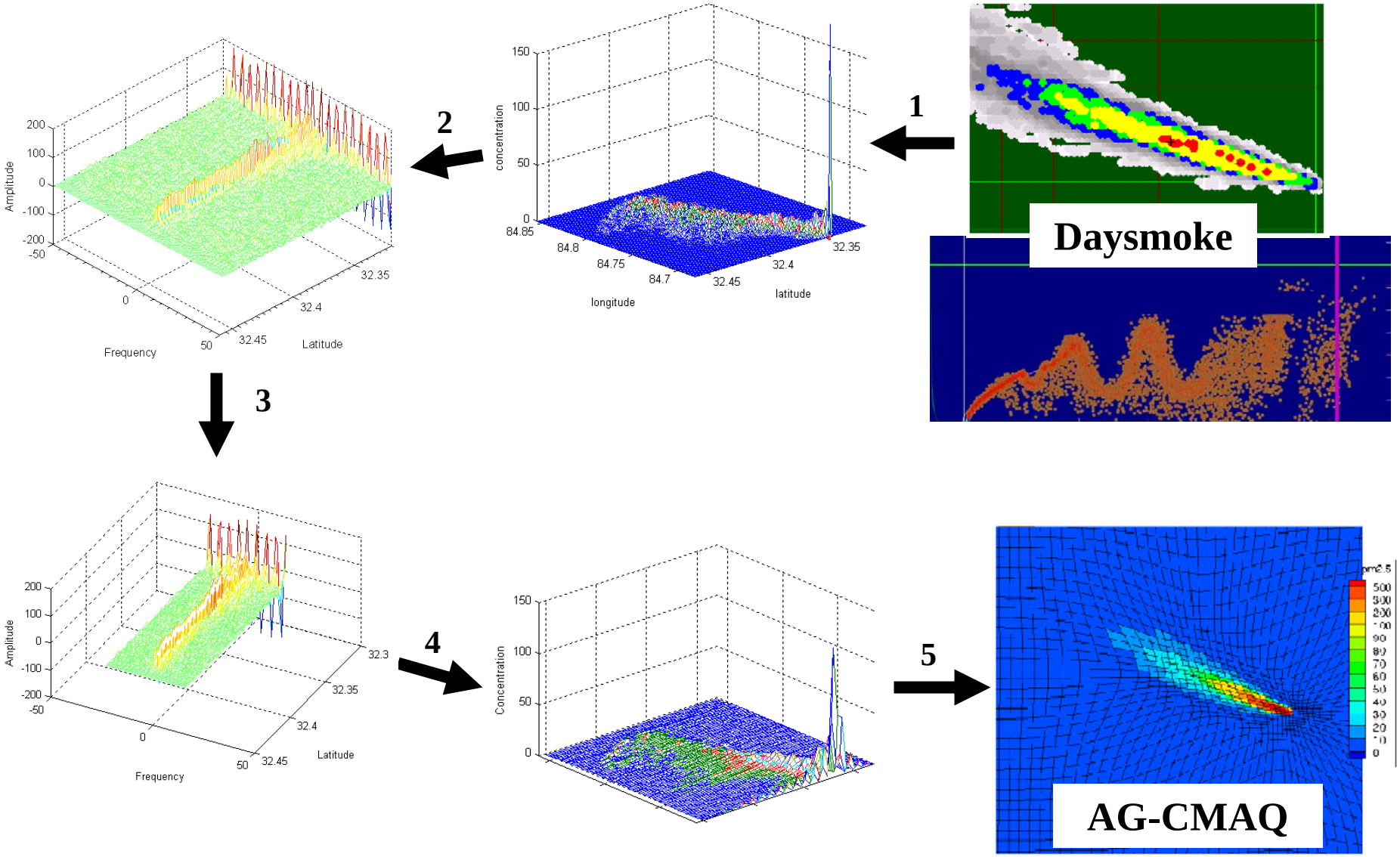


Comparison to Observations:

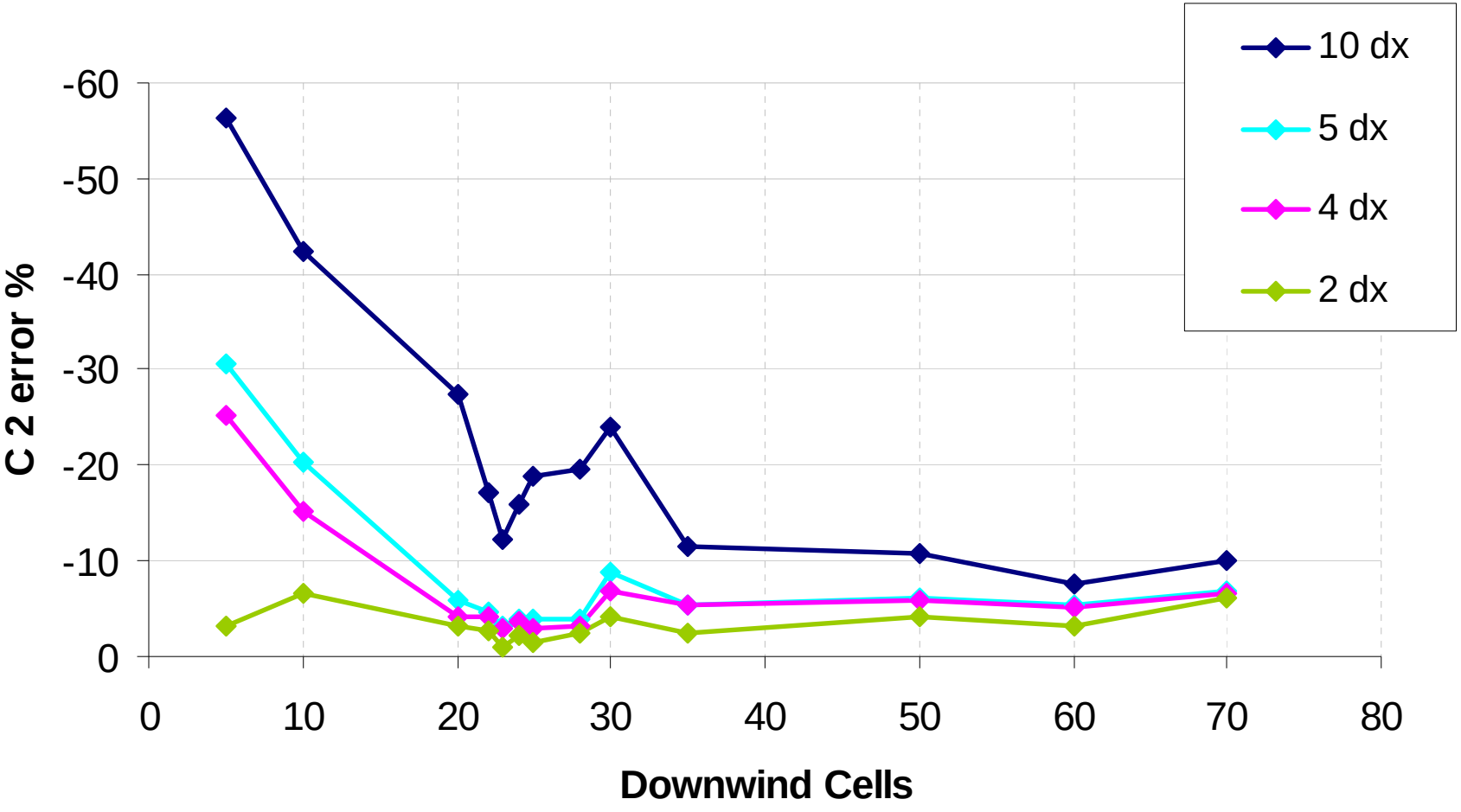
13-layer CMAQ vs 34-layer CMAQ



Coupling Daysmoke with AG-CMAQ



Error as a Function of Downwind Distance and Grid Resolution



Summary

- 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 is being coupled with Daysmoke, a sub-grid scale plume model.
- An adaptive grid version of WRF is under development
- Fully interactive coupling of AG-CMAQ / Daysmoke with AG-WRF will be the next step.

Acknowledgements

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- Imagine your logo here !