NARSTO, Conceptual Models and Multiple Pollutant-Media Assessments:

Merging space, time, chemistry and environmental media - Monitoring and Assessment Challenges

AQMP Meeting

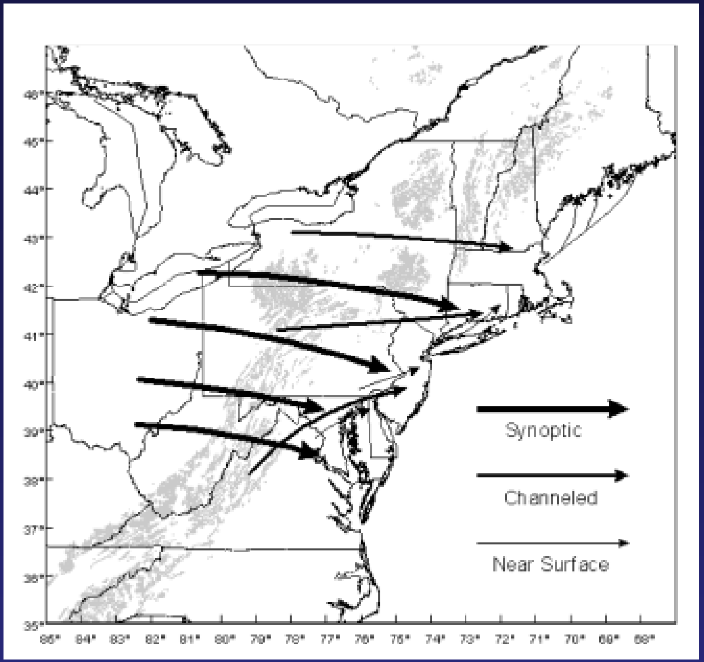
RTP, NC
June 5, 2008

Rich Scheffe, U.S. EPA, Office of Air Quality Planning and Standards

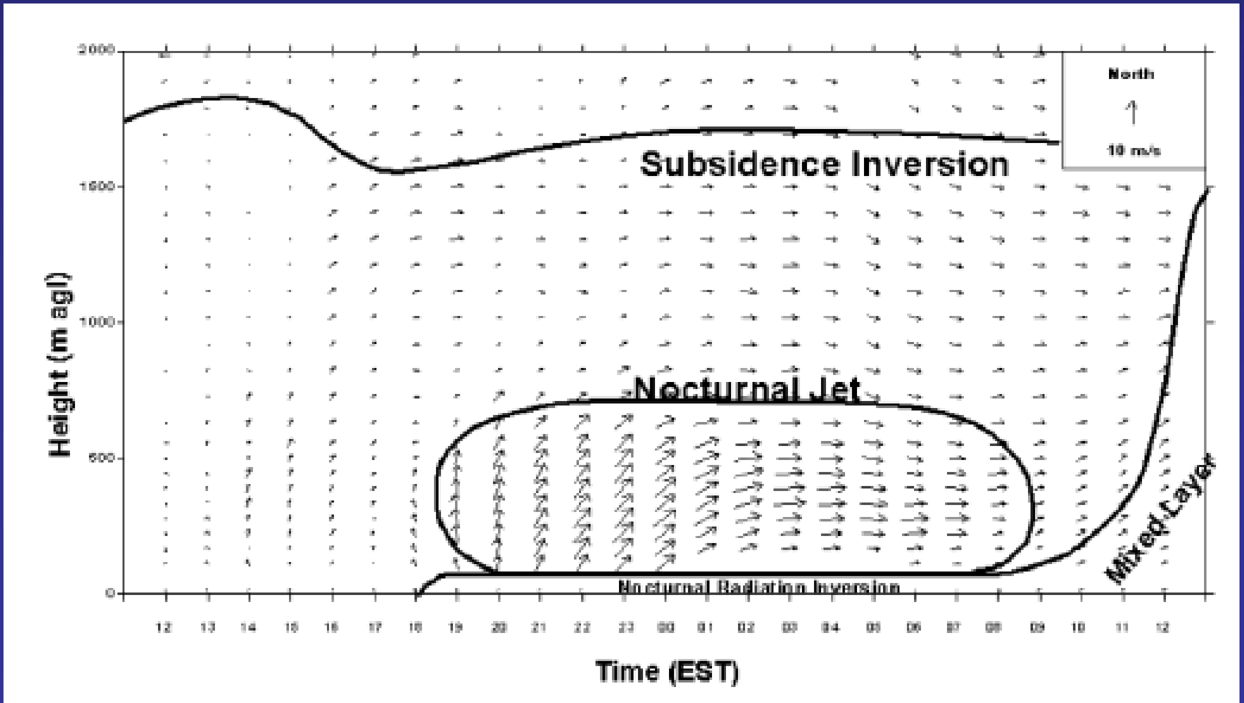
Major NARSTO AQ Assessments

- An Assessment of Tropospheric Ozone Pollution (2000) – in response to 1991 NAS Report, Rethinking the Ozone Problem in Rural and Urban Environments
- Particulate Matter Science for Policy Makers (2004) – in response to NAS series on PM research priorities (1998- 2004)
- Multi-Pollutant Air Quality Assessment (2008 or 9) - in response to NAS, Air Quality Management in the United States (2004)

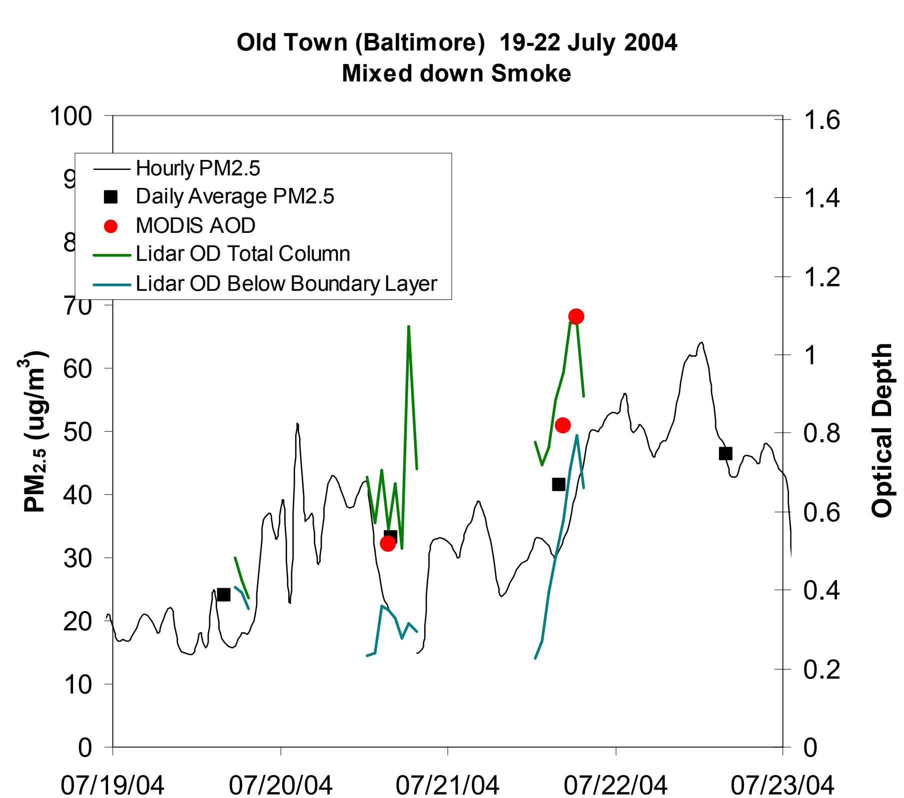
NARSTO O3 Assessment – Single pollutant conceptual model development

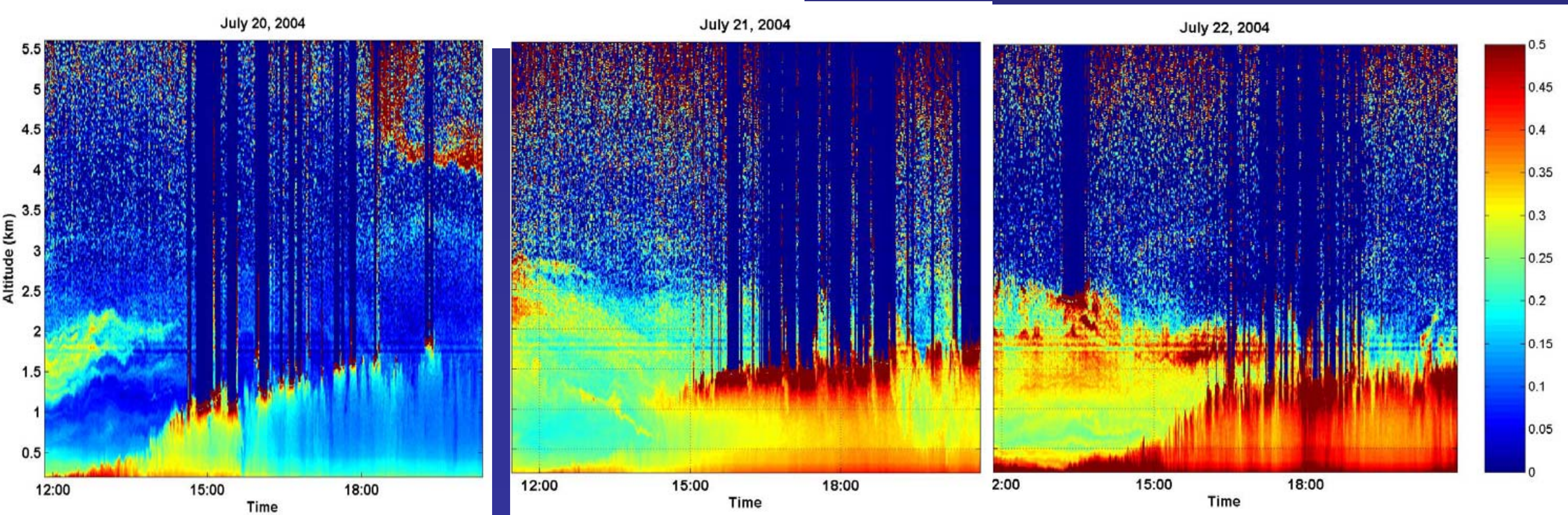


"conceptual model building..
attempting to visualize cause-effect phenomena"



Smoke mixing in Maryland 20-22 July 2004 (source, 3D CAIR)

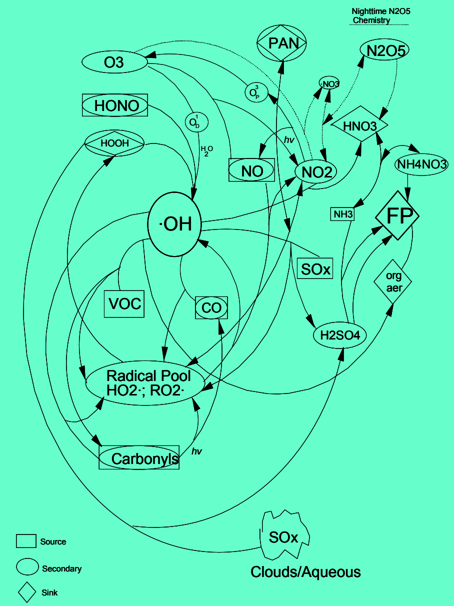


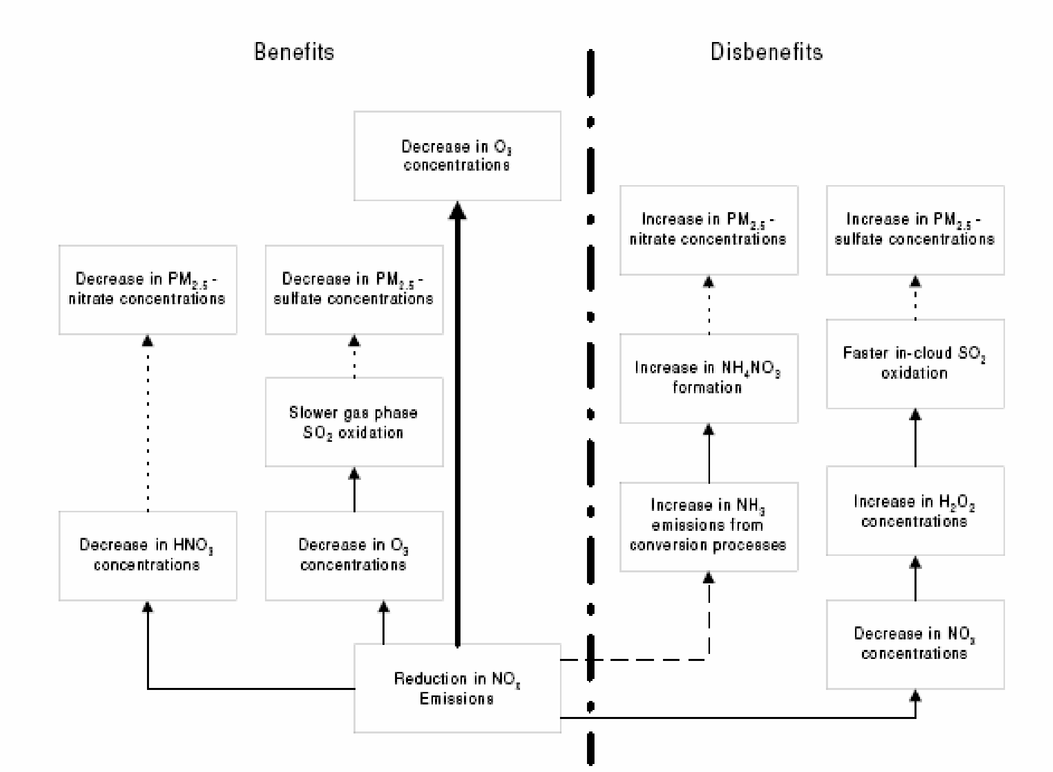


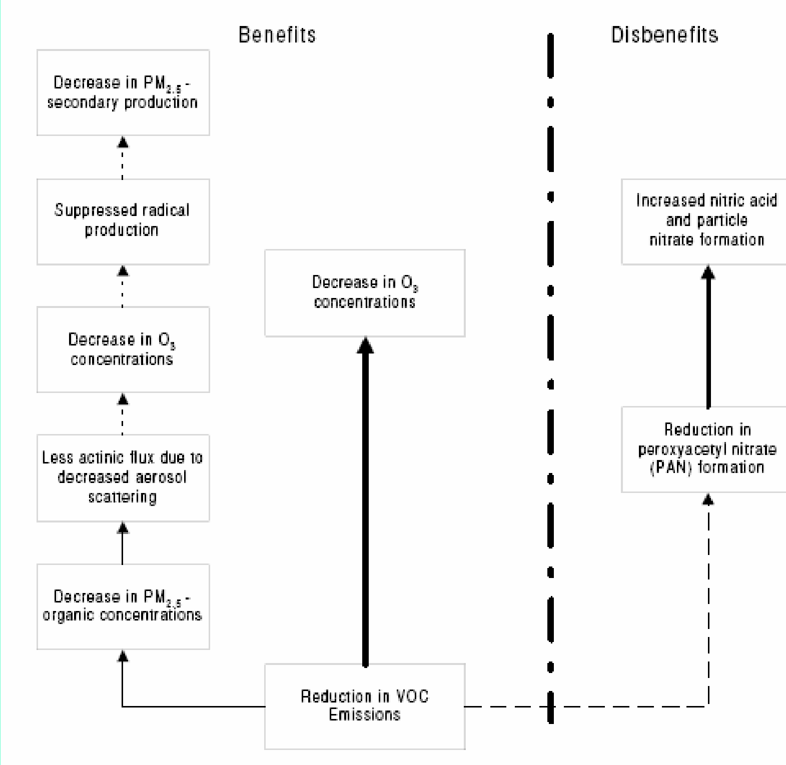
Conceptual Model's and MPAQM

- An episodic event of modest interest to multiple pollutants
- A collection of episodic events, each of severe interest to a particular pollutant
- Beyond episodicity to seasonal, annual and other periods relevant to regulatory and other metrics
- Message – encompassing , not limiting

NARSTO O3 Assessment – Raising consequences of multiple pollutant interactions – conceptual model Development (contemporary with FACA and OTAG)







NARSTO PM3 Assessment – Expanding consequences of multiple pollutant interactions conceptual model development

Table 3.2. Typical pollutant / atmospheric issue relationships.[a]

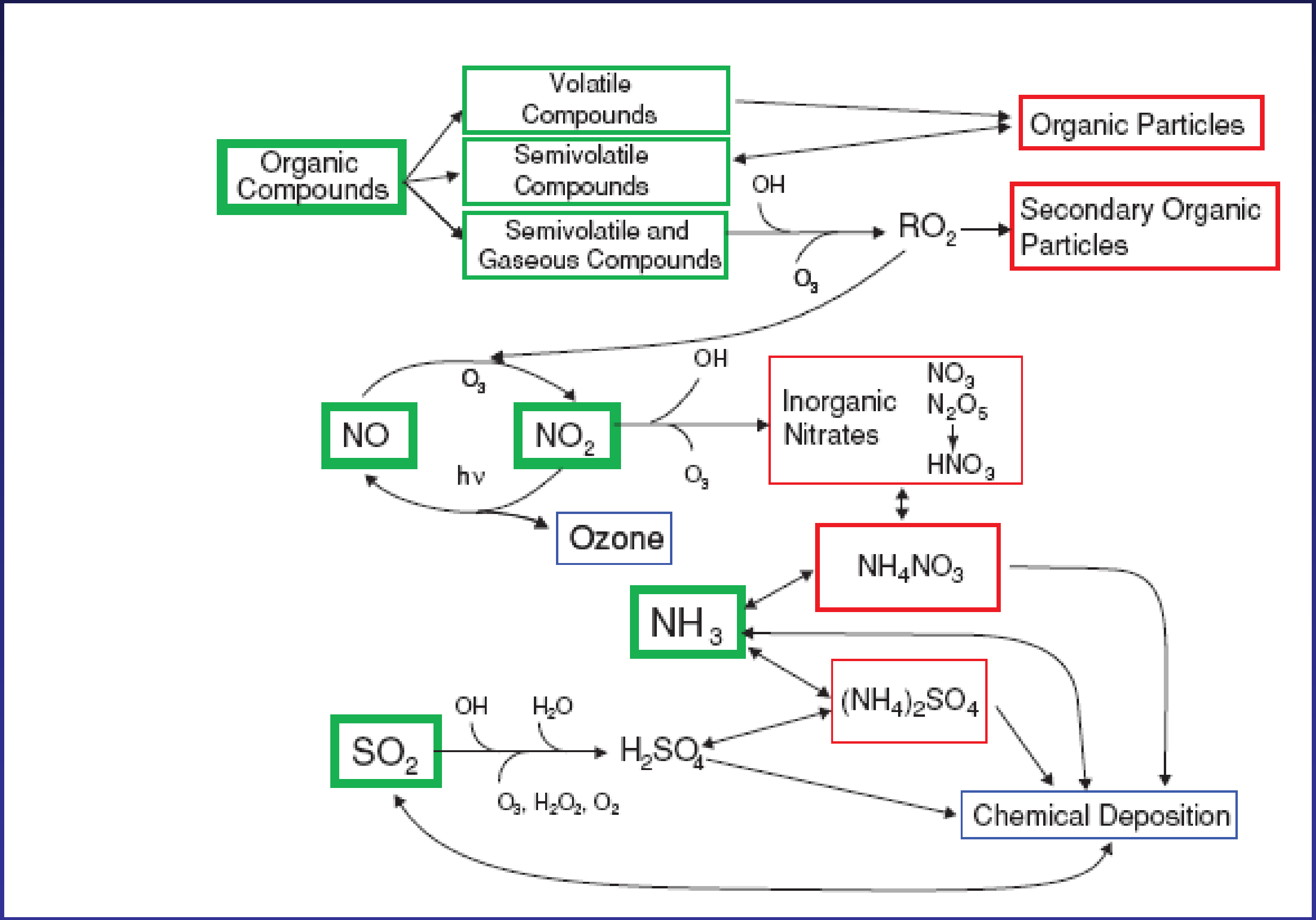
Reduction in pollutant emissions	Change in associated pollutant or atmospheric issue					
	Ozone	PM Composition			$PM_{2.5}$ [k]	Acid Deposition
		$SO_4^{=}$	NO_3^{-}	Organic compounds		
SO_2		↓	↑ (e)		↓	↓
NO_x	↓ (a) ↑	↑ ↓ (c)	↓ (f)	↓↑ (h)	↓↑	↓↑
VOC	↓	↑ ↓	↓↑ (g)	↓ (i)	↓↑	↓↑
NH_3		↓ (d)	↓		↓	↑ (l)
Black Carbon	↑ (b)			↓ (j)	↓	
Primary Organic Compounds	↑ (b)			↓	↓	
Other primary PM (crustal, metals, etc.)	↑ (b)				↓	↑ (l)

Table 1. Possible pollutant/atmospheric relationships[a] associated with emission precursor reductions.[9,10]

Reduction in Pollutant Emissions	Change in Associated Pollutant or Atmospheric Issue										
	Ozone	PM Composition			$PM_{2.5}$	Visibility	HAPs/VOCs	HAP Metals	Acid Deposition	Watershed Eutrophication	Mercury Deposition/Methylation
		Sulfate	Nitrate	Organic Carbon							
SO_2	↓[b]	↓	↑[e]		↓	↓			↓		↓[g]
NO	↓↑[c]	↓[d]↑[e]	↓	↓[d]	↓	↓	↓		↓	↓	↑[g]
VOC HAPs VOC	↓	↓	↑[f]↓[d]	↓	↓	↓	↓			↓	
CO	↓	↓	↓[d]	↓[d]	↓	↓	↓[d]		↓[d]		
NH_3		↓	↓		↓	↓				↓	↑[g]
Primary PM-organic C				↓	↓	↓					
Primary PM-black C					↓	↓					
Primary PM-(crustal/metals)	↓[b]				↓	↓		↓			
Hg											↓

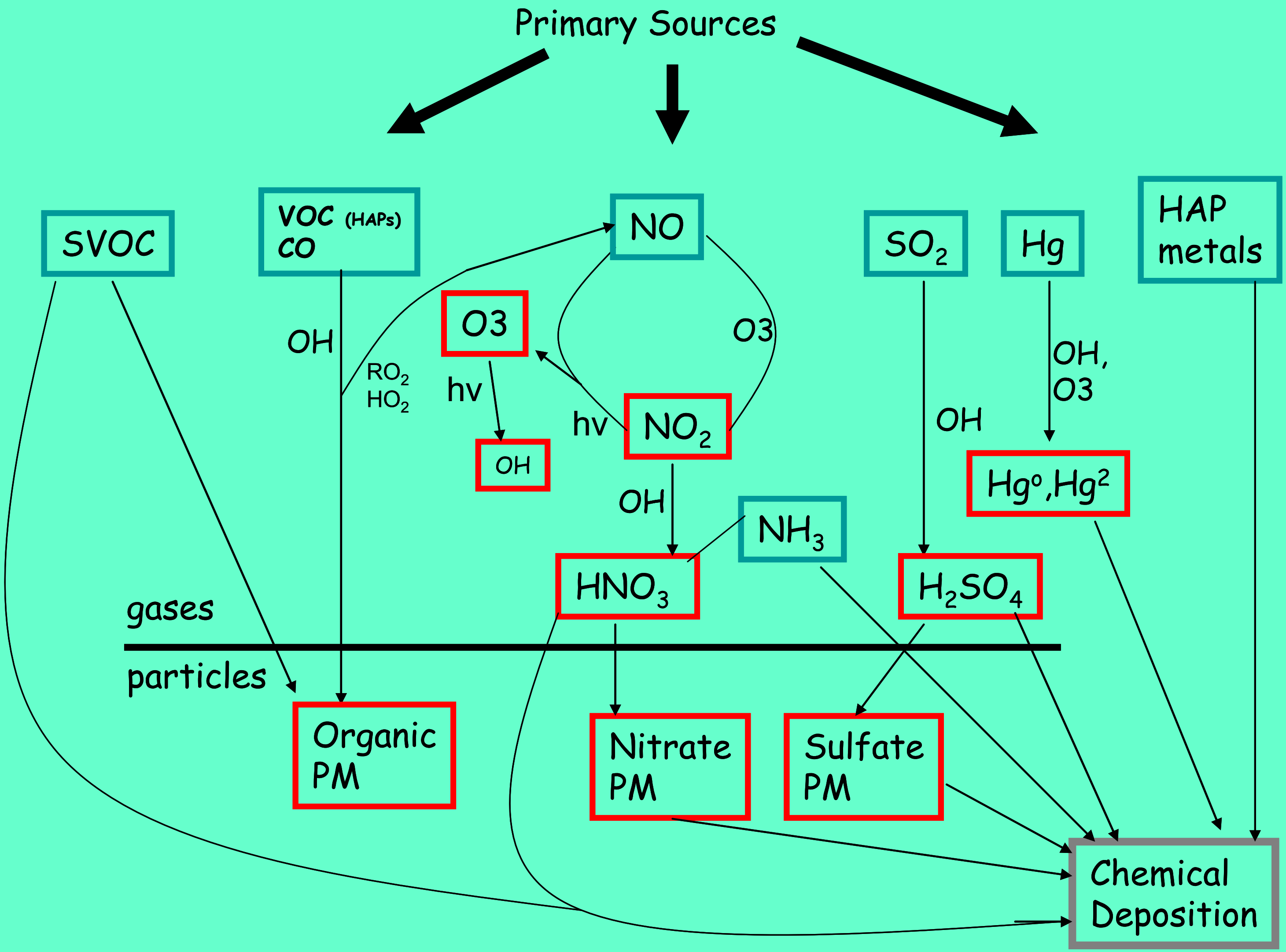
Notes: [a]Arrow direction denotes relative increase ↑ or decrease ↓ of pollutant resulting from a decrease in associated emissions. Large arrow indicates either well established relationship and/or substantial magnitude of effect. Small arrow implies possible response that is likely to be of minimal magnitude. [b]O_3 reduction associated with decreased light scattering from decrease in fine particle levels. [c]NO_x titration effect on O_3 largely limited to VOC-limited urban areas. [d]associated with effect on decreasing OH and O_3 levels. [e]substitution effect in competition for NH_3 in NH_3-limited regions (and increase in H_2O_2 leading to increased in cloud SO_2 production). [f]associated with reduction of peroxyacetyl radicals leading to increased nitric acid formation. [g]associated with nitrogen, sulfur, and mercury interactions within sediments.

NARSTO PM3 Assessment – Basic linkages across ozone and aerosol transformation processes



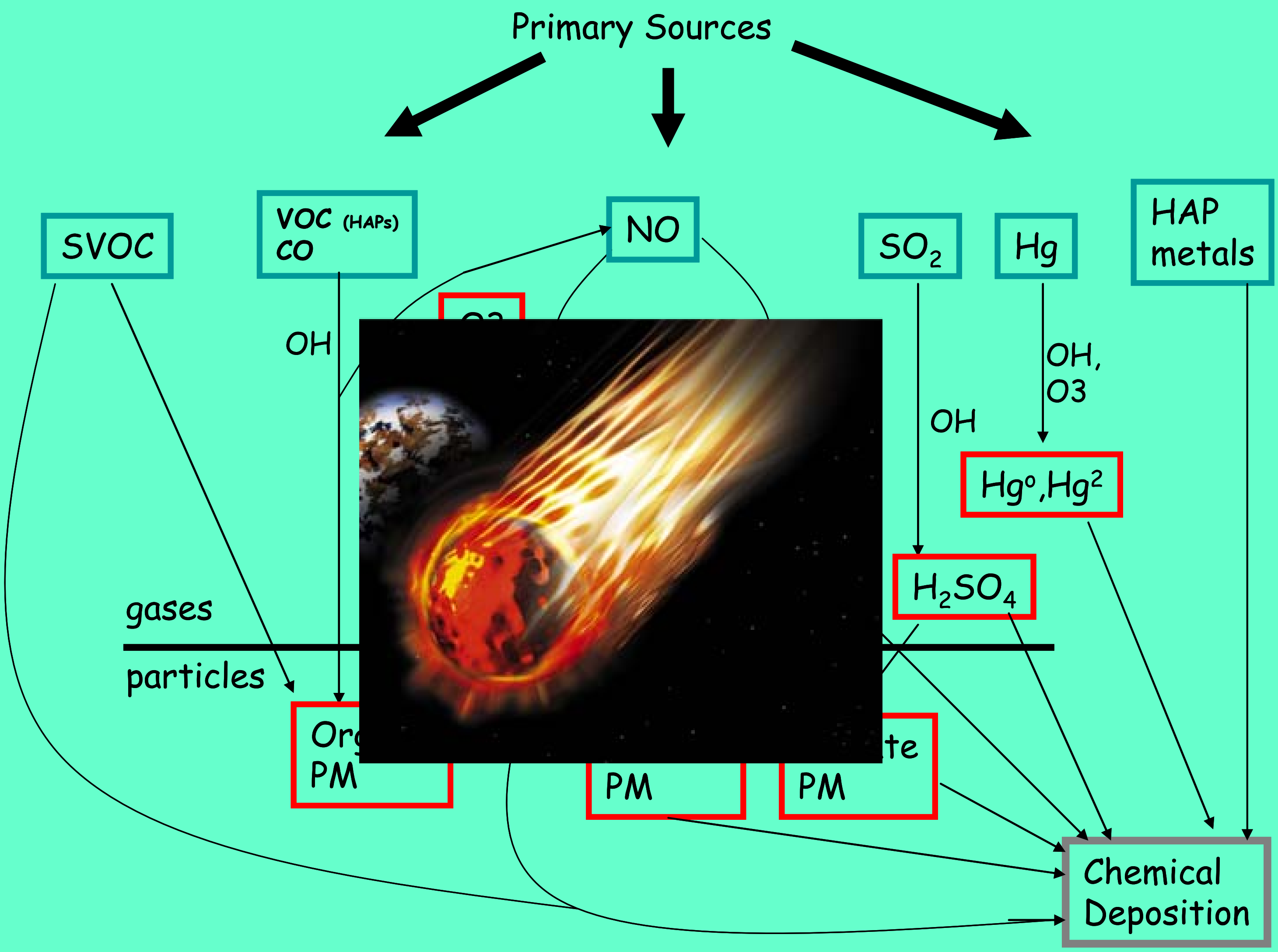
NARSTO MPMM Assessment – Basic linkages across ozone, PM, HAPs, and deposition

Integration across pollutants and media: tradeoffs and optimum strategies?



NARSTO MPMM Assessment – Basic linkages across ozone, PM, HAPs, and deposition

Integration across pollutants and media: tradeoffs and optimum strategies?



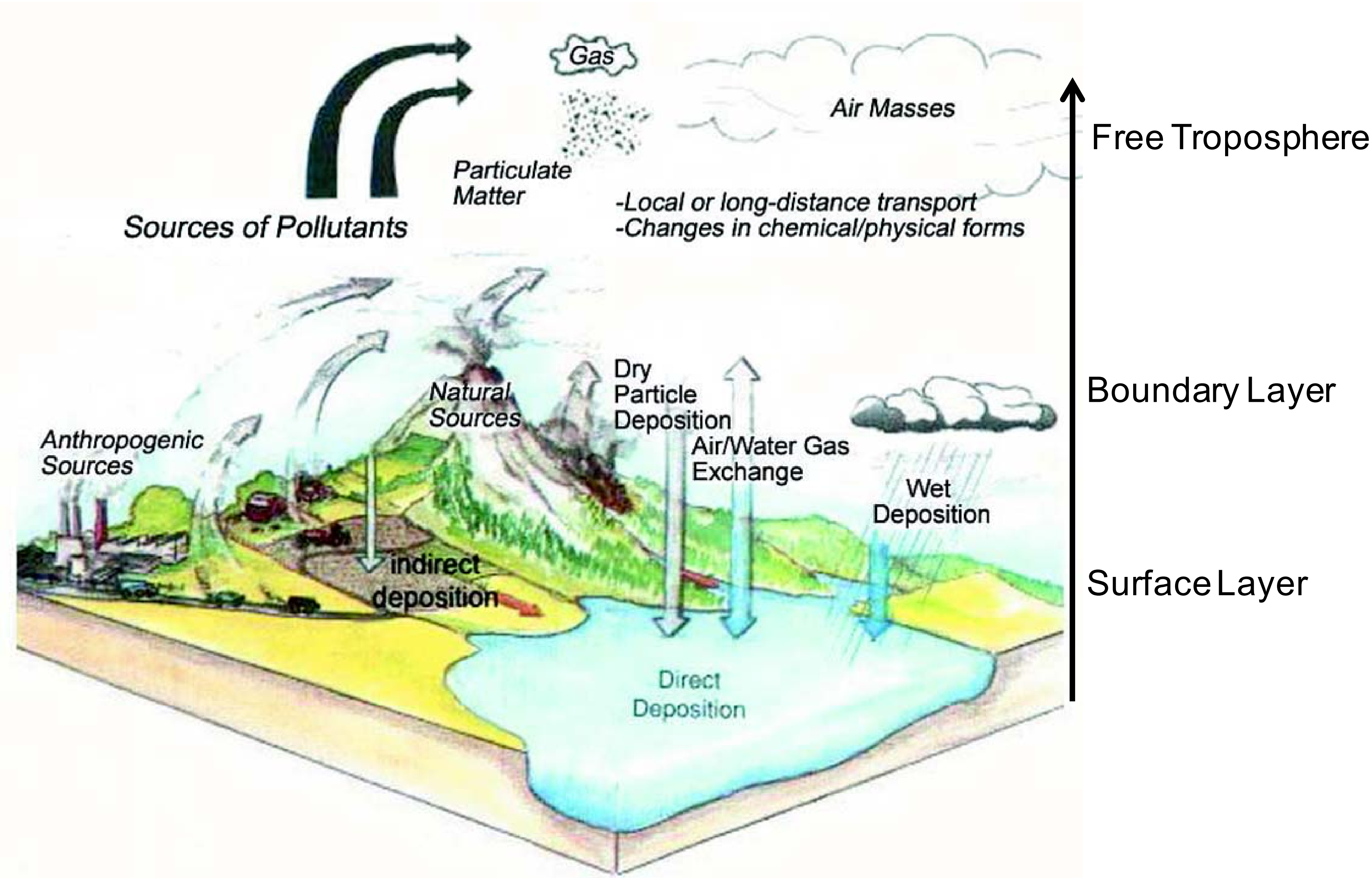
Note on climate-AQ interactions

- What are the relative response differences across pollutant categories in changing climate scenarios
  - e.g., do we see greater or lesser benefits of formaldehyde relative to sulfate forced by temperature, moisture changes

Current NARSTO MP Assessment

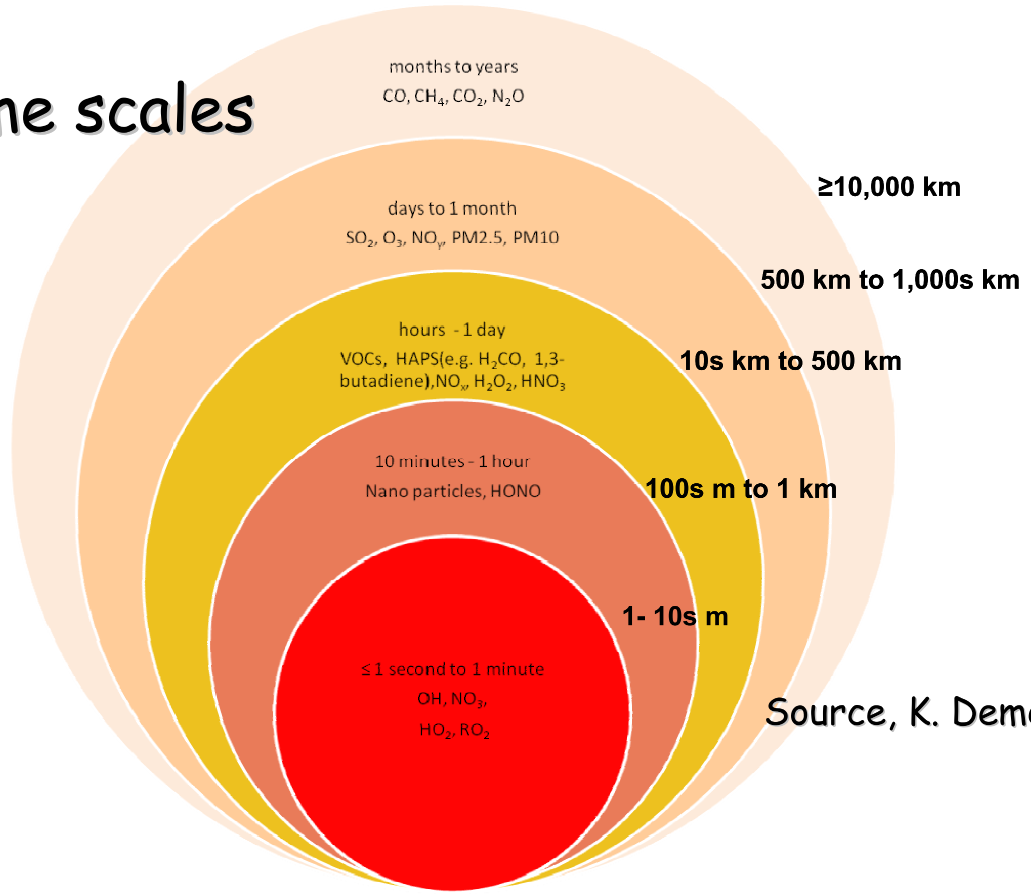
- Response to 2004 NAS Report
- yin and yang or who comes first regarding MP and accountability
- Expanded from atmospheric science focus to include –
  - All pollutant categories
  - Health effects and human exposure
  - Ecosystem effects
  - Air quality climate interactions
- Chapters addressing
  - Air quality management frameworks and Policy considerations
  - Risk based management (Hubbell)
  - Emissions, modeling, chemistry, measurements, ecosystems, health, climate,
- Preliminary Findings (Hubbell)
  - emphasis on obstacles compromising MPAQM risk assessments
    - E.g., inadequate health outcome data based on MP exposures

Multiple processes in addressing MPMM assessments



Source, K. Demerjian

Multiple space and time scales when addressing MPs



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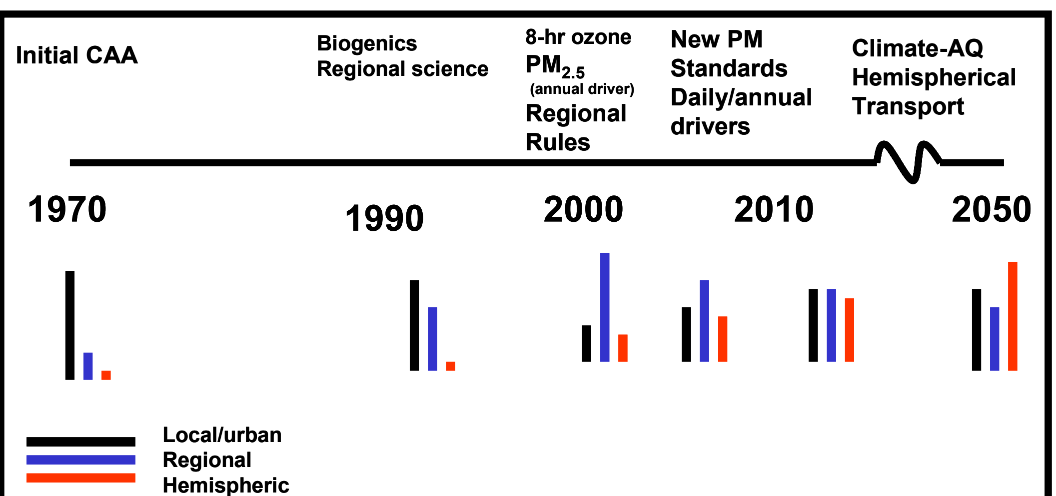
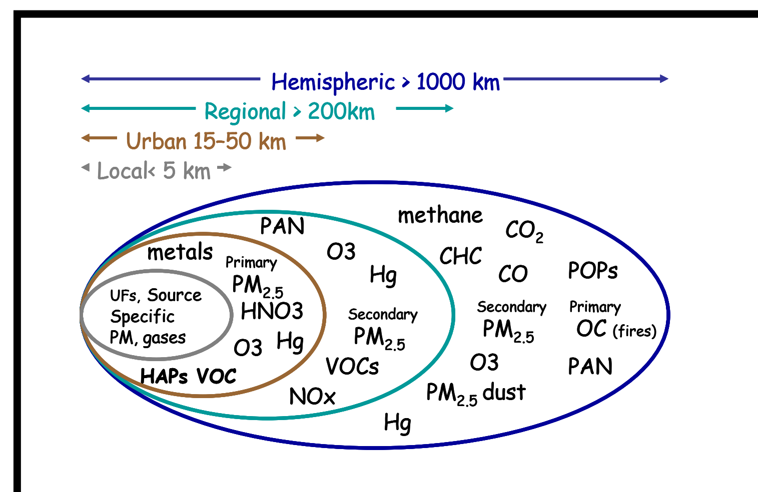
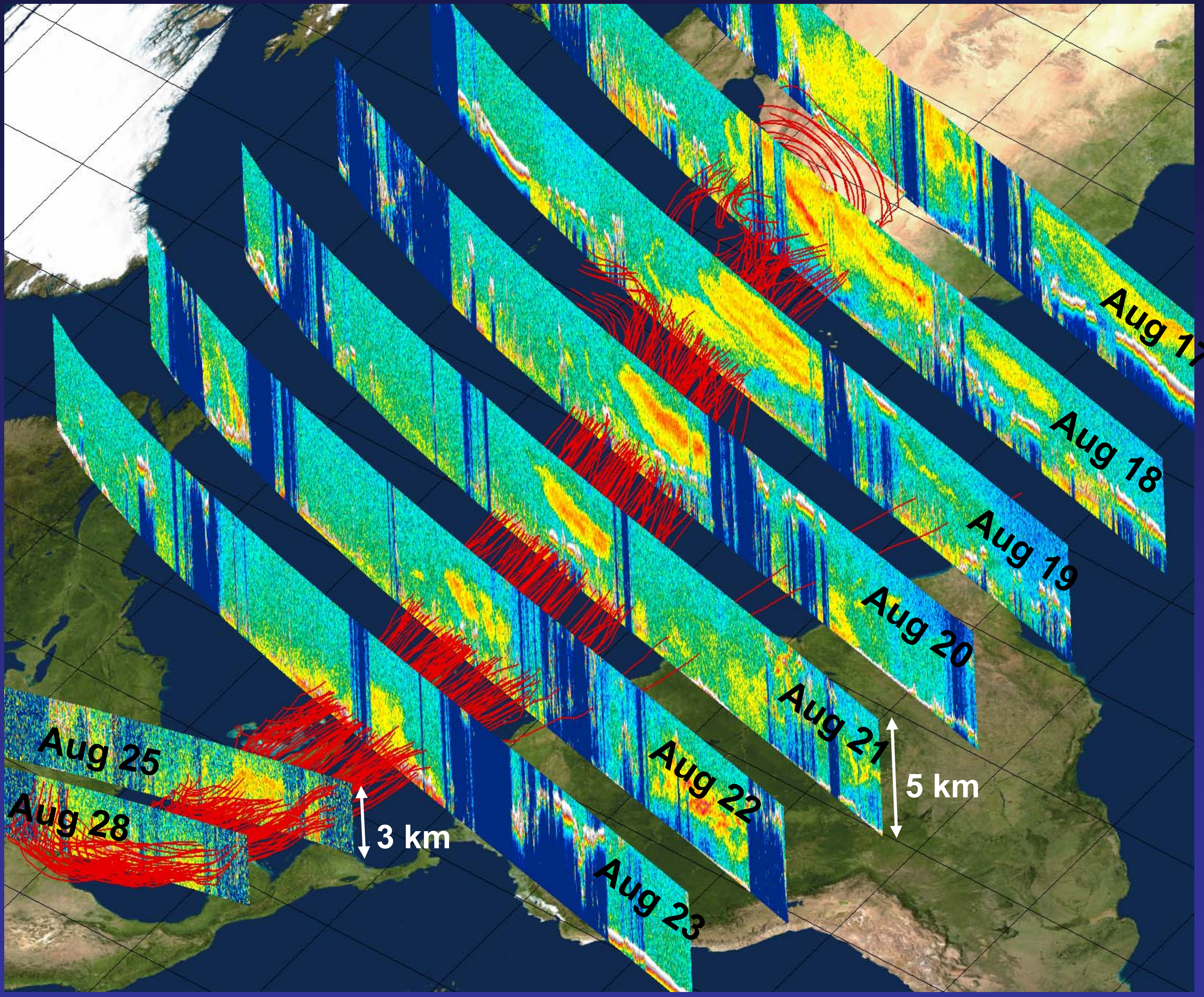




2006 Dust Transport Event Observed from CALIPSO

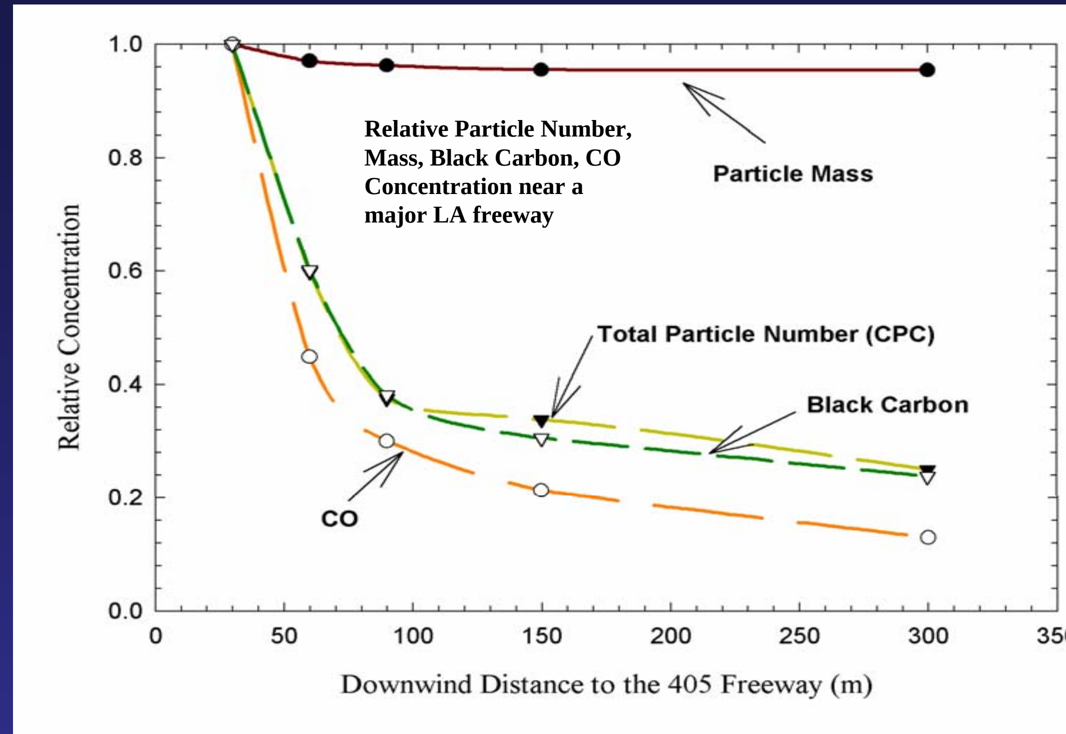


David Winker

New findings on roadway pollution

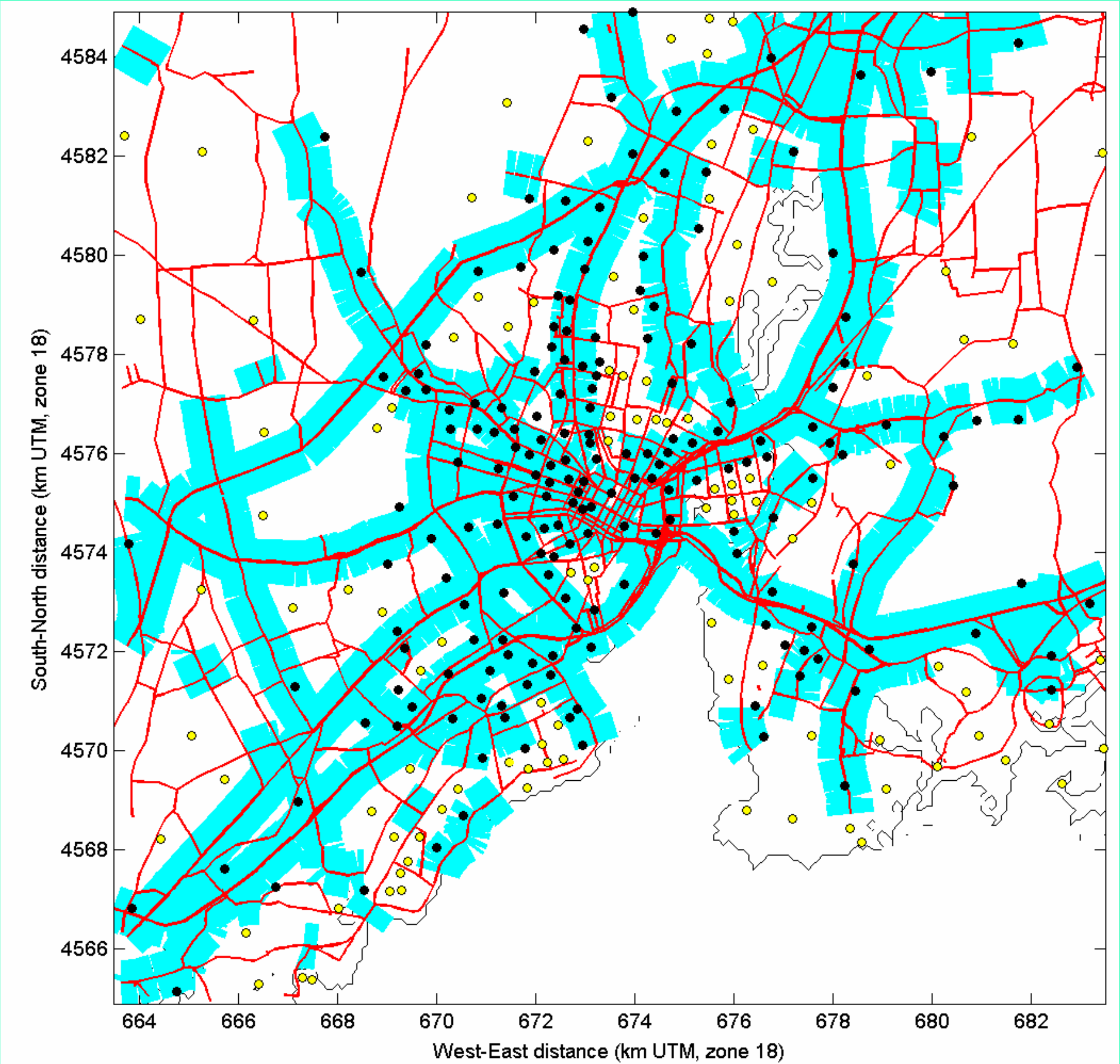
High exposure to ultrafine particles, CO, other pollution near roadway

Increased risk near and on roadways

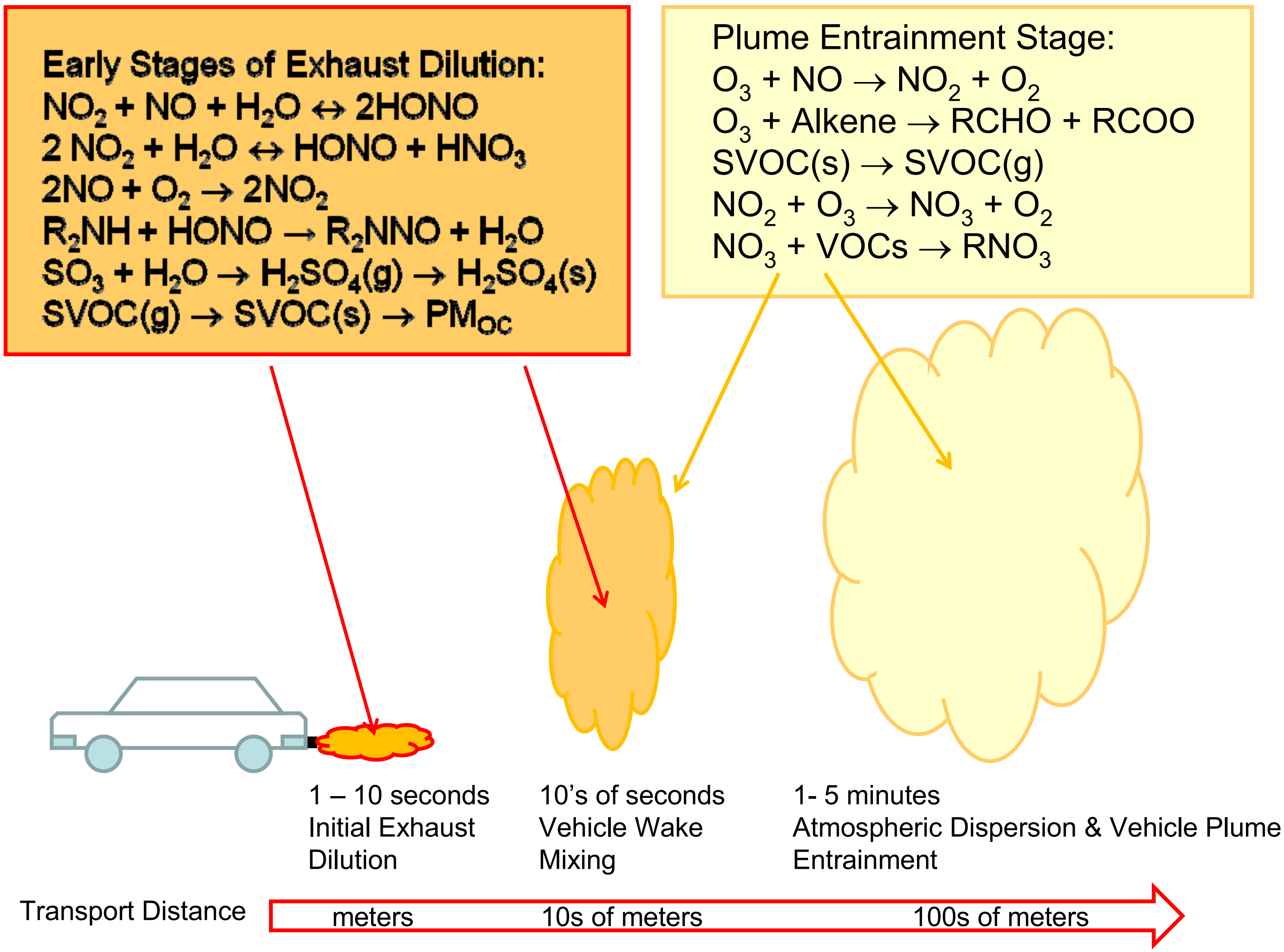


Example: New Haven, CT

70% of block group centroids are within 500m from a major road >10,000 ADT

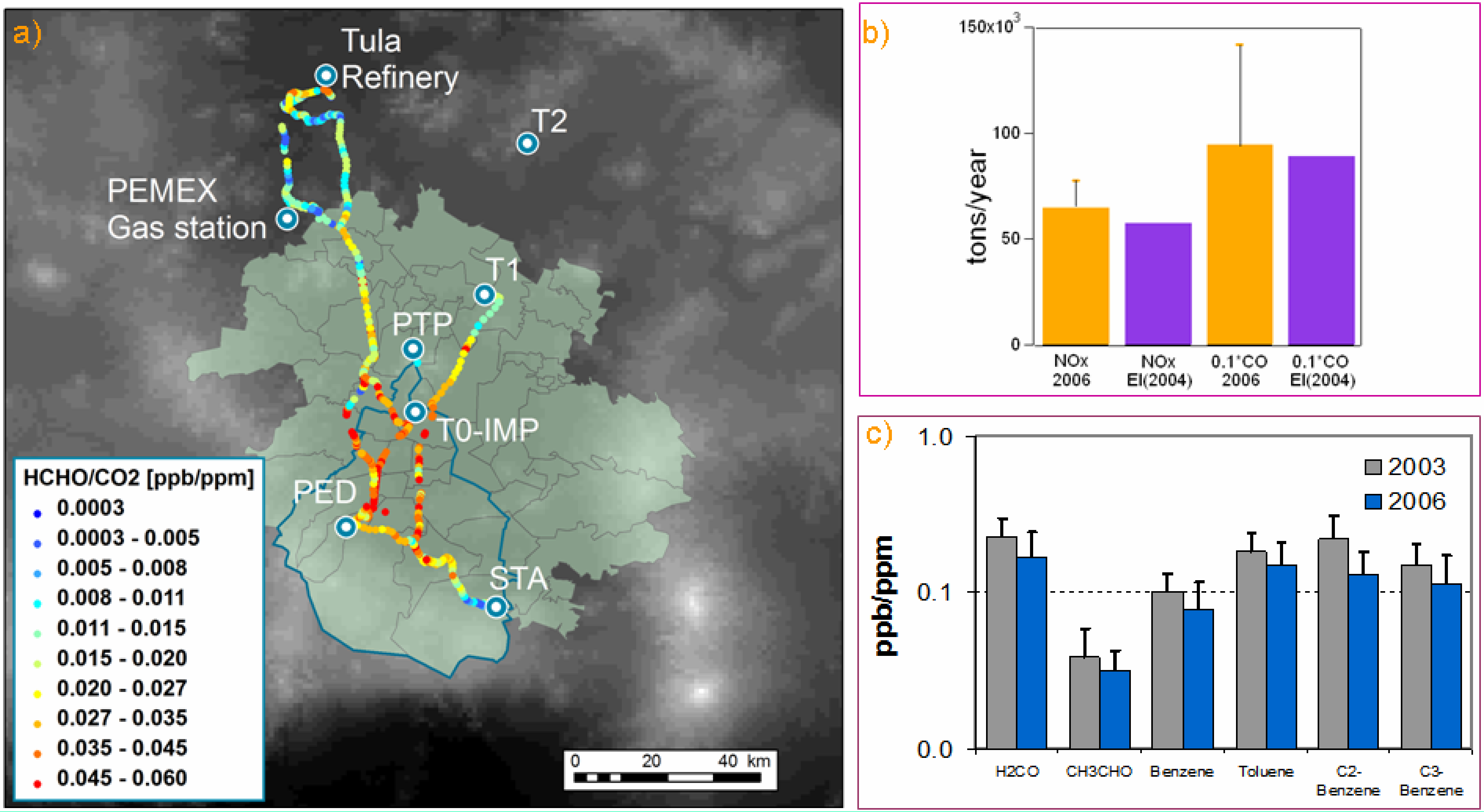


Local (near source) scale processes



Source, K. Demerjian

MPAQM/multiscale assessments benefit from nontraditional monitoring strategies: example – intensive, yet iterative, mobile platform based sampling in Mexico City

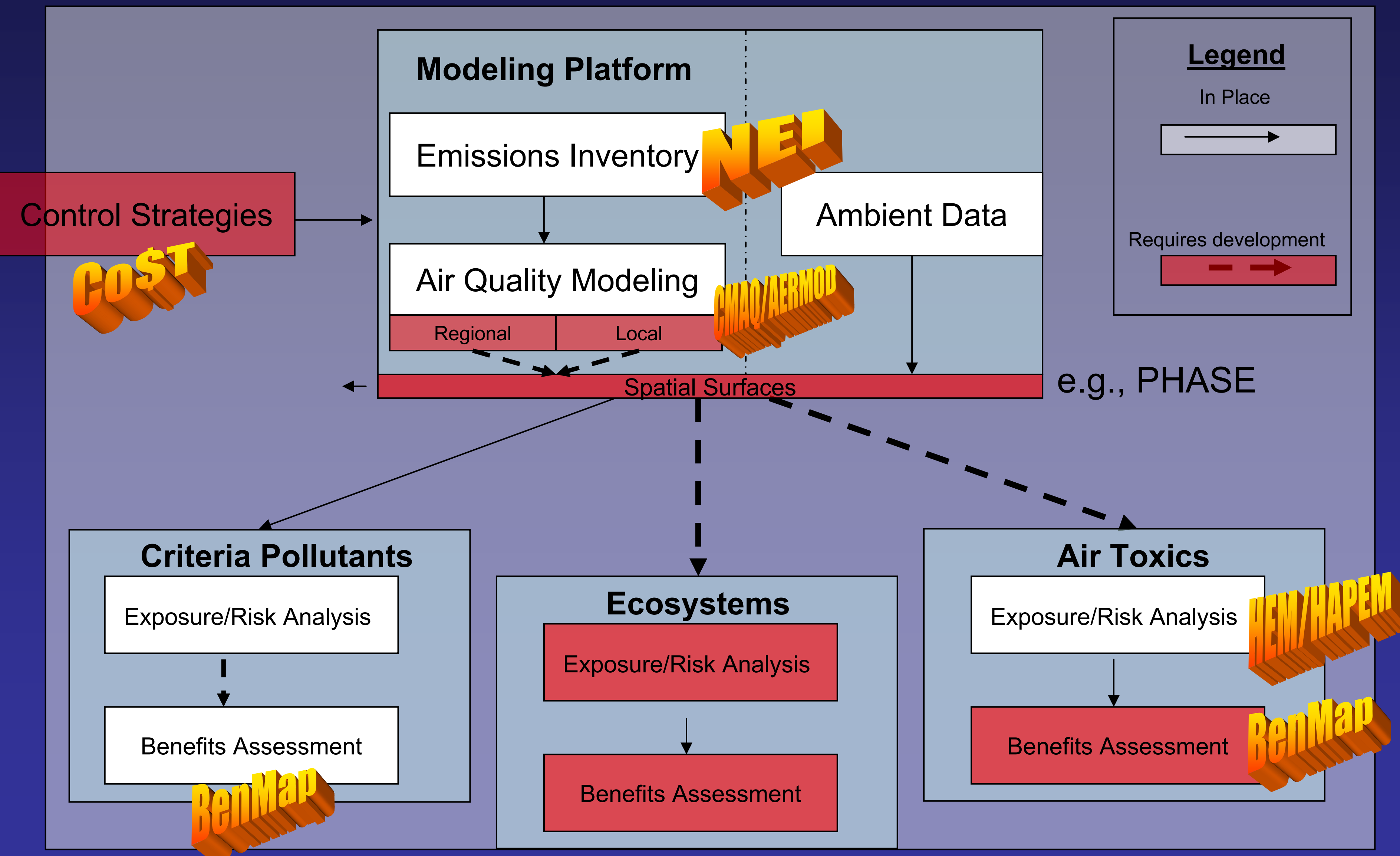


(source, L. Molina)

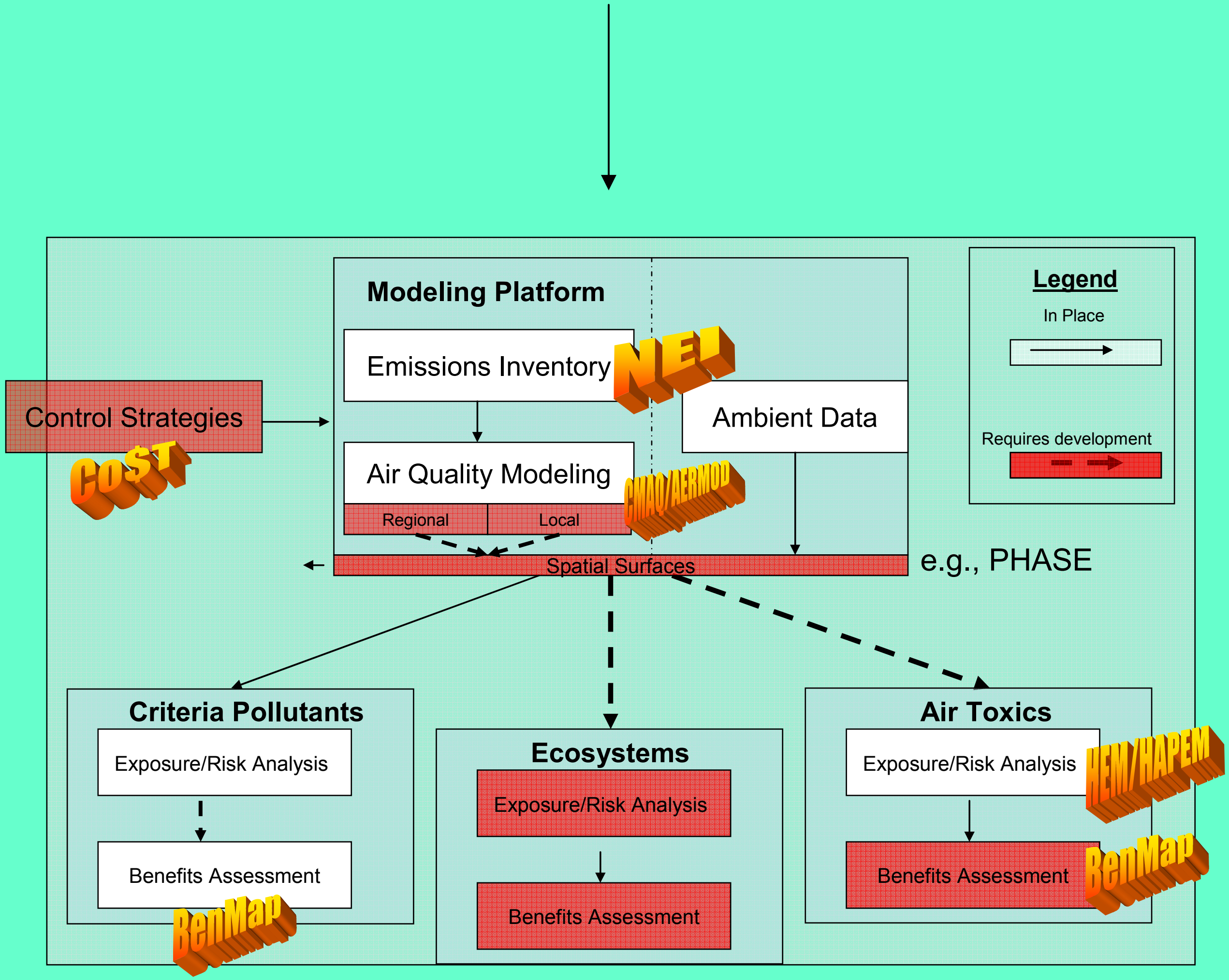
Toolboxes for Integrated Assessments

Multi-Pollutant Analytical Framework

Future = National Air Pollutant Assessment

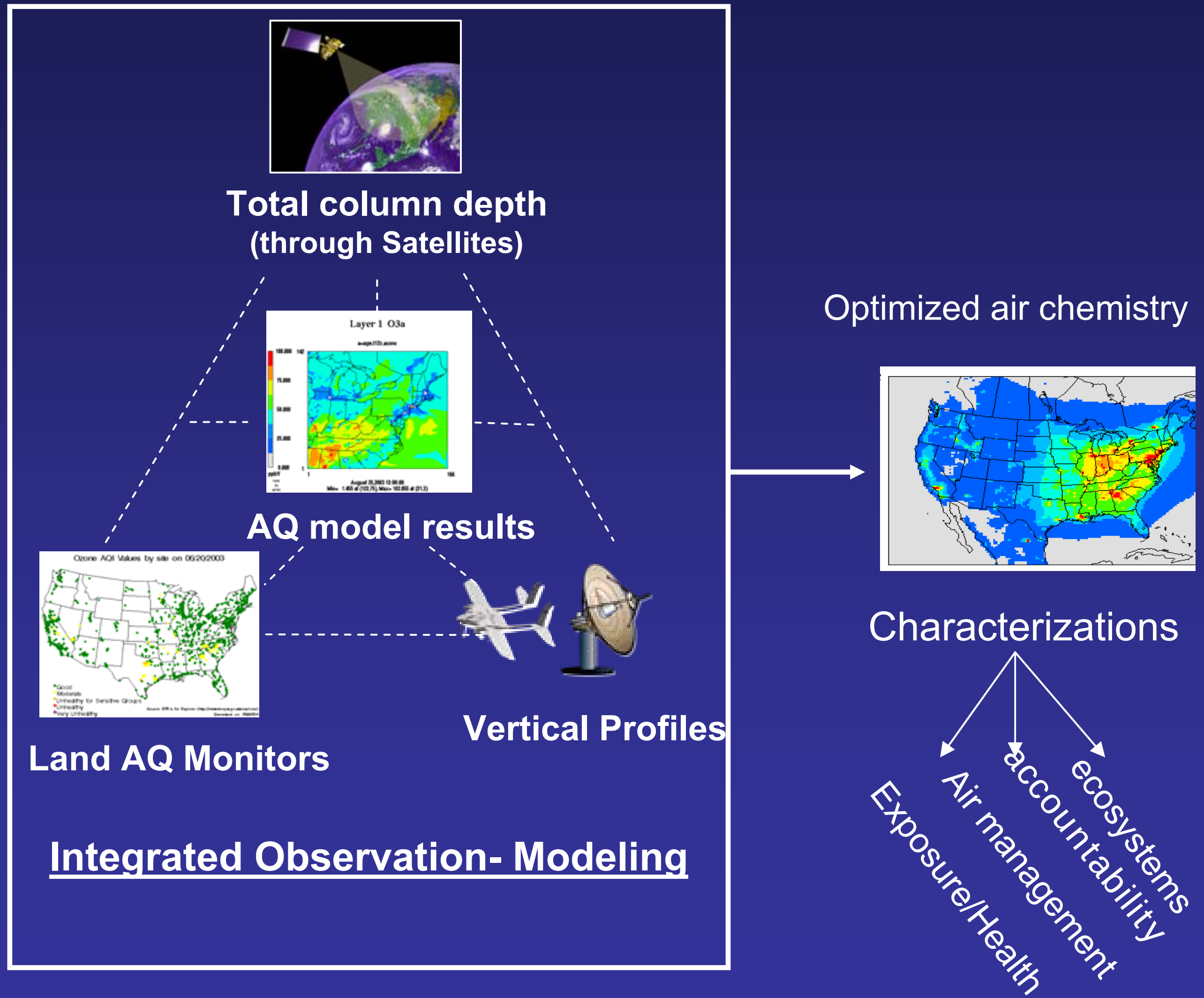


Conceptual Model(s)



Maximizing space/time/composition through systems integration

- Integration of systems to improve
  - air quality models for forecast
  - Current and
  - Retrospective assessments
- Global-Regional Air Quality Connections
- Climate-AQ connections



Increased complexity of assessments benefits from conceptualizing the problem

- e.g, shift to weight-of-evidence for ozone SIPs required multiple sources of analyses
- as variables increase, rigid solutions limit flexibility
- A robust analytical approach will enable incorporation of the unanticipated

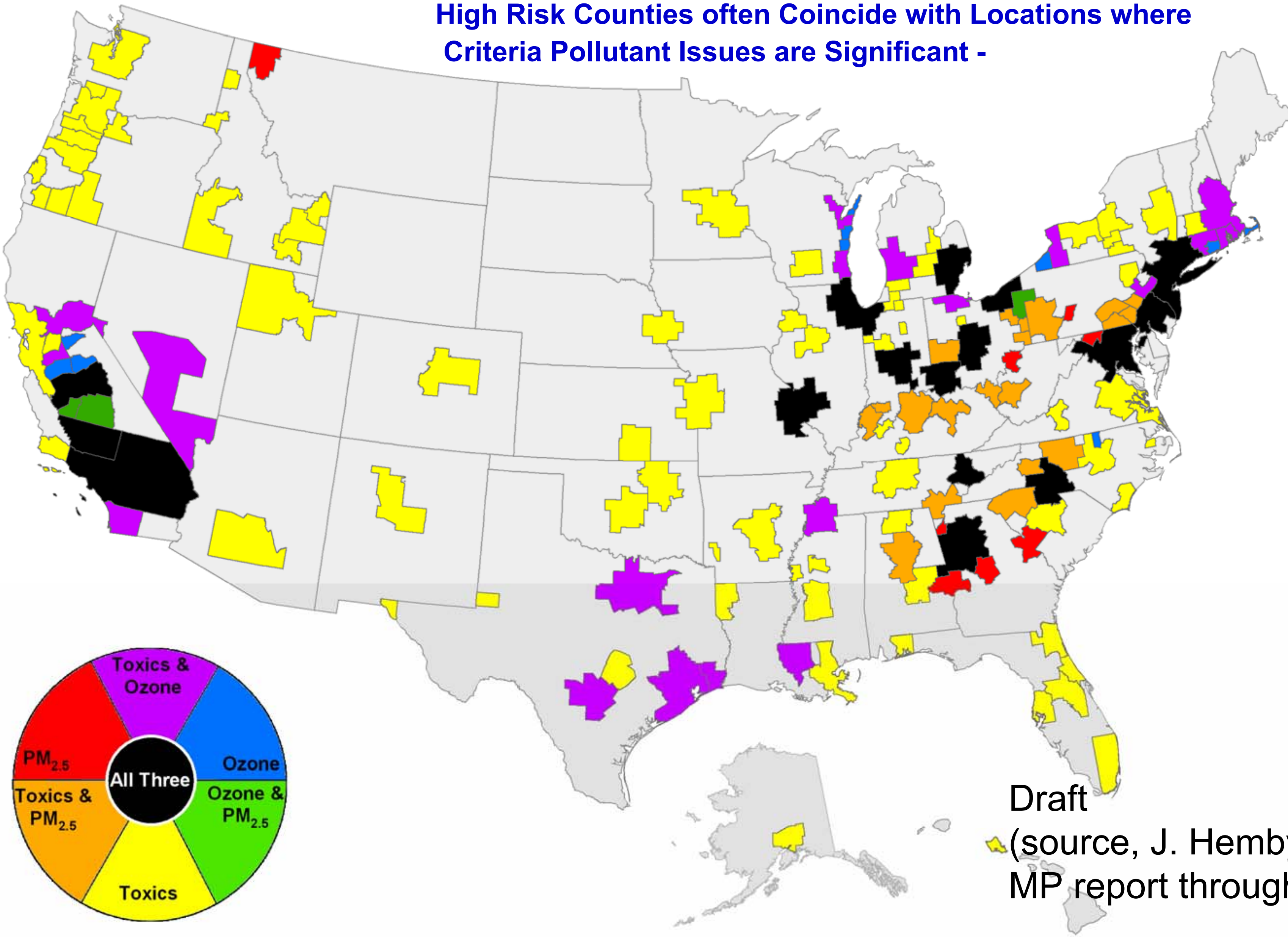
How do we start building MP conceptual models?

- Step 1 – Develop broad range environmental characterization map addressing multiple pollutants, space, and temporal patterns (annual, seasons, daily events) – accommodating space/time attributes of different pollutants
  - Ideally, national or regional resources available (e.g., NAPA)
  - Base case modeling results; available observations; and blending where appropriate
- Step 2 – constrain/focus problem by identifying practical air quality management objectives, without closing opportunities.
  - arctic POPs deposition?
  - Example objectives
    - Ozone focus, options to maximize HAPS and PM co-benefits
    - Variations of above
    - Equivalent importance for 2 or more parameters
    - Expanded in risk assessment discussion (Hubbell)
- Step 3 – Develop a basic concept picture based meteorological, topographical and emissions features
- Step 4 – Develop an analytical plan that includes an observations strategy: acknowledge the unknown and unexpected early on
- Step 5 – Use these characterizations to focus on specific quantitative analyses

Example questions

- What pollutant categories are of concern now, after expected implementation of emission strategies?
  - How does changing meteorology, landscape dynamics affect..
- What information is available to construct an environmental state map?
- What information is needed?
- What time (space frames) periods are of concern for what indicators of interest?
- What are the needs of downstream analytical tools that assess exposures, risks and benefits across pollutant categories?
- What is the intersection among regulatory and analytical timeframes – what steps can be taken to harmonize?

Nexus of ozone, $PM_{2.5}$ (2003-5) and air toxics (NATA 1999))



Draft
(source, J. Hemby
MP report through w

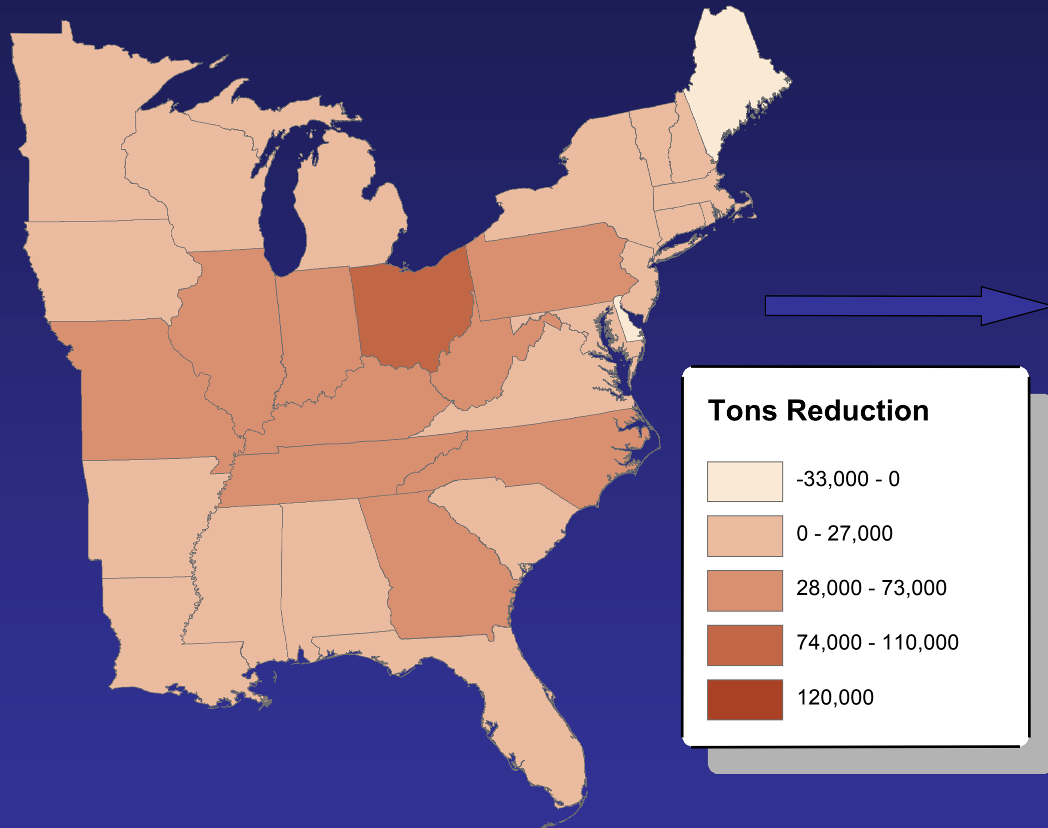
Added challenges for MPMM conceptual models

- Multiple conceptual models
  - Limit on how well integrated pollutants are
  - Consider variety of time, spatial scales; meteorological patterns
- Final product account for
  - Individual as well as linked physical/chemical descriptions

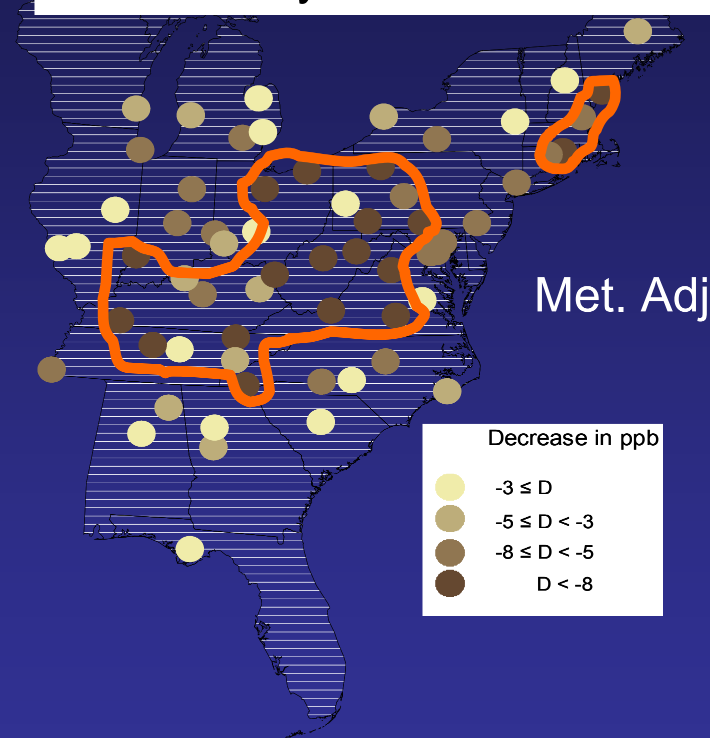
Remember time sequences (accountability)

Largest decline in ozone occurs in and downwind of EGU NOx emissions reductions (2002-2004)
(analysis constrained by absence ambient NOx data)

EGU NOx Tons Reduced



Decline in "Seasonal Average" 8-Hour Daily Maximum Ozone



Met. Adj.

The major EGU NOx emissions reductions occurs after 2002 (mostly NOx SIP Call)

Average rate of decline in ozone between 1997 and 2002 is 1.1%/year.

Average rate of decline in ozone between 2002 and 2004 is 3.1%/year.

Satellites provide best source of ambient NO_2: Accountability and Trends

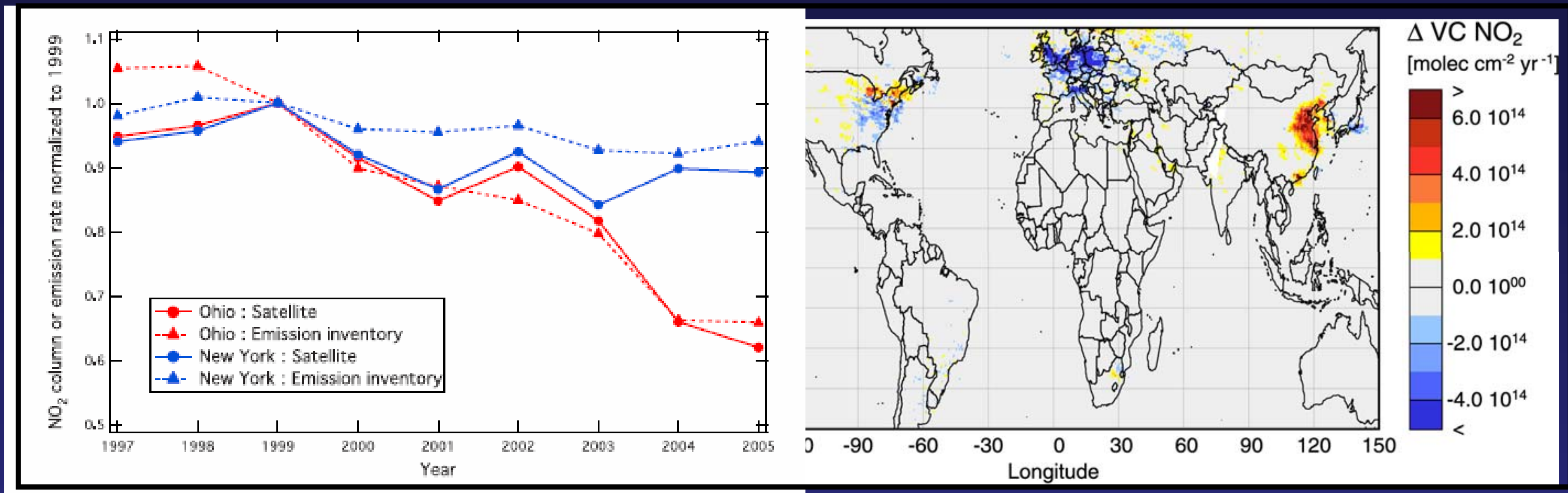


Figure 20. Left - **s**uperimposed Eastern U.S. emission and combined GOME and SCIAMACHY NO2 1997-2002 trends (Kim et al., 2006); right - GOME NO2 trends from 1995 – 2002 (after Richter, 2005). Clear evidence of reductions in midwest U.S. and European NOx emissions, and increased NOx generated in Eastern Asia.

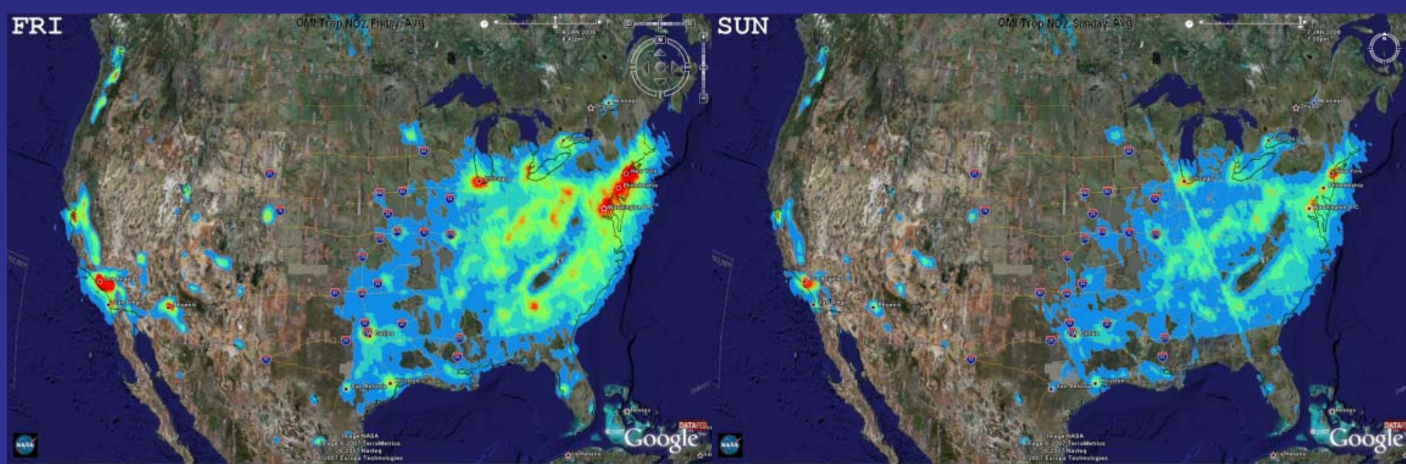
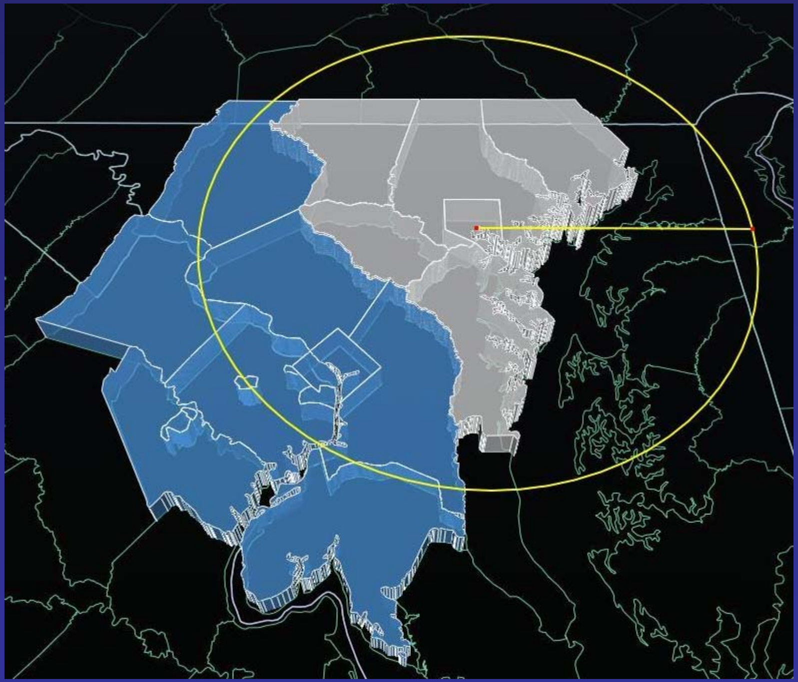


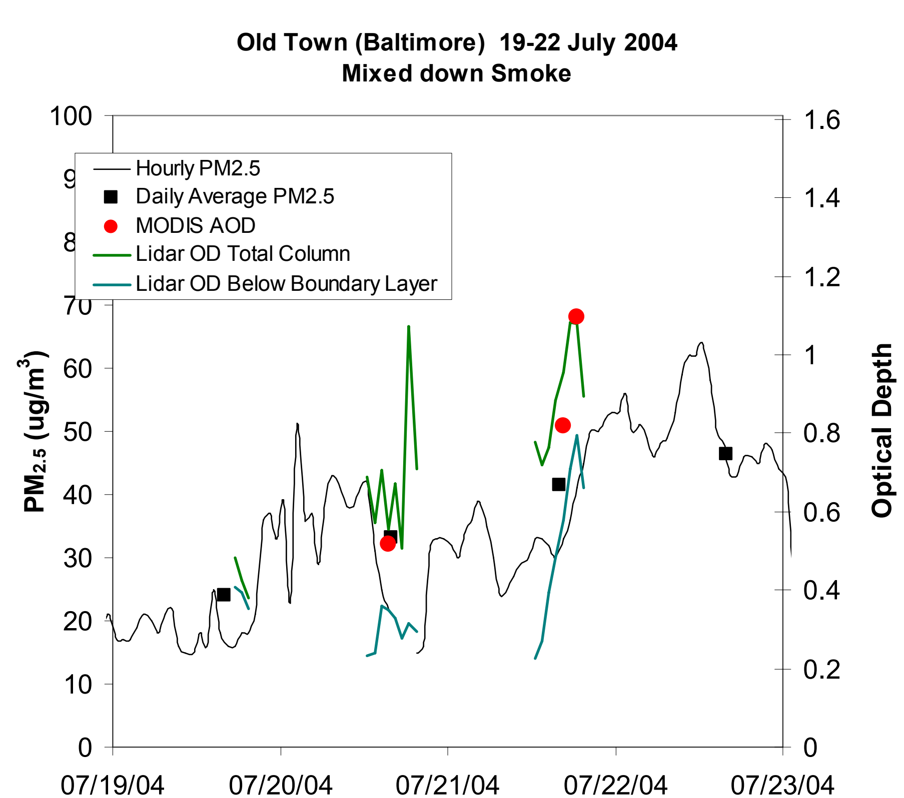
Figure 21. 2004 OMI NO2 column images aggregated for all Fridays (left) and Sundays (right) indicating weekend/weekday patterns associated with reduced Sunday emissions (source, Husar).

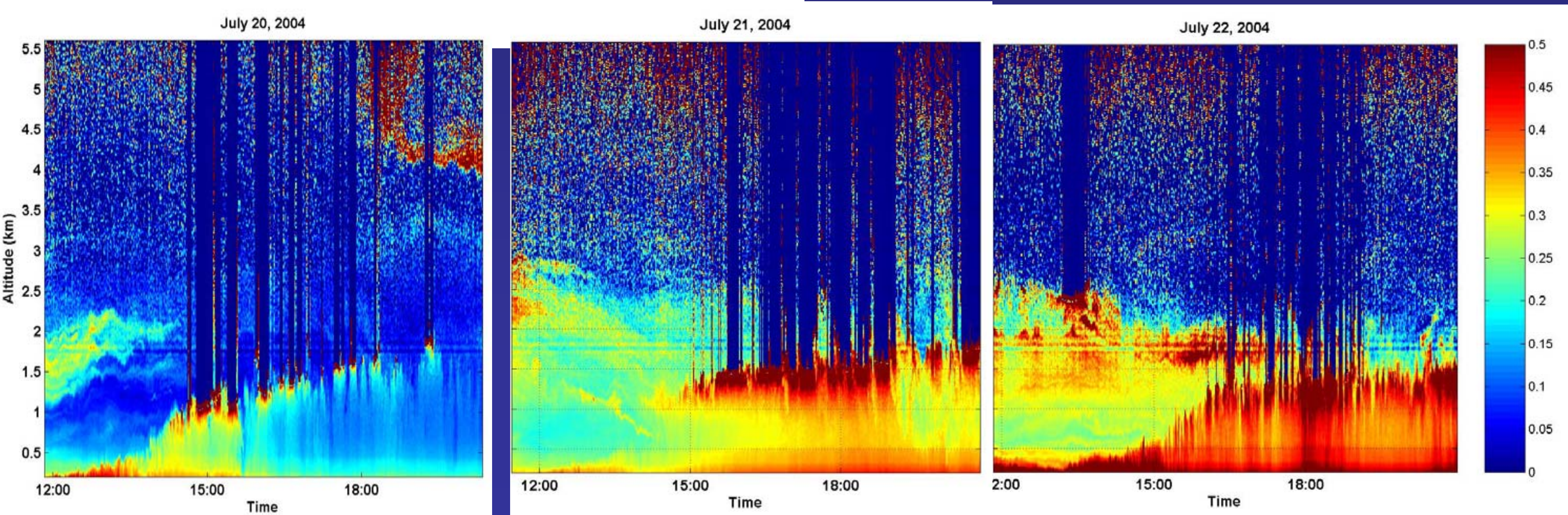
Case Example: 3D CAIR..mid-Atlantic sulfate transport 2004

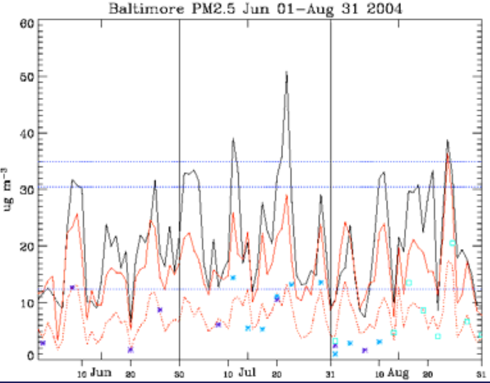
- **3.0 What can be learned about fine particulates and sulfate in the BALTIMORE, MD AREA BY COMBINING DATA FROM MULTIPLE OBSERVATIONAL AND SIMULATED SOURCES?**



Smoke mixing in Maryland 20-22 July 2004






Baltimore PM2.5 Jun 01–Aug 31 2004
ug m⁻³
0
10
20
30
40
50
60
10 Jun
20
30
10 Jul
20
31
10 Aug
20
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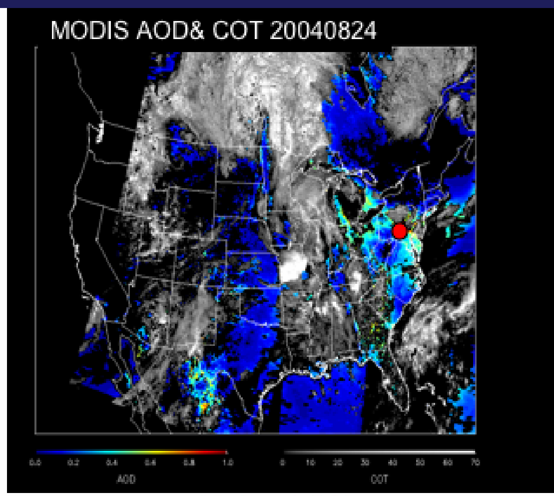
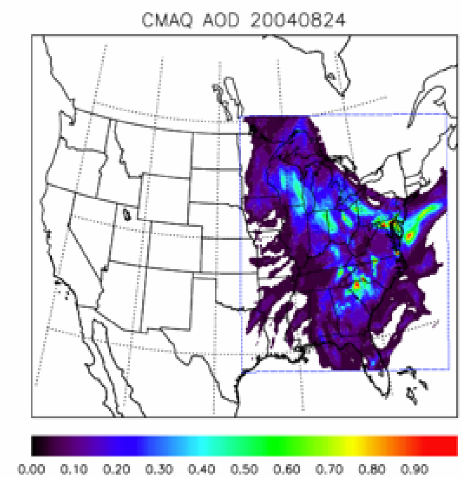
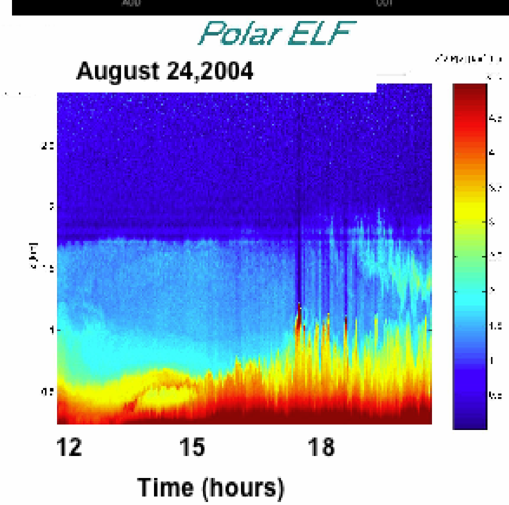
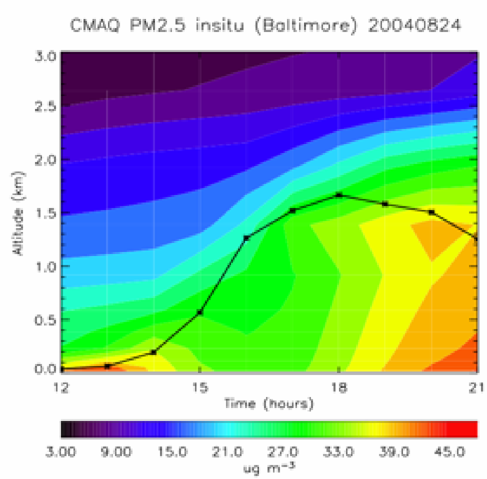

MODIS AOD& COT 20040824
AOD
COT


CMAQ AOD 20040824
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90


Polar ELF
August 24,2004
12
15
18
Time (hours)


CMAQ PM2.5 insitu (Baltimore) 20040824
Altitude (km)
0.0
0.5
1.0
1.5
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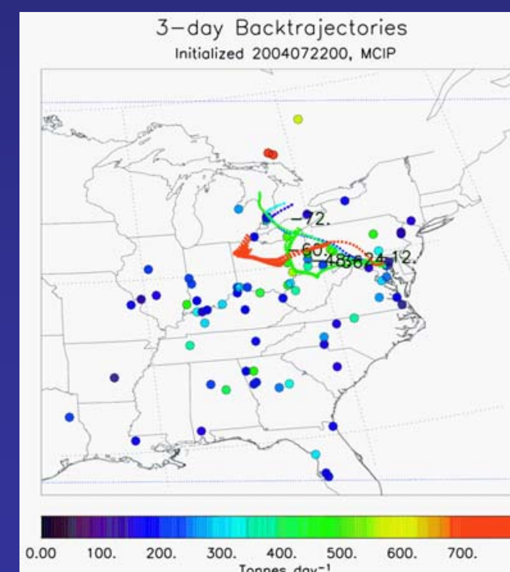
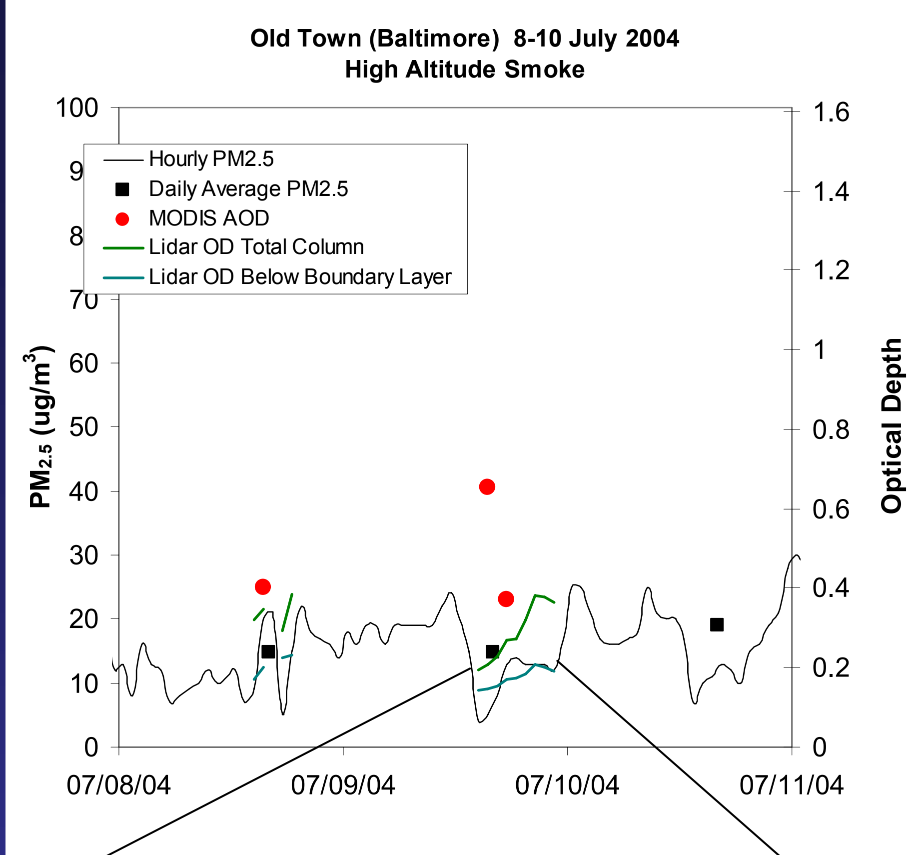
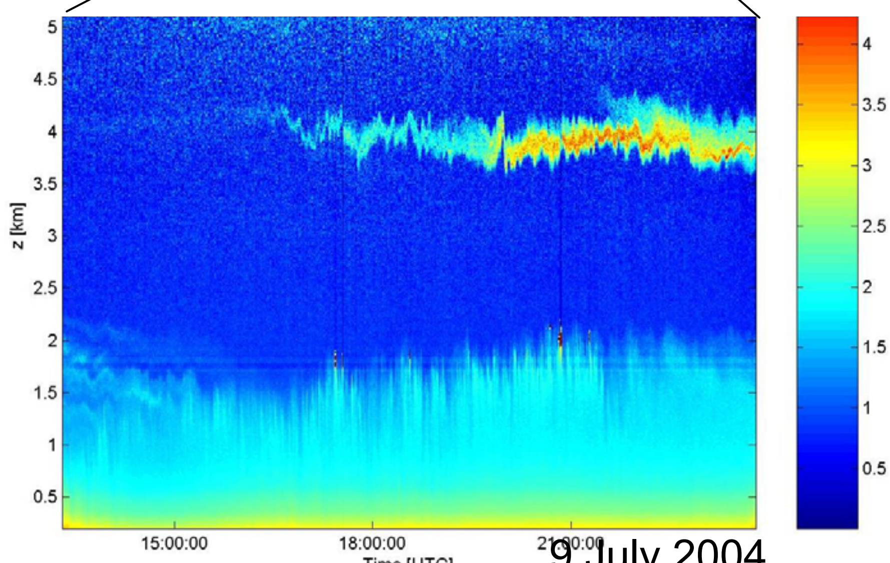
Time (hours)
3.00 9.00 15.0 21.0 27.0 33.0 39.0 45.0
ug m⁻³

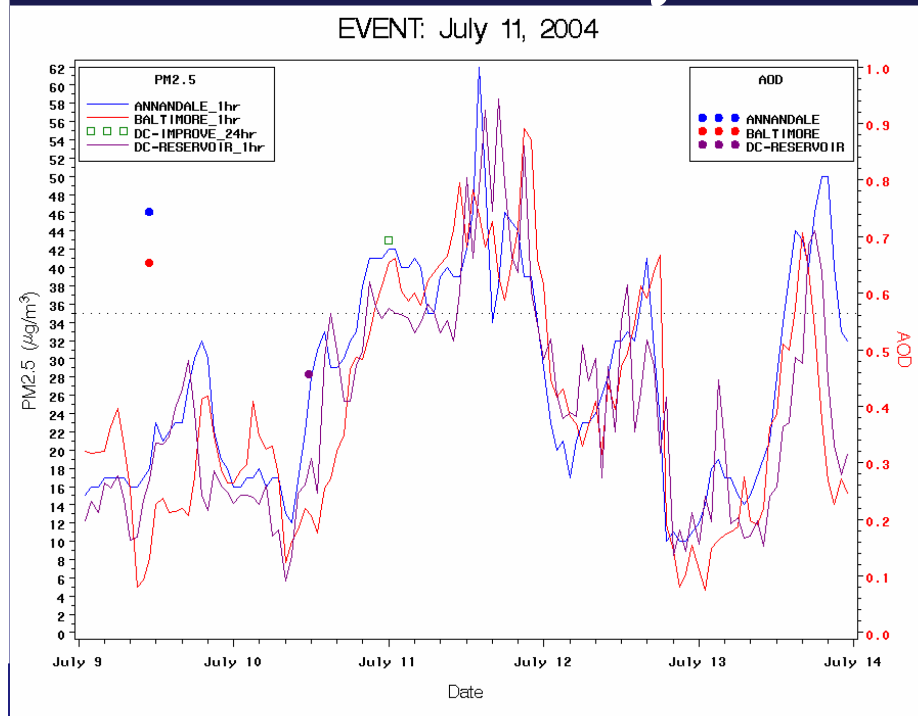

3-day Backtrajectories
Initialized 2004072200, MCIP
0.00 100. 200. 300. 400. 500. 600. 700.
Tonnes day⁻¹

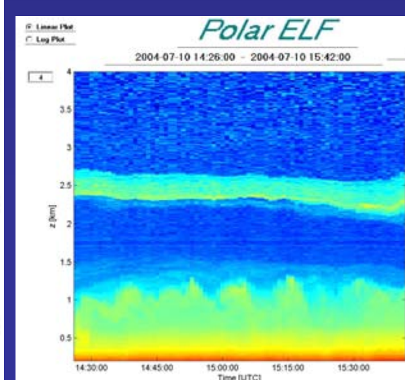
Alaskan Smoke 9-11 July 2004





9 July 2004

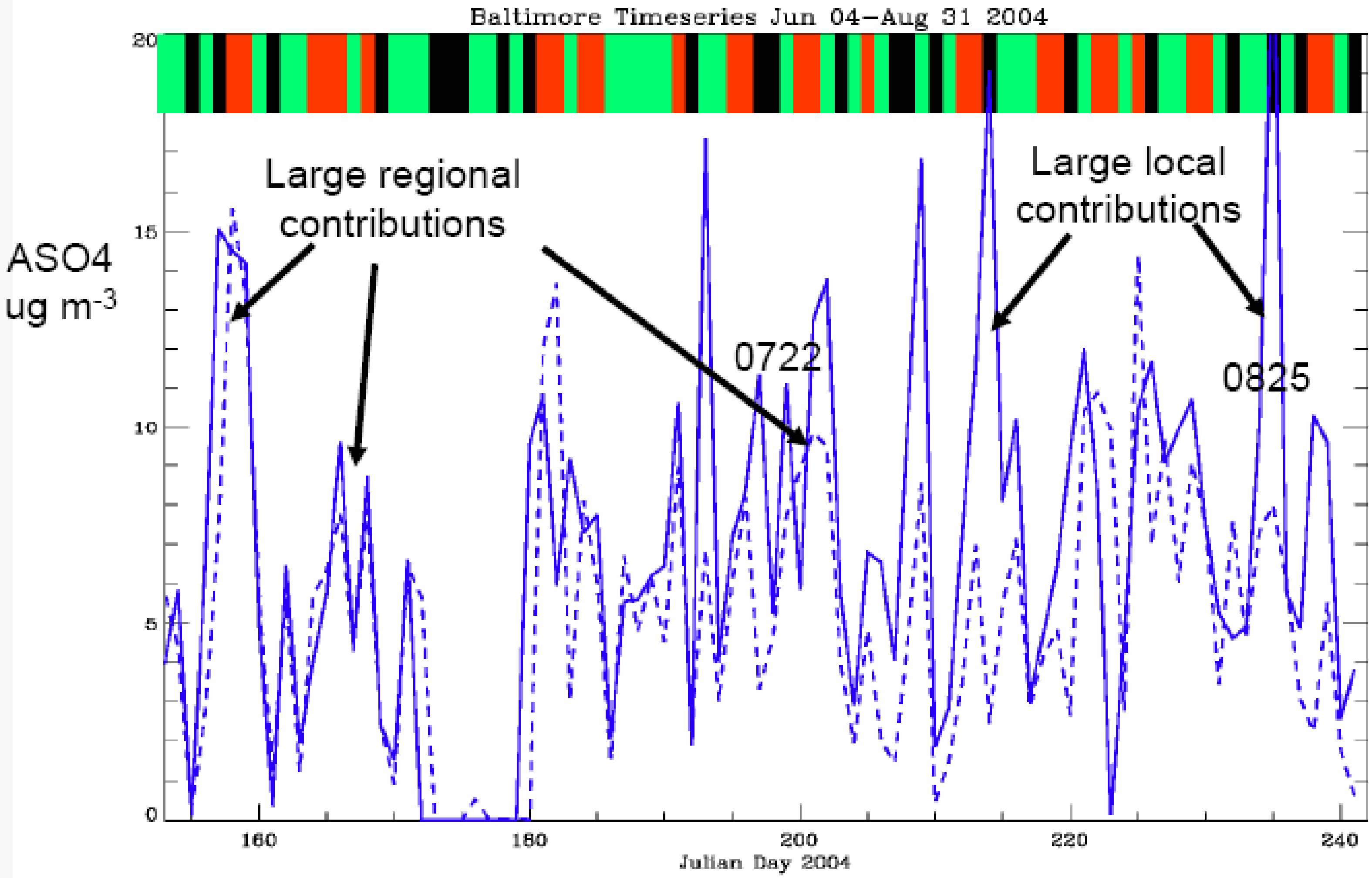




10 July 2004, am

RED: regional SO4 increase
Green: neutral
Black: regional SO4 decrease

Solid: SO4 at Baltimore (CMAQ)
Dashed: SO4 at regional boundary



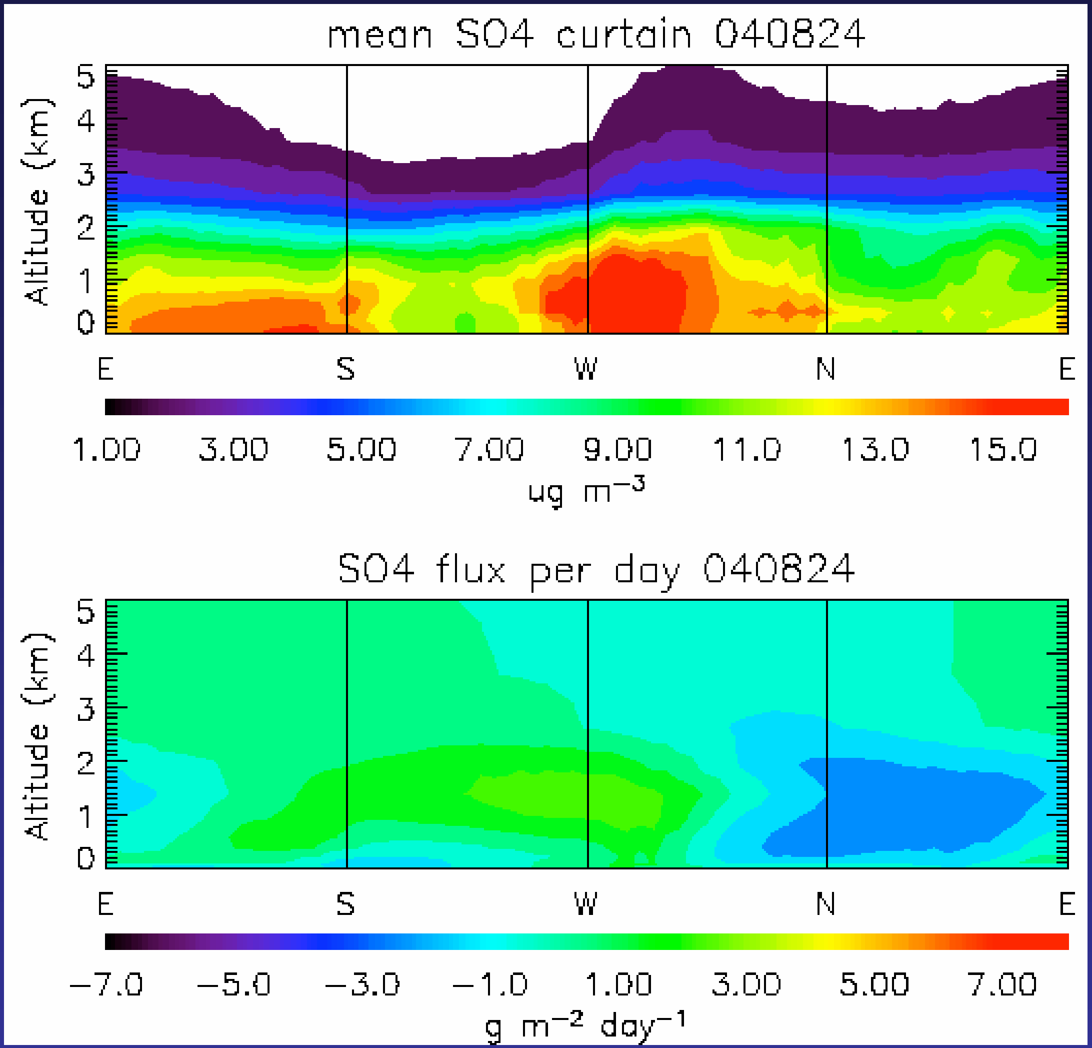
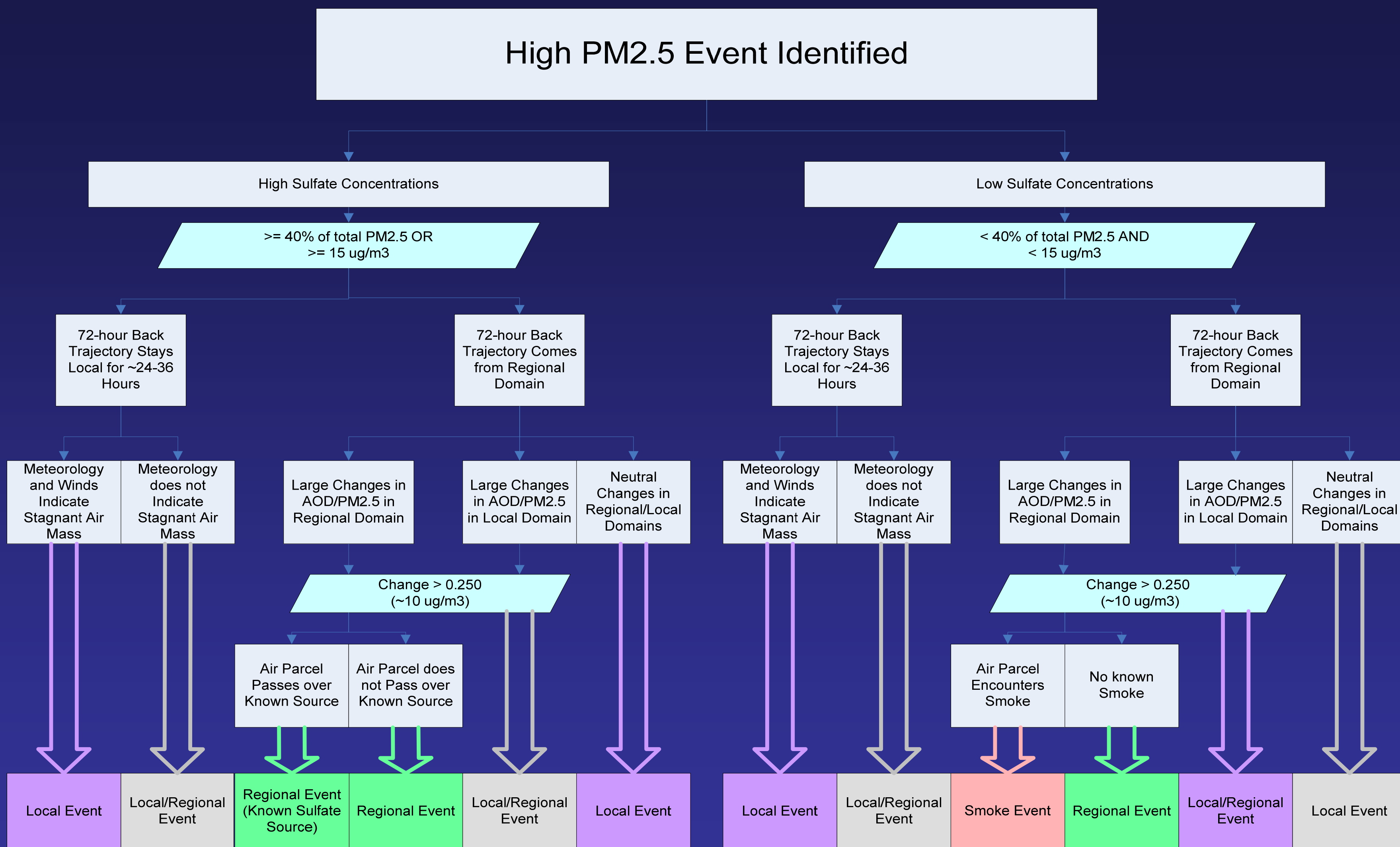


Figure 3.38. Mean sulfate concentration and total daily sulfate flux into (negative) and out of (positive) the local domain boundary for August 24, 2004.


High PM2.5 Event Identified
High Sulfate Concentrations
>= 40% of total PM2.5 OR >= 15 ug/m3
Low Sulfate Concentrations
< 40% of total PM2.5 AND < 15 ug/m3
72-hour Back Trajectory Stays Local for ~24-36 Hours
72-hour Back Trajectory Comes from Regional Domain
72-hour Back Trajectory Stays Local for ~24-36 Hours
72-hour Back Trajectory Comes from Regional Domain
Meteorology and Winds Indicate Stagnant Air Mass
Meteorology does not Indicate Stagnant Air Mass
Large Changes in AOD/PM2.5 in Regional Domain
Large Changes in AOD/PM2.5 in Local Domain
Neutral Changes in Regional/Local Domains
Meteorology and Winds Indicate Stagnant Air Mass
Meteorology does not Indicate Stagnant Air Mass
Large Changes in AOD/PM2.5 in Regional Domain
Large Changes in AOD/PM2.5 in Local Domain
Neutral Changes in Regional/Local Domains
Change > 0.250 (~10 ug/m3)
Change > 0.250 (~10 ug/m3)
Air Parcel Passes over Known Source
Air Parcel does not Pass over Known Source
Air Parcel Encounters Smoke
No known Smoke
Local Event
Local/Regional Event
Regional Event (Known Sulfate Source)
Regional Event
Local/Regional Event
Local Event
Local Event
Local/Regional Event
Smoke Event
Regional Event
Local/Regional Event
Local Event