Plume-in-grid Modeling of Atmospheric Mercury Deposition in the United States

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Traditional Modeling Approaches for Atmospheric Mercury Deposition

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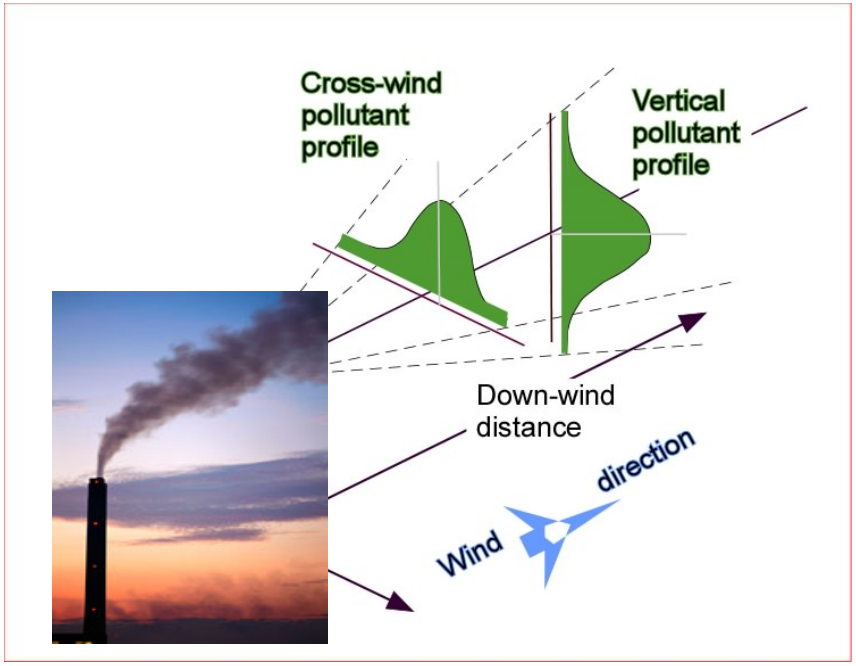
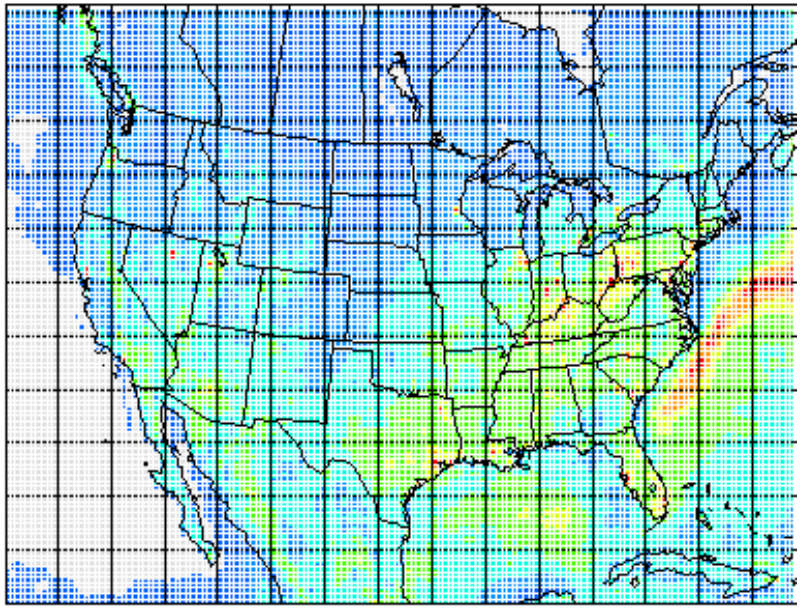
Puff Model



(source: epa.gov and www.colorado.edu)

Examples:
ISC, AERMOD, ROME, CALPUFF, SCICHEM etc.

Eulerian Gridded Model



Examples:
CMAQ, TEAM, MADRID, REMSAD, CAMx etc.

Why Use Plume-in-Grid Approach?

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Plume Size vs Grid Size

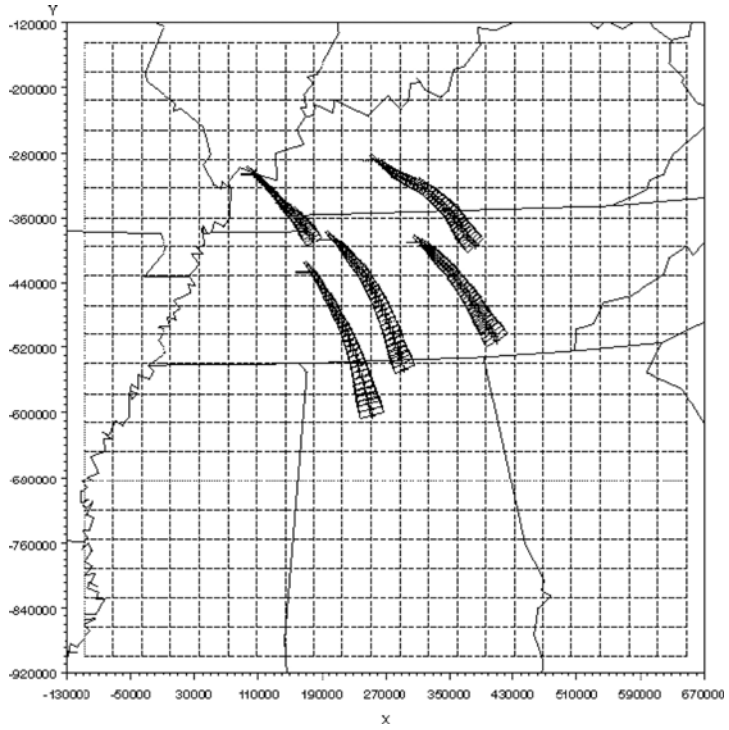

Fig. Top-down view of plumes from five point sources (hypothetical case)

Source: Godowitch, 2004

Limitations of Purely Grid-Based Approach

- Artificial dilution of stack emissions
- Unrealistic near-stack plume concentrations
- Incorrect representation of plume chemistry and transport

Using a plume model embedded in a grid model helps overcome these limitations.

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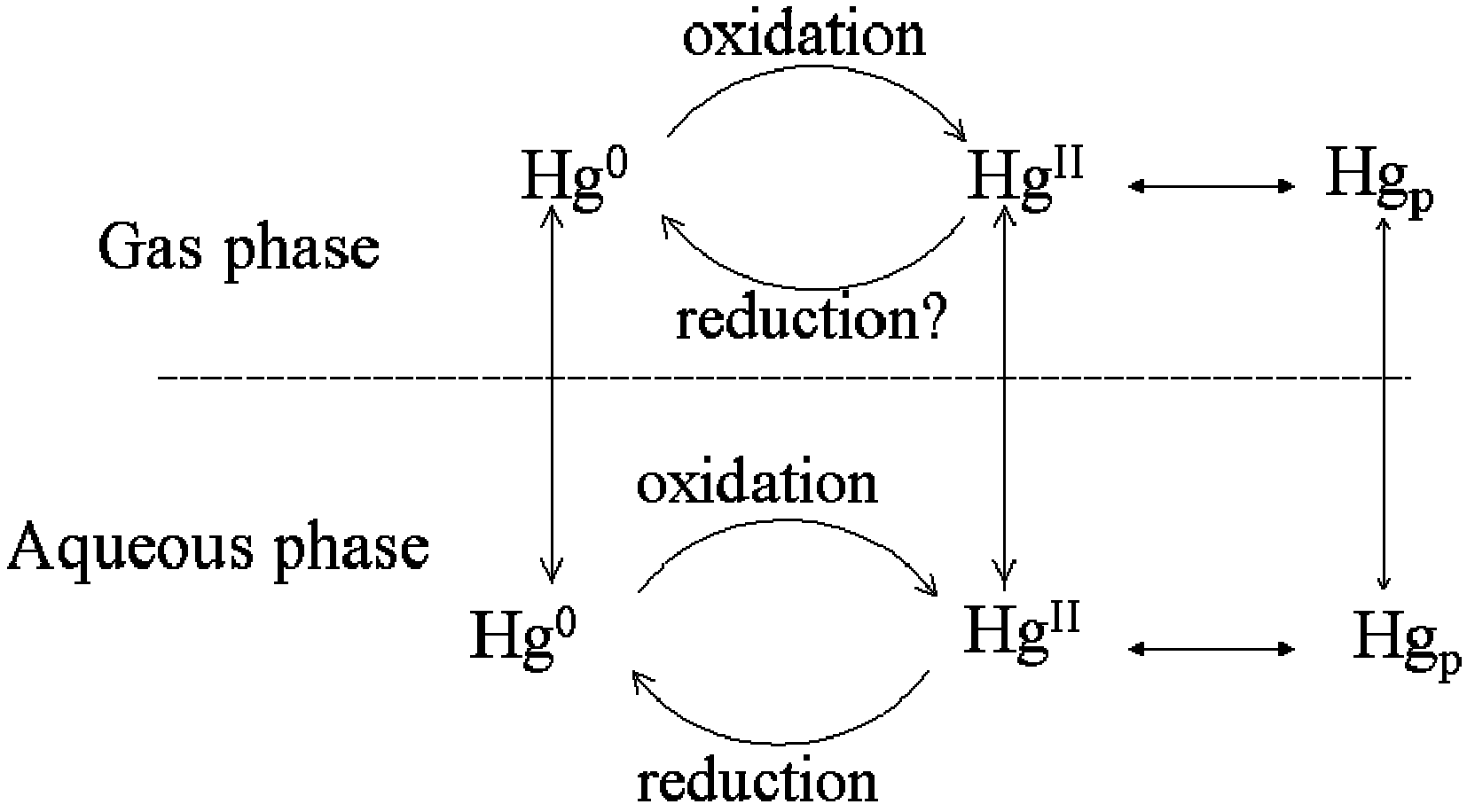
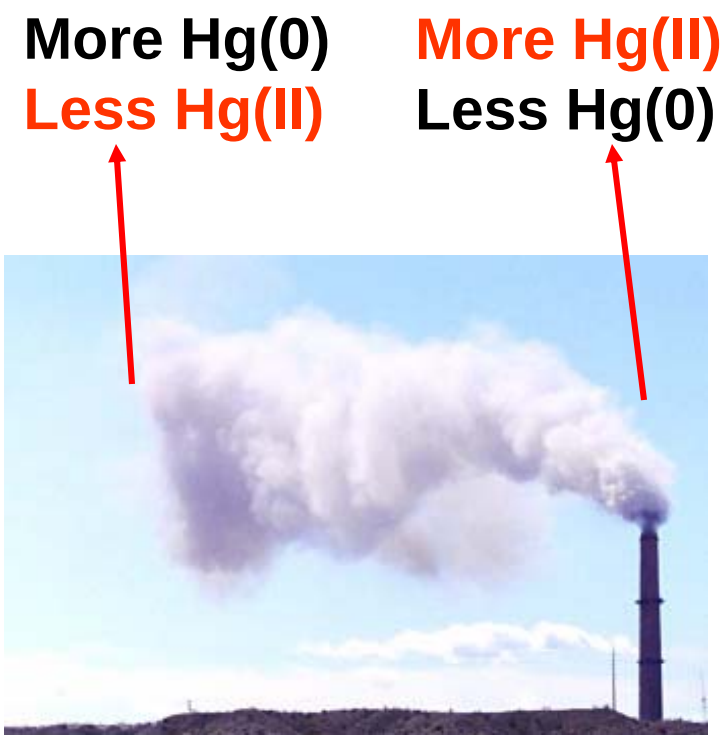
Atmospheric Chemistry of Mercury



Mercury Chemistry in Power Plant Plumes



Schematic not to scale

Adapted from nih.gov

- Evidence of Hg^{II} reduction in power plant plumes from measurements and modeling (Edgerton et al., *ES&T*, 2006; Lohman et al., *ES&T*, 2006)
- Reduction of Hg^{II} by SO_2 (possibly via heterogeneous reaction on particles) is compatible with global Hg cycling budget (Seigneur et al., *J. Geophys. Res.*, 2006).
- Rate constant for Hg^{II} reduction by SO_2 was derived from nine plume events and used in modeling.

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Plume-in-grid Model Description: CMAQ-MADRID-APT

- EPA's CMAQ as host model
- MADRID: Model of Aerosol Dynamics, Reaction, Ionization and Dissolution
- APT: Advanced Plume Treatment with embedded plume model SCICHEM (state-of-the science treatment of stack plumes at the sub-grid scale)
- Mercury treatment in grid and plumes
- Consistent treatments for chemical transformations of all species in the host model and the embedded plume model
- Freely available to the public at http://www.cmascenter.org

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Modeling Approach

- Plume-in-grid Model – CMAQ-MADRID-APT v. 4.5.1
- Time period – 2001
- Modeling grid – N. America domain at 36 km horizontal resolution and 14 vertical levels
- Meteorology – MM5-driven from EPA
- Initial and boundary conditions –from EPA using GEOS-Chem output (10 day model spinup for each quarter)
- Mercury emissions – EPA 2001 inventory based on 1999 NEI with updates by EPA to waste incinerator emissions based on MACT
- Emissions of other species – EPA 2001 inventory based on 1999 NEI

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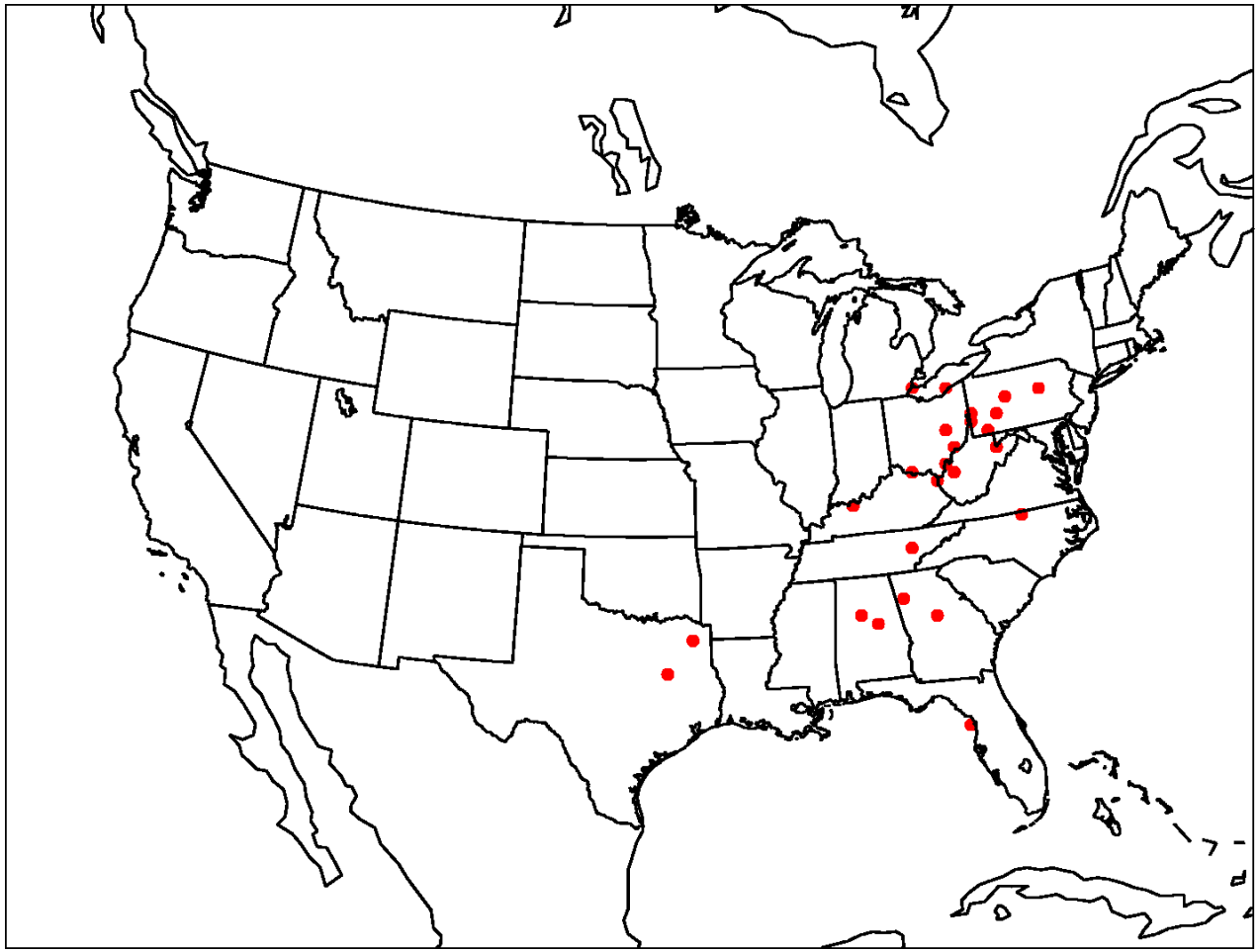
Modeling Domain and Locations of Power Plants selected for Advanced Plume Treatment (APT)



- 36 km grid resolution
- 30 large power plants with APT

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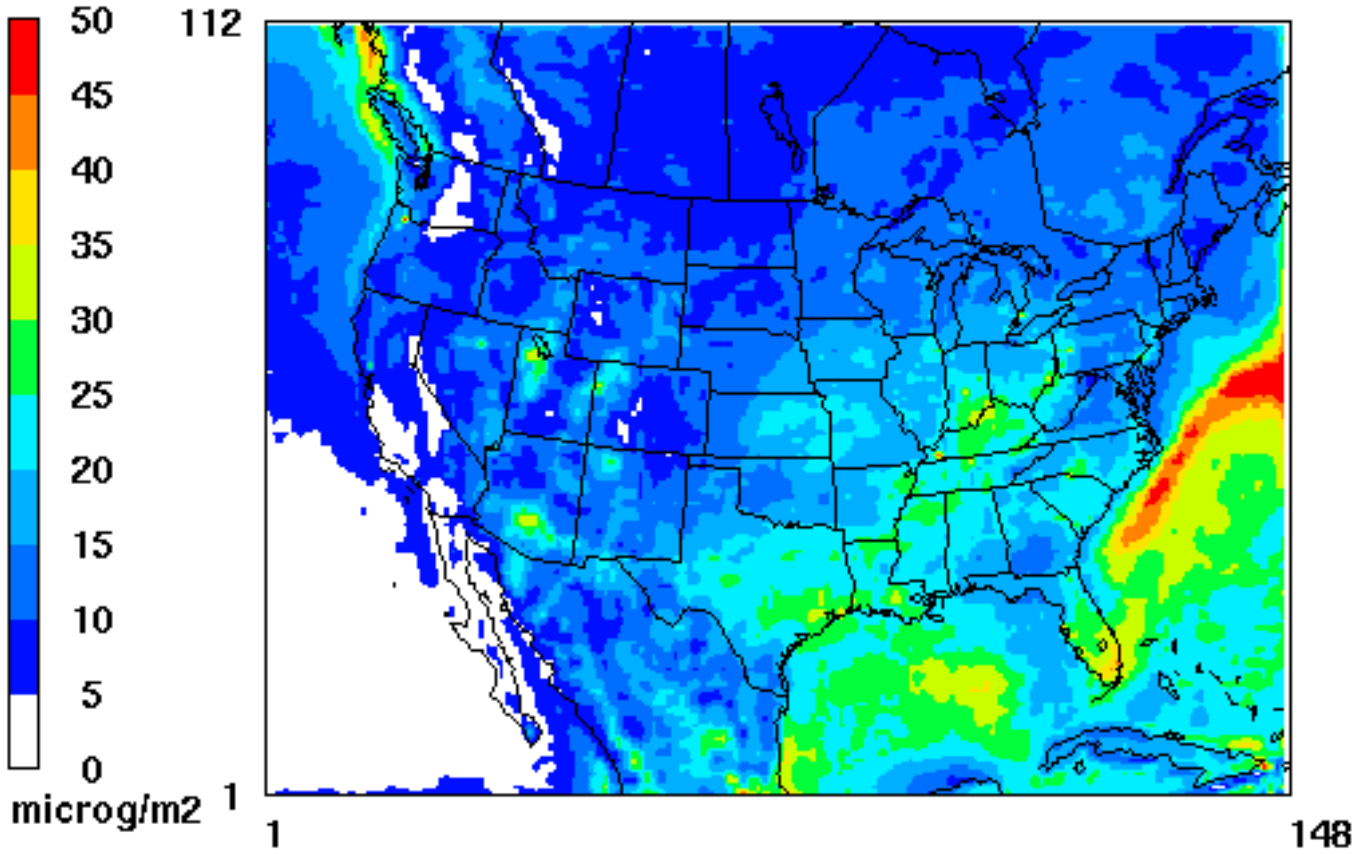
Simulated Hg Wet Deposition in 2001



*** Preliminary results**

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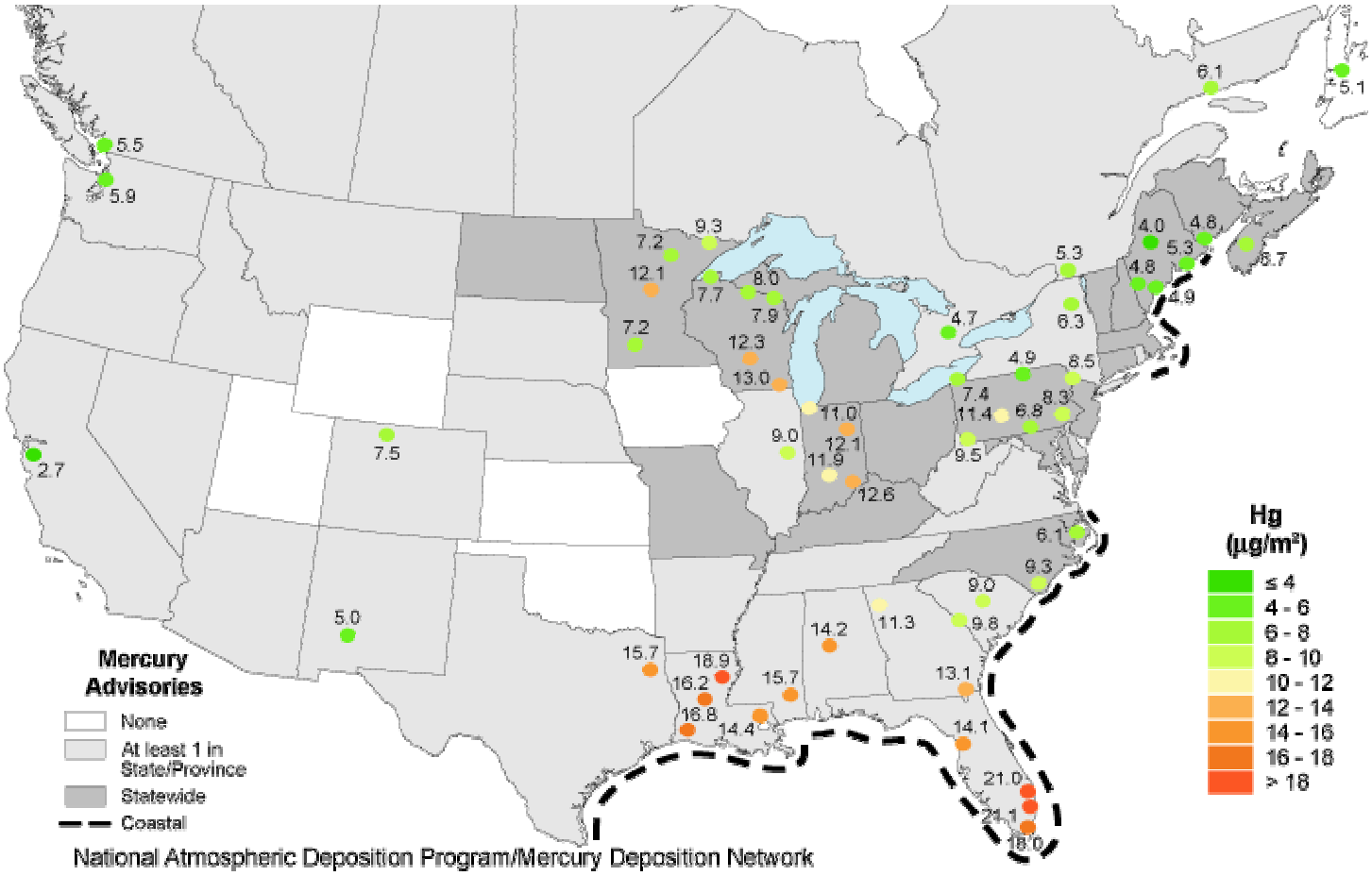
MDN Hg Wet Deposition in 2001



Comparison of Hg Wet Deposition from 2001 with MDN data

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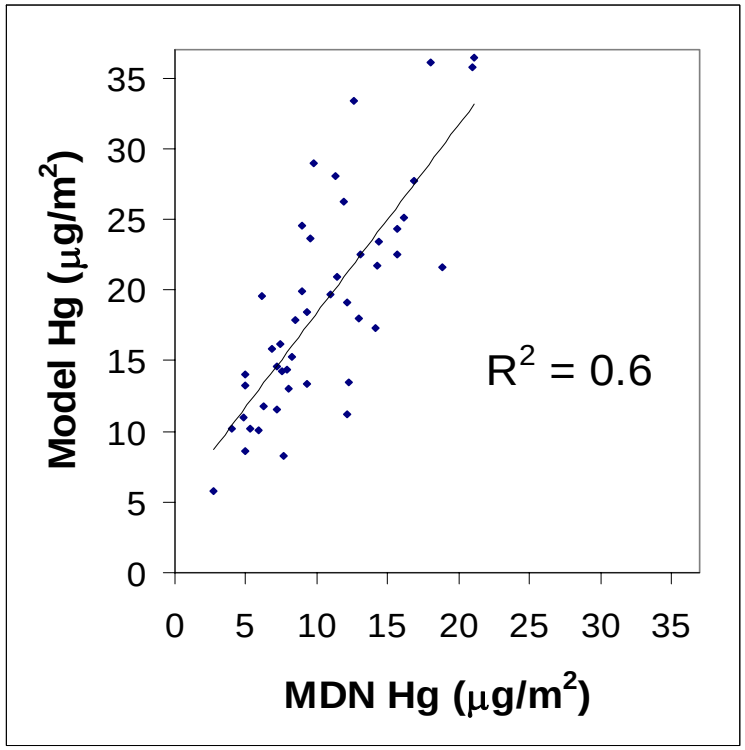
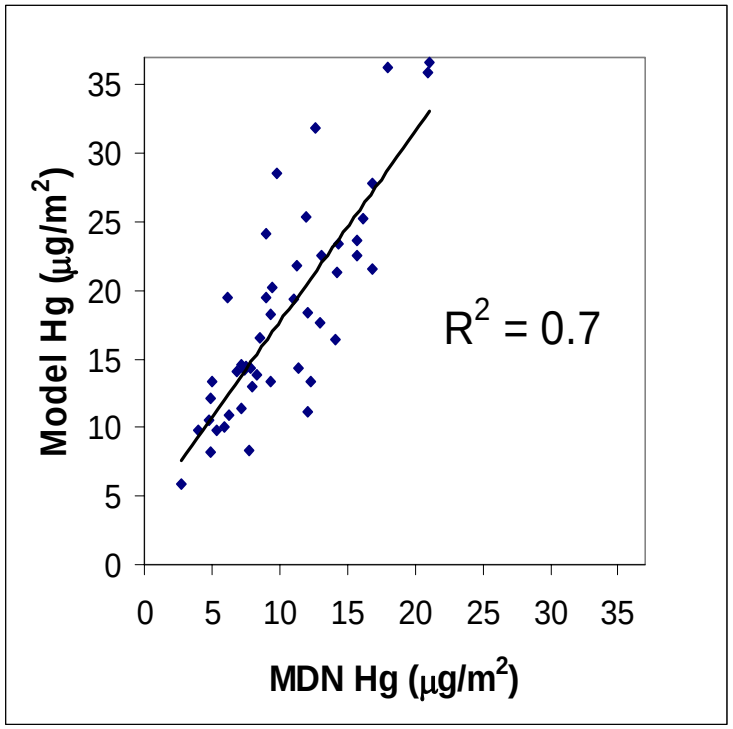
Gridded Model
CMAQ-MADRID



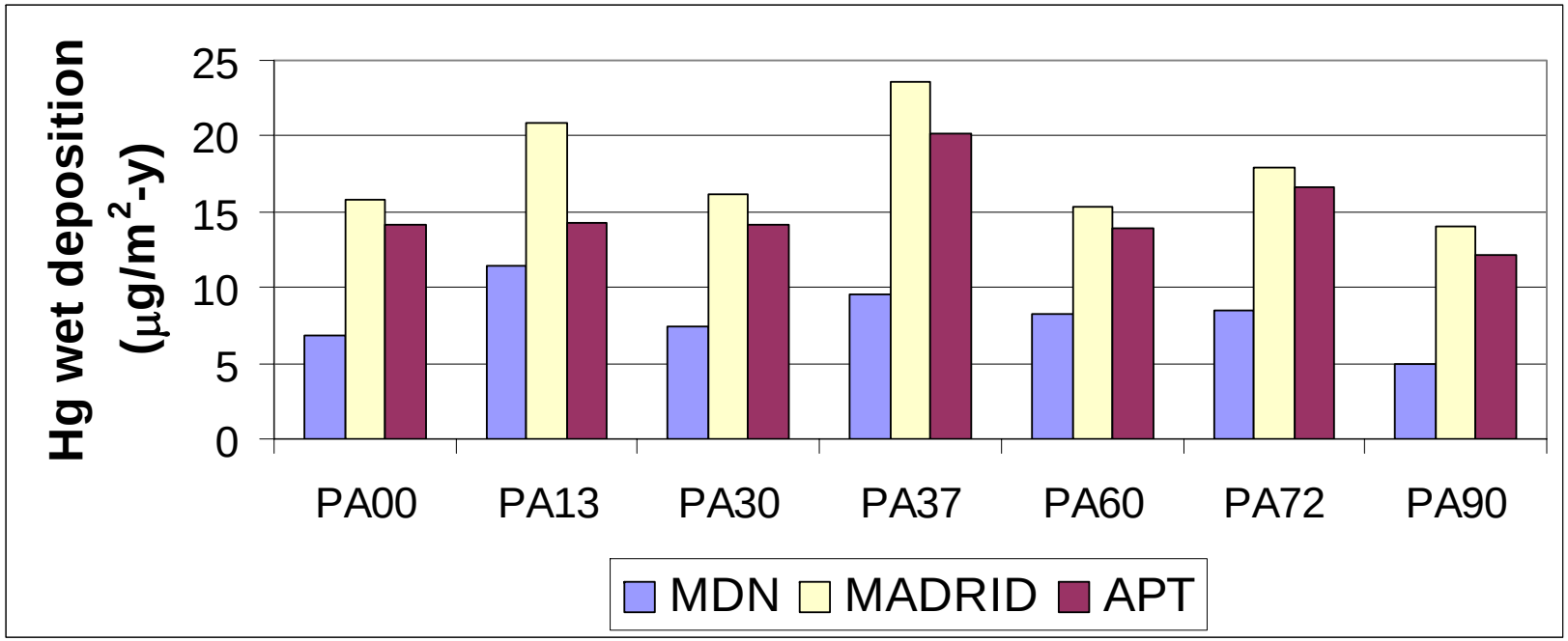
Error = 92% **Bias = 92%**

Plume-in-Grid Model
CMAQ-MADRID-APT



Error = 84% **Bias = 84%**

Comparison of Hg Wet Deposition from 2001 with MDN data in Pennsylvania



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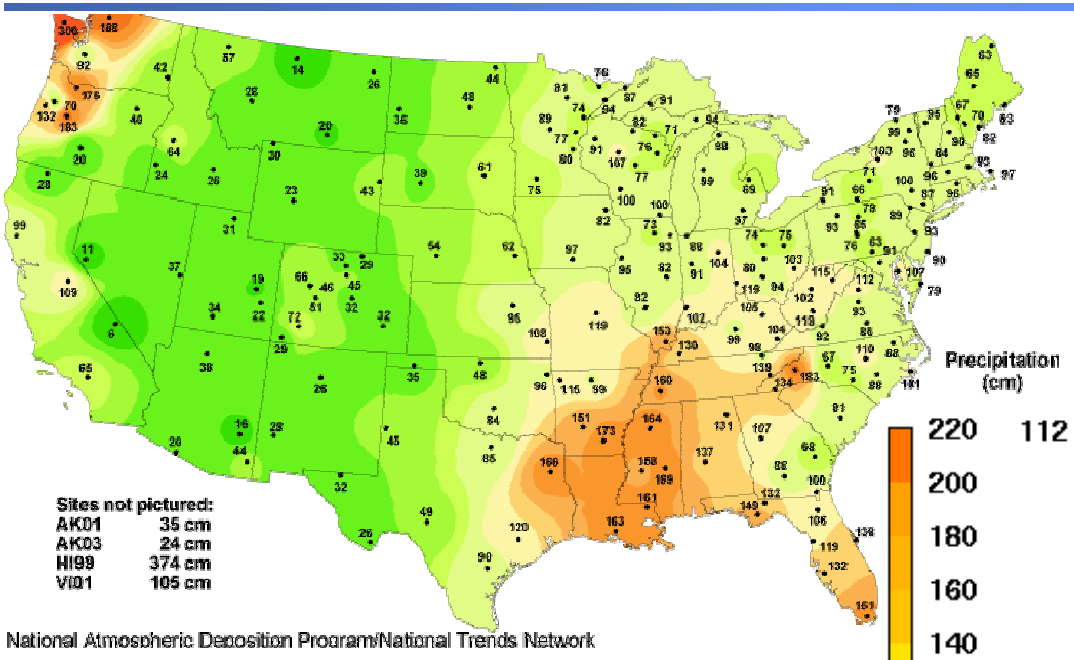
Precipitation in 2001

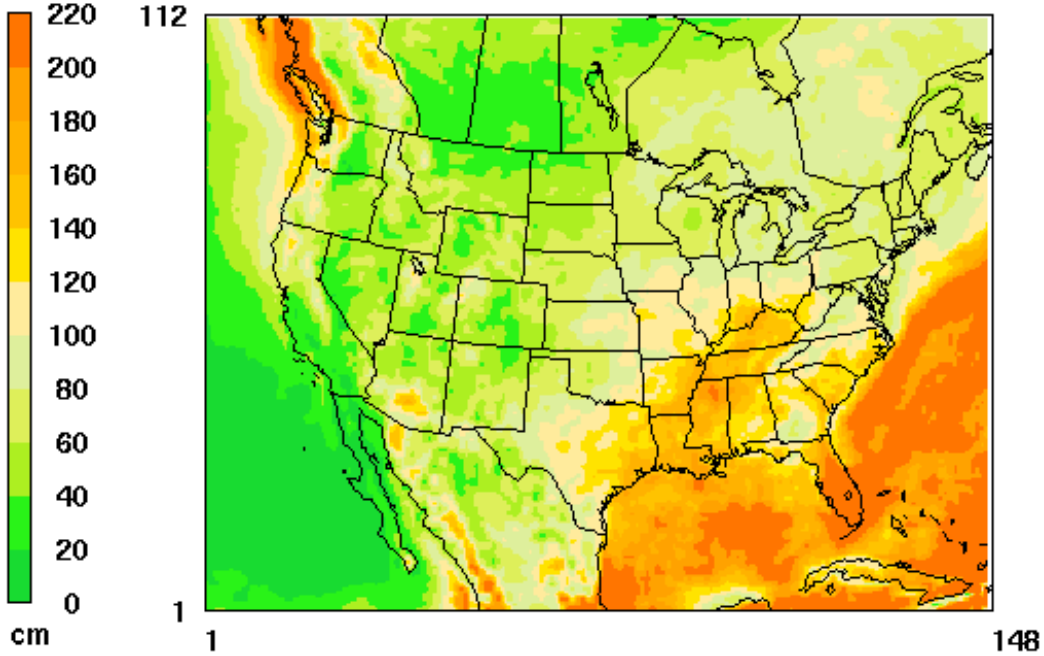


NADP/NTN

Model vs. NADP Precipitation:

Error = 48% ; Bias = 30%

- Bias in precipitation is partially responsible for wet deposition bias.



Model

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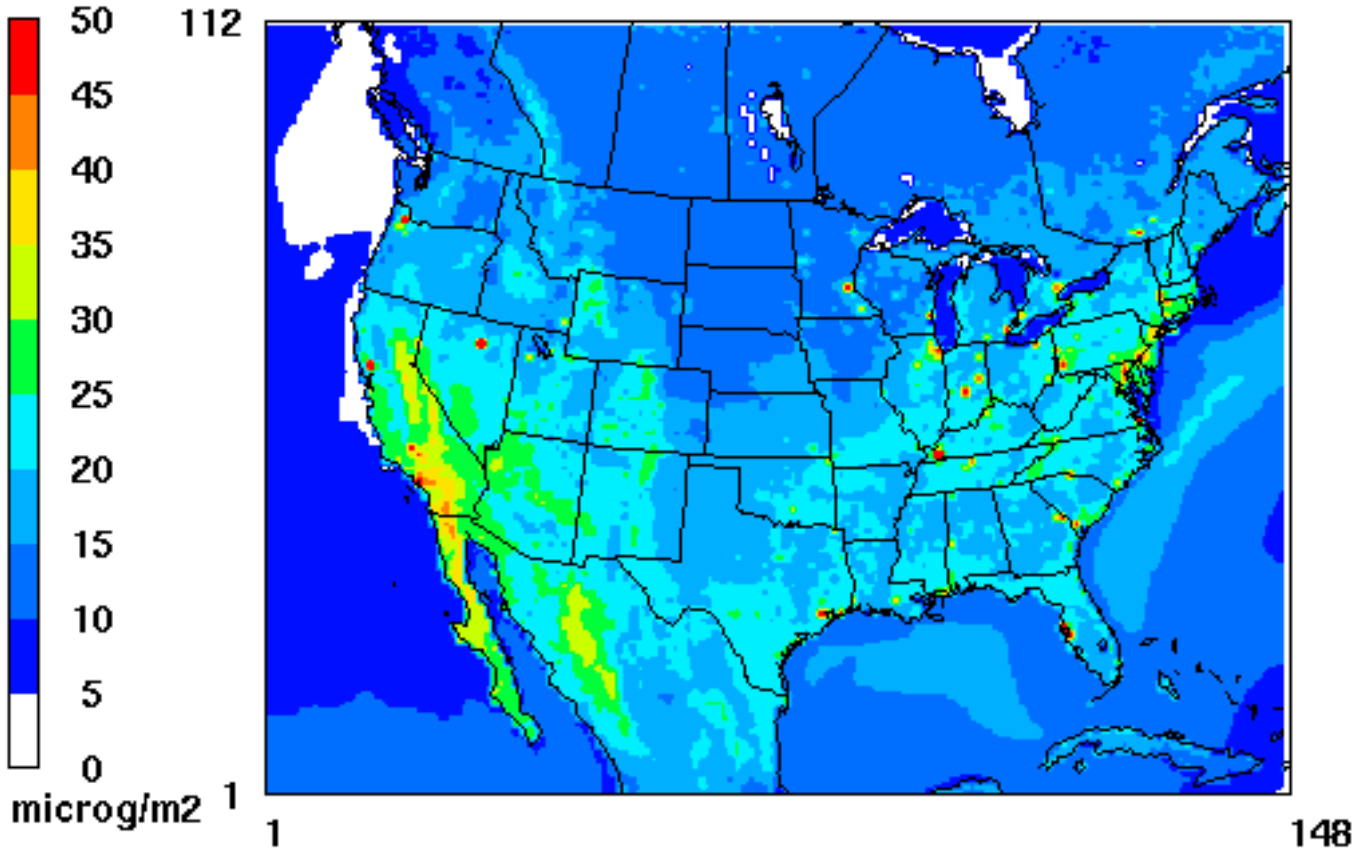
Simulated Hg Dry Deposition in 2001



*** Preliminary results**

Impact of Advanced Plume Treatment on Simulated Hg "Dry + Wet" Deposition

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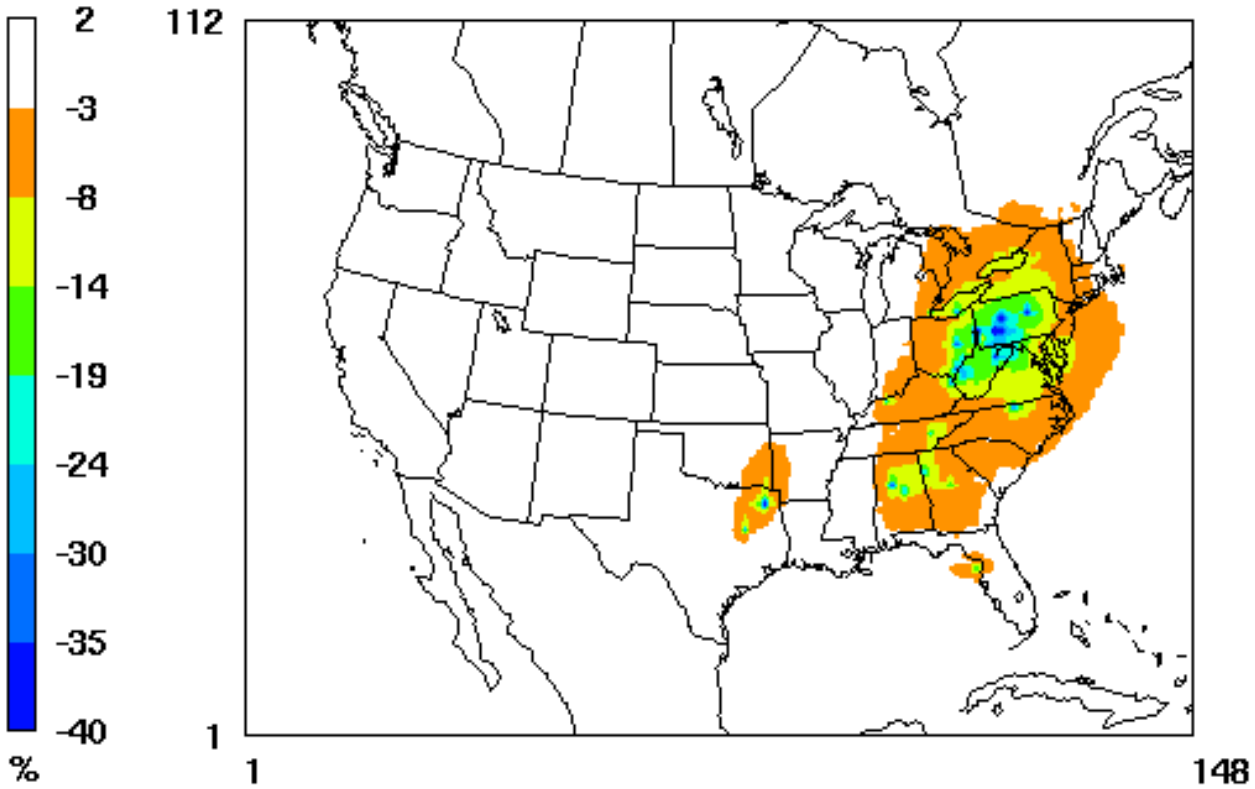
Change (%) in annual Hg dry + wet deposition due to plume treatment



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Conclusions

- A new plume-in-grid modeling system was applied to simulate mercury deposition in the United States in 2001.
- A rate constant for Hg^{II} reduction by SO_2 was derived from plume measurements and used in both gridded and plume-in-grid modeling.
- Thirty large coal-fired power plants were selected for advanced plume treatment (APT).
- Model performance (r^2 and error) w.r.t MDN wet deposition data improved with APT.
- The model still shows a strong positive bias which is likely due to a combination of insufficient reduction of Hg^{II} to Hg^0 and biased precipitation.
- The use of APT results in 3-40% decreases in annual mercury deposition compared to a purely gridded approach.

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Questions ?

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