Geographic Sensitivity of $PM_{2.5}$ Mass to Large Point Source Emissions

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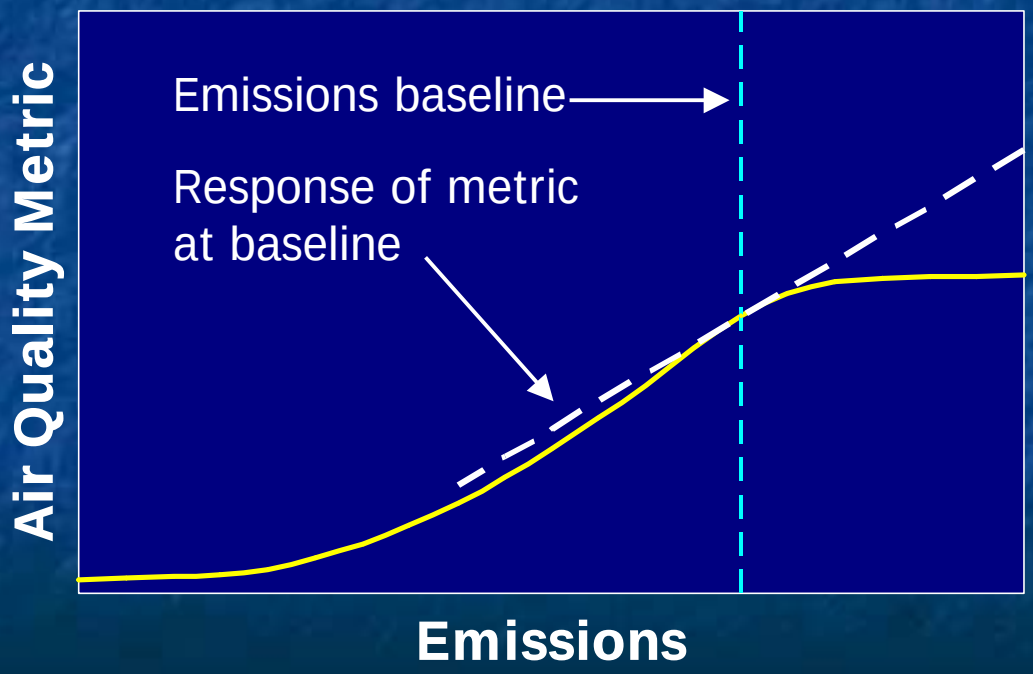
Policy Questions

- Which components of $PM_{2.5}$ are most sensitive to emission reductions?
- Are there any trade-offs between reductions in one species and increases in another?
- How do benefits from point source reductions compare to those from other sources?
- How do geographic regions impact each other?
- Do potential benefits of regional reductions occur where they are most needed?

One Option for Sensitivity Modeling

- Decoupled direct method (DDM) solves the set of first-order derivative equations of all relevant transport, source, sink and chemical processes.



DDM Uses & Limitations

What it can provide:

- A sense of direction for responses to emission changes.
- Semi-quantitative estimates of the efficiency of responses to emission changes.
- Qualitative information on the geographic extent of responses to emission changes.

What it cannot provide:

- Quantitative estimates of air quality changes for emission changes >30%.
- Quantitative or qualitative estimates of air quality changes from changes in multiple emission species.

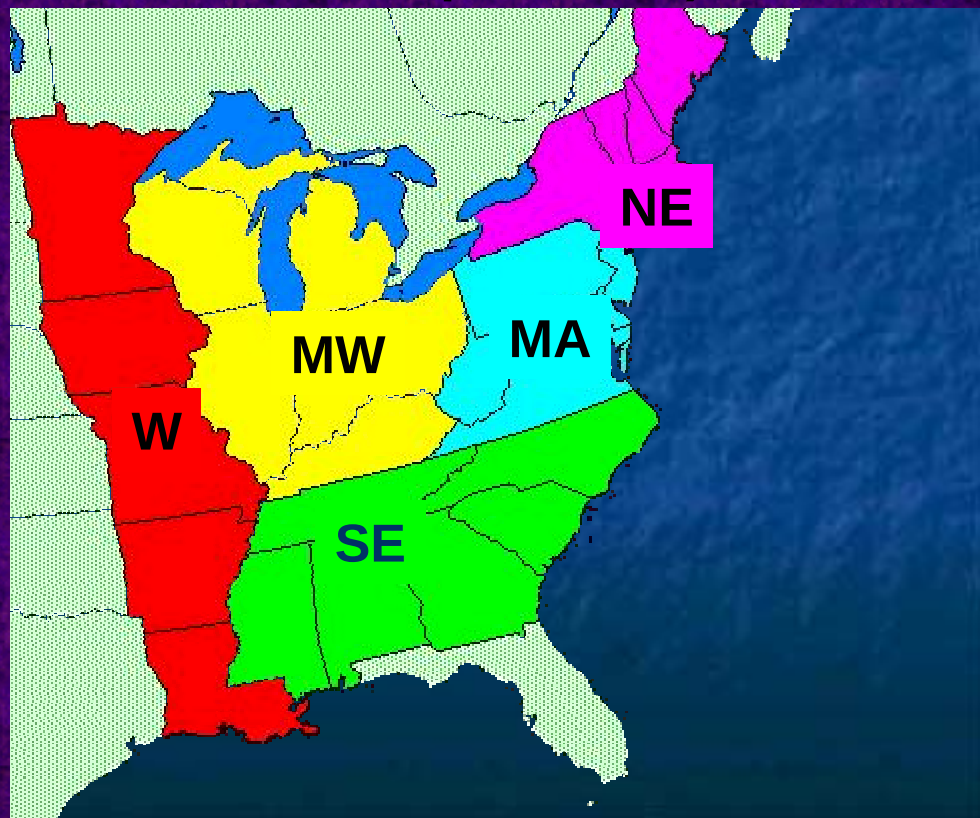
Basis of Analysis

- Meteorological fields: RAMS
- Emissions baseline: 2010
- Air quality model: URM-1ATM model
- Air quality model grid: Eastern ½ of U.S.
- Modeling periods: 4 of SAMI episodes

Source & Impact Regions

- Five source regions & four impact regions (impacts in region W are not reported)

Region Names:
NE: Northeast
MA: Mid-Atlantic
MW: Midwest
SE: Southeast
W: West of Miss. River



Episode Characterization

Number of Modeled High* $PM_{2.5}$ Days per Impact Region

Dates	MA	MW	NE	SE
26 Apr - 3 May 1993	0	3	0	0
24-29 June 1992	1	6	0	3
11-19 July 1995	4	9	1	9
3-11 August 1993	0	8	0	3
Total	5	26	1	15

*24-h average $PM_{2.5}$ in at least one grid cell " 35 µg/m^3.

Emission Source Types

- SO_2, denoted “SO2”
- Point source NO_x, denoted “Pt_NOx”
- Low-level NO_x, denoted “LL_NOx”

Aerosol Species for which Emissions Sensitivity was Examined

- $PM_{2.5}$ mass
- Sulfate component of $PM_{2.5}$
- Organic component of $PM_{2.5}$
- Nitrate component of $PM_{2.5}$

Shorthand—

Sulfate="SO4"

Organic compounds="OC"

Nitrate="NO3"

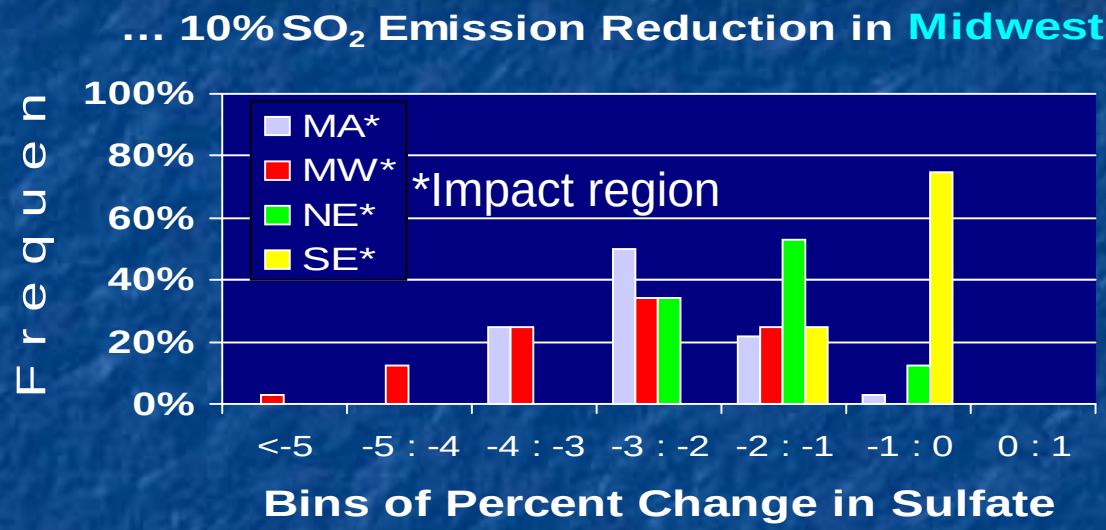
Fine mass="PM2.5"

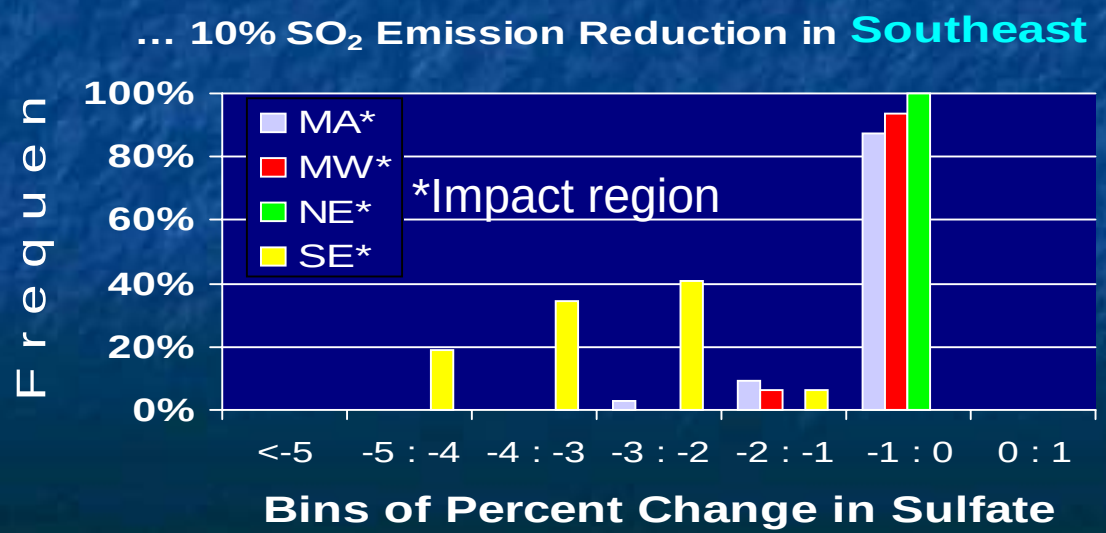
Sensitivity Response Metrics for Source-Impact Regional Pairings

- Average relative change in 24-h sulfate, OC and $PM_{2.5}$ concentrations.
- Maximum relative change in 24-h sulfate, OC and $PM_{2.5}$ concentrations.
- Average relative change for grid cells exceeding threshold values (OC=5, sulfate=10, $PM_{2.5}$=35 $\mu g/m^3$).
- For nitrate only, average & maximum *non-normalized* changes in concs.

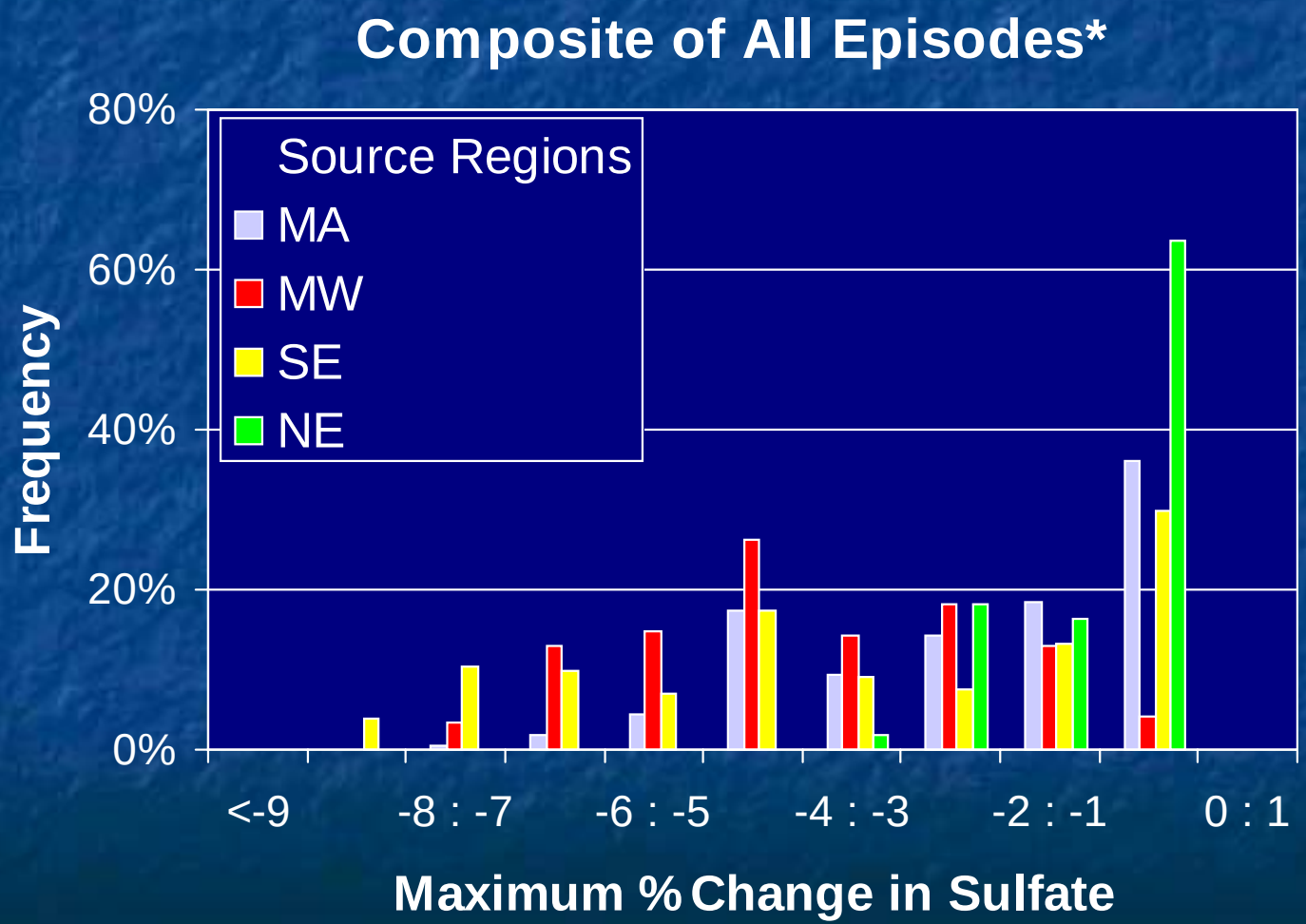
Regional Interactions

Average 24-h Sulfate Responses within Impact Regions from ...



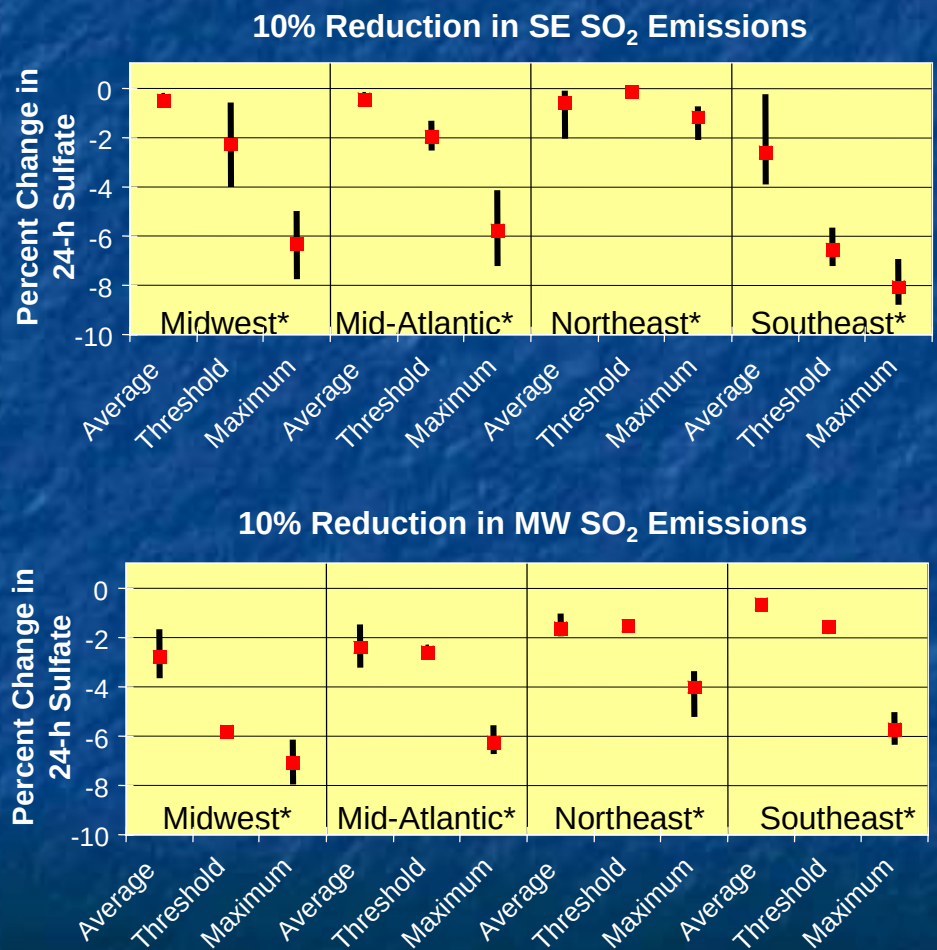


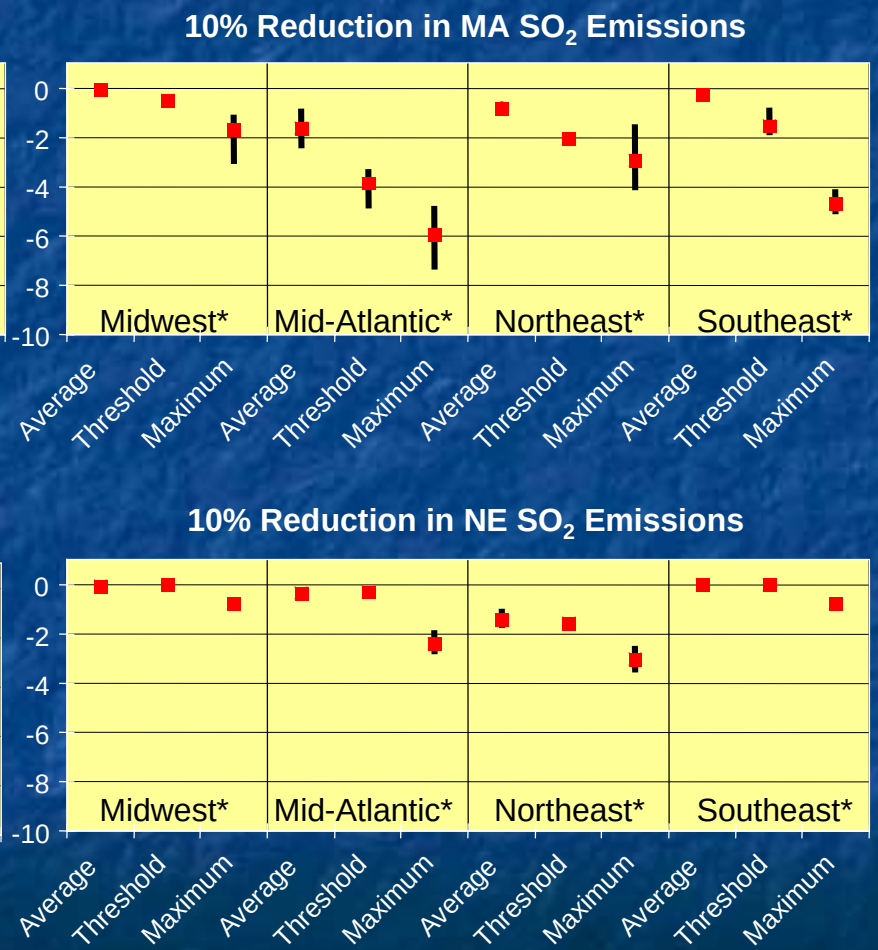
Sensitivity of 24-h SO4 to 10% SO_2 Emission Reductions



*Responses are across all regions.

Sulfate Metric Sensitivities Across All Episodes

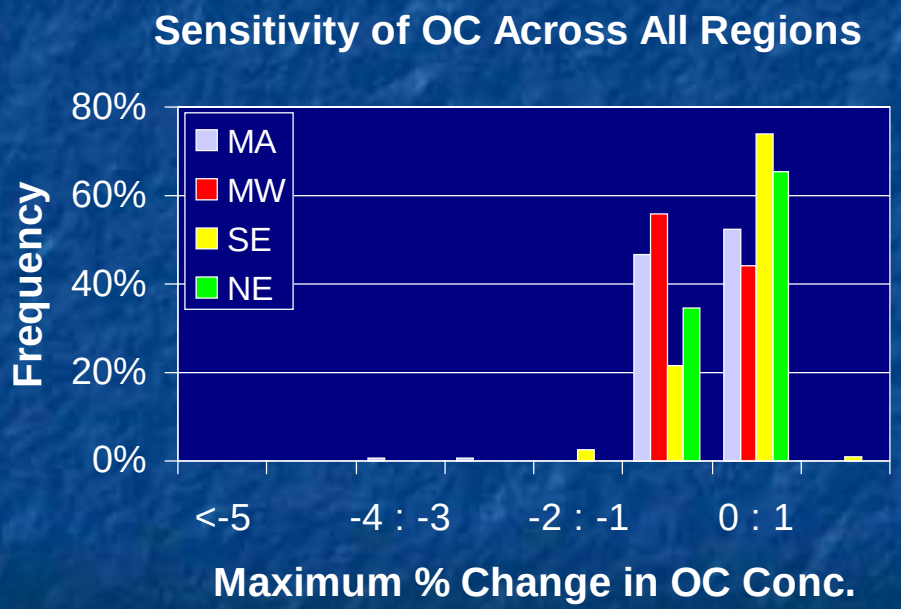


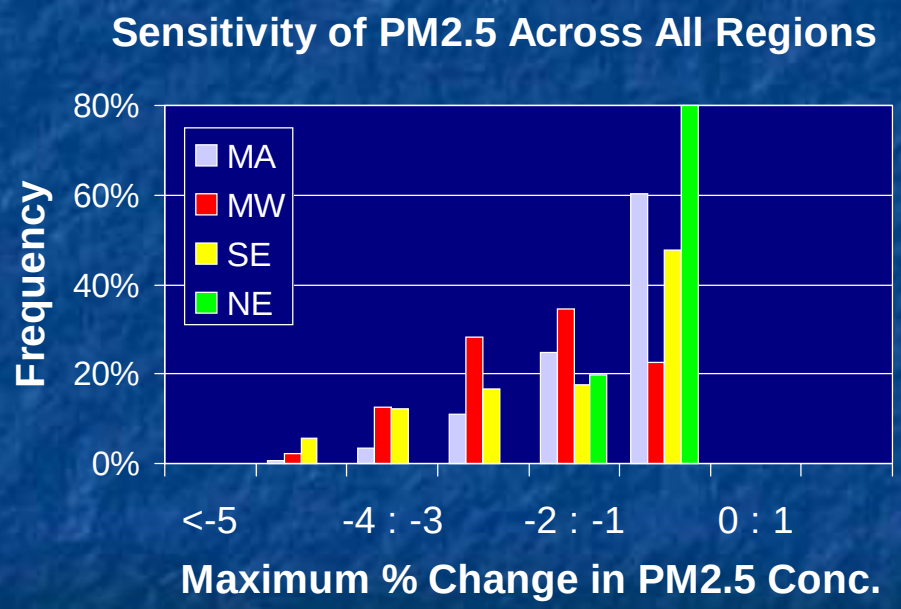


***Denotes impact region**

Sensitivities of OC & PM2.5 to 10% SO_2 Emission Reductions

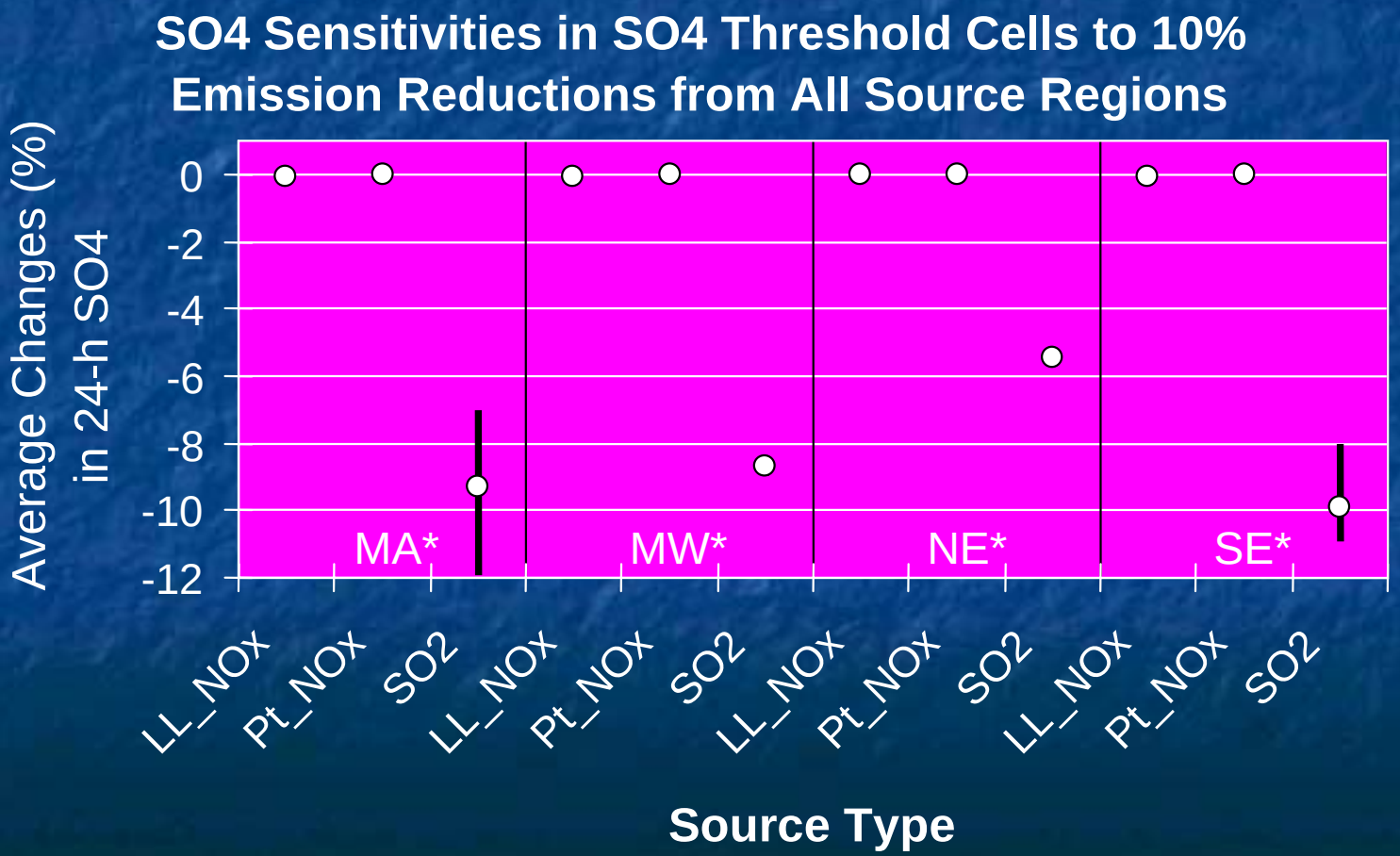
Colored bars represent different source regions.
Plots are episode composites.





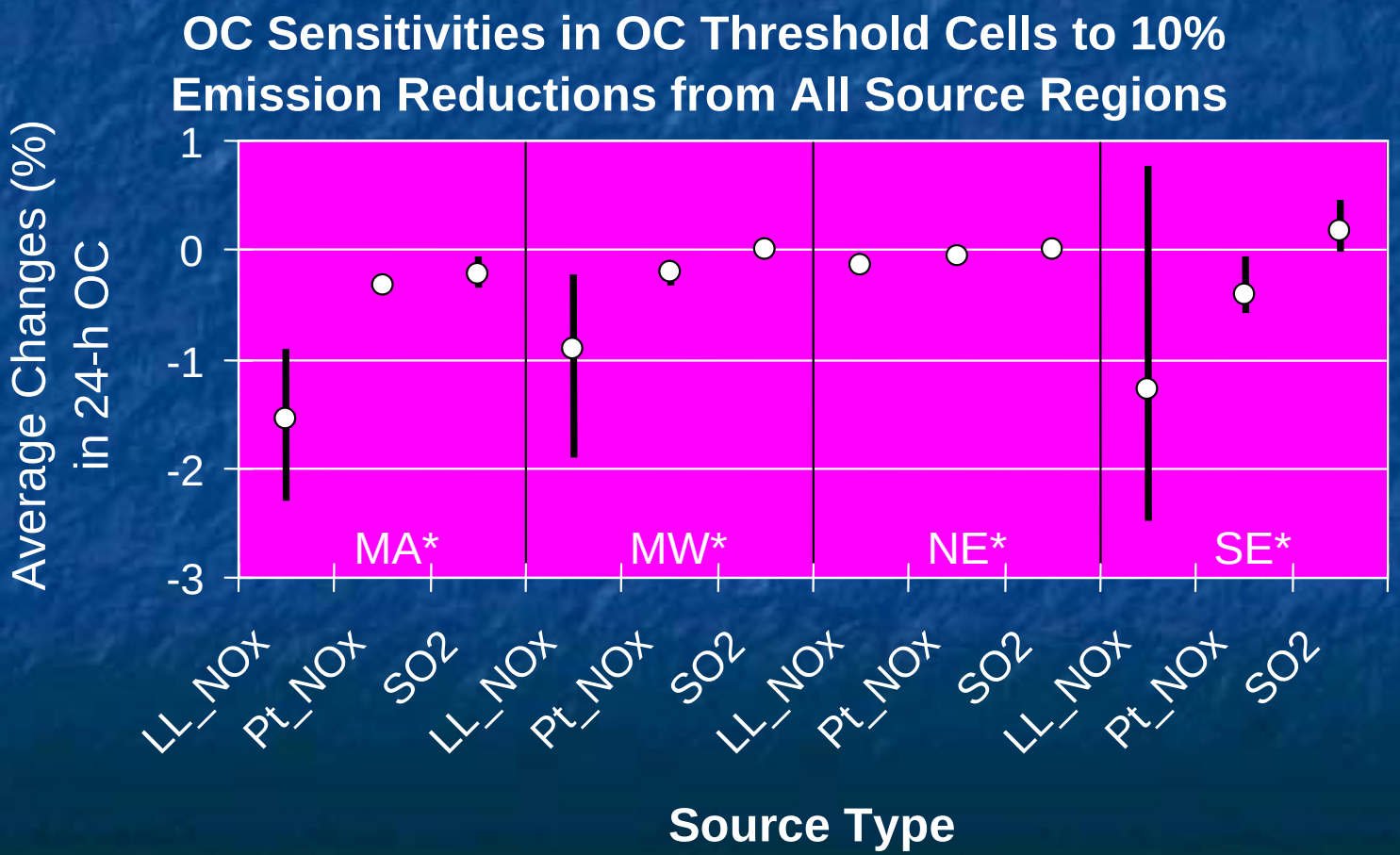
SO4 Sensitivities Compared for Different Source Types

Episode Composites for Selected Impact Regions (denoted with *)



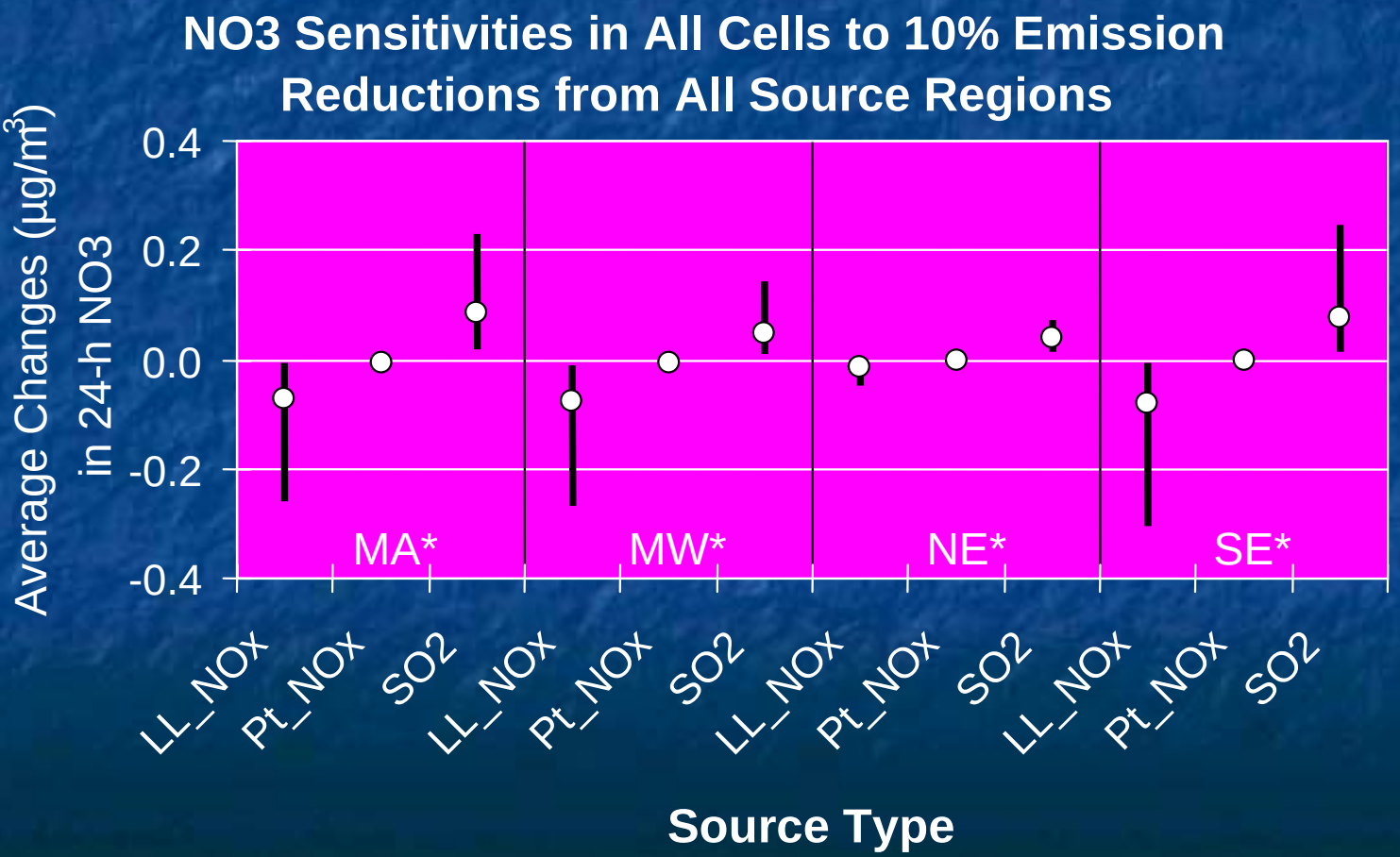
OC Sensitivities Compared for Different Source Types

Episode Composites for Selected Impact Regions (denoted with *)



NO3 Sensitivities Compared for Different Source Types

Episode Composites for Selected Impact Regions (denoted with *)



Conclusions: Inter-regional Transport

- The Midwest, Mid-Atlantic and Southeast regions have the greatest impact on their own aerosol levels.
- The greatest influence on Northeast aerosols is from Midwest and Mid-Atlantic emissions.
- In general, Midwest emissions have the most influence of any region on other regions.
- The Southeast is relatively isolated: its emissions have the least affect on other regions and it is least affected by neighboring regions.

Conclusions: Species Sensitivity to Emissions

- Sulfate is the most sensitive of the fine particle species to emission changes.
- $PM_{2.5}$ is somewhat sensitive, primarily because of the influence of sulfate.
- 2010 SO_2 levels will be sufficiently high that small emission reductions are insufficient to produce substantial nitrate aerosol increases.
- A small decrease in low-level NO_x emissions may result in small decreases in organic aerosols while point source NO_x appears to have little influence on any fine particle species.

Conclusions: The Geography of Species Sensitivity

- The largest efficiency, $\Delta C / \Delta E$, of an aerosol change relative to an emission change is for sulfate in the Southeast. There, the maximum efficiency of regional SO_2 emissions impacting sulfate approaches 0.8 for the four (1 spring, 3 summer) modeled episodes.
- The maximum efficiency for the SO_2-sulfate system approaches 0.7 in the Midwest and 0.6 in the Mid-Atlantic regions for these same episodes.
- In general, the largest modeled reductions in sulfate, organic aerosols and $PM_{2.5}$ did not occur in those areas where exceptionally high levels of their own kind were computed to occur.