Research and Monitoring of Atmospheric Mercury in Vermont Forests

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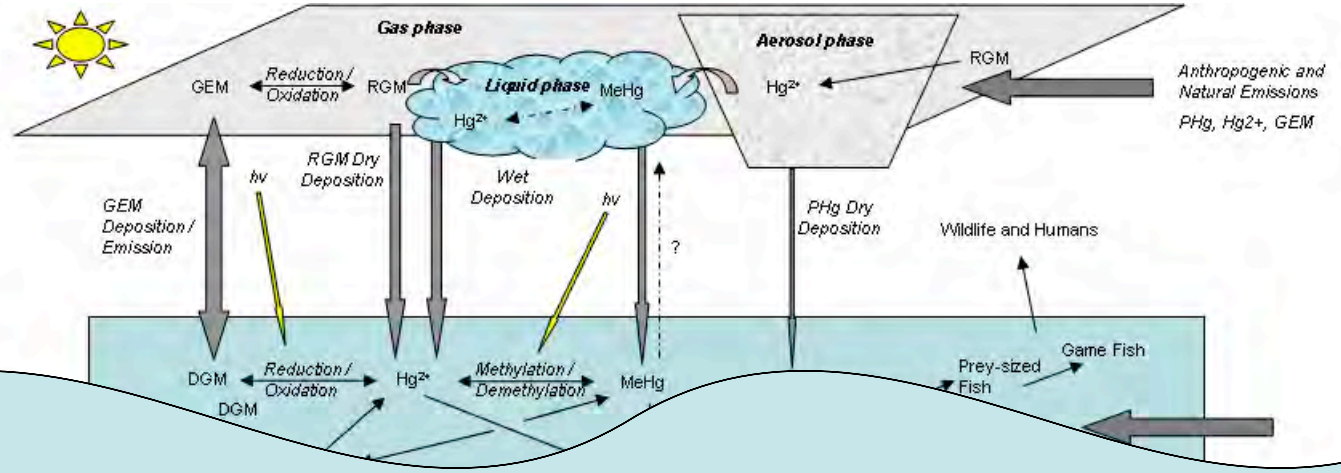
Overview

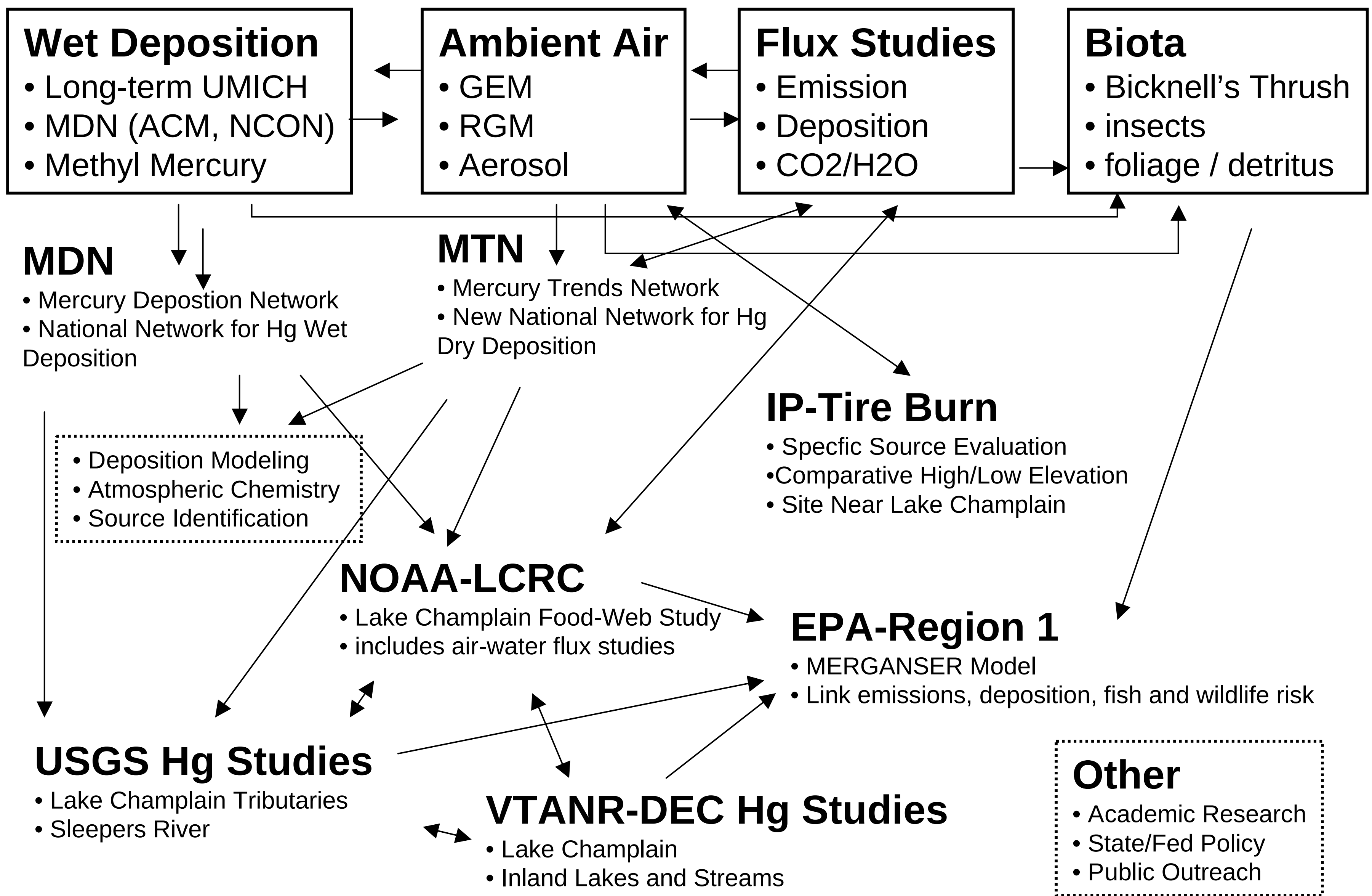
- Scope of VMC Atmospheric Mercury Studies
- State of Funding / Current Activities
- Highlights of Research Findings

Atmospheric Mercury



Water or Land Surface

Scope of VMC Atmospheric Mercury Studies



Scope of VMC Atmospheric Mercury Studies

Wet Deposition
- Long-term UMICH
- MDN (ACM, NCON)
- Methyl Mercury

Ambient Air
- GEM
- RGM
- Aerosol

Flux Studies
- Emission
- Deposition
- CO_2/H_2O

Biota
- Bicknell's Thrush
- insects
- foliage / detritus

Funding Transitions
- NOAA-LCRC (prior UMICH)
- EPA-ORD (prior UMICH / NCON)
- EPA-ORD (prior Methyl Mercury)

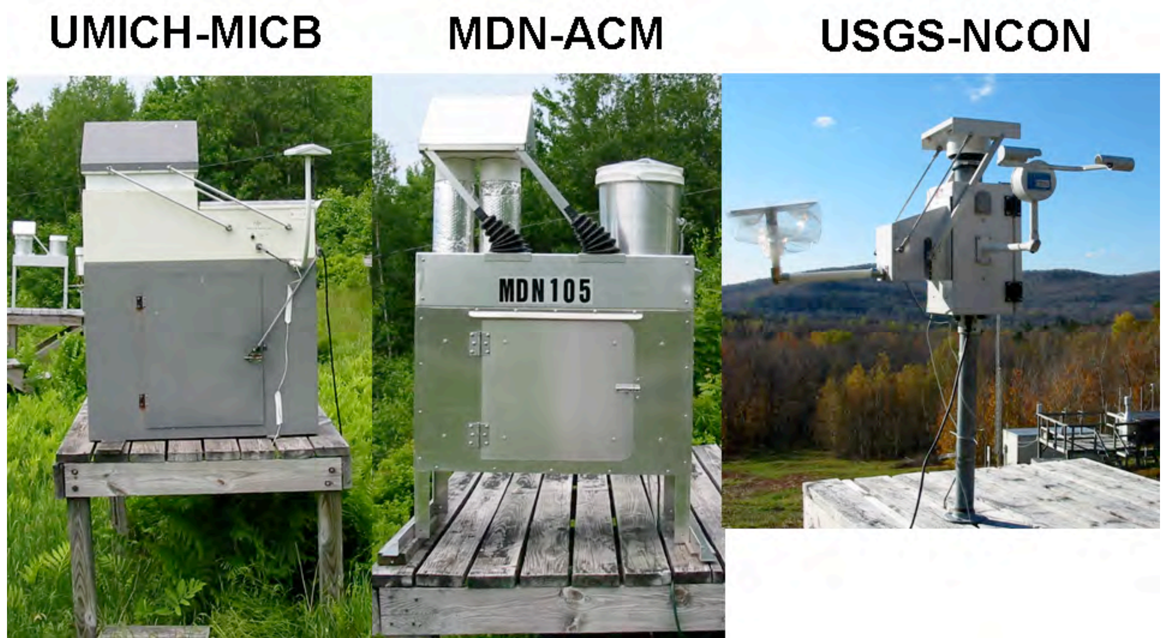
- NOAA-LCRC (MDN Event Mercury)
- NOAA-LCRC (Methyl Mercury)
    - Monthly NOAA LCRC baseline
    - Summer Event NOAA LC Hg Study

- VTANR-AQ (Ambient Air Startup)
- EPA-ORD (Ambient Air through 2007)

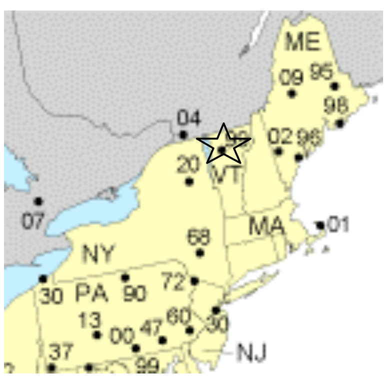
- EPA-OAR (Ambient Air pending future)

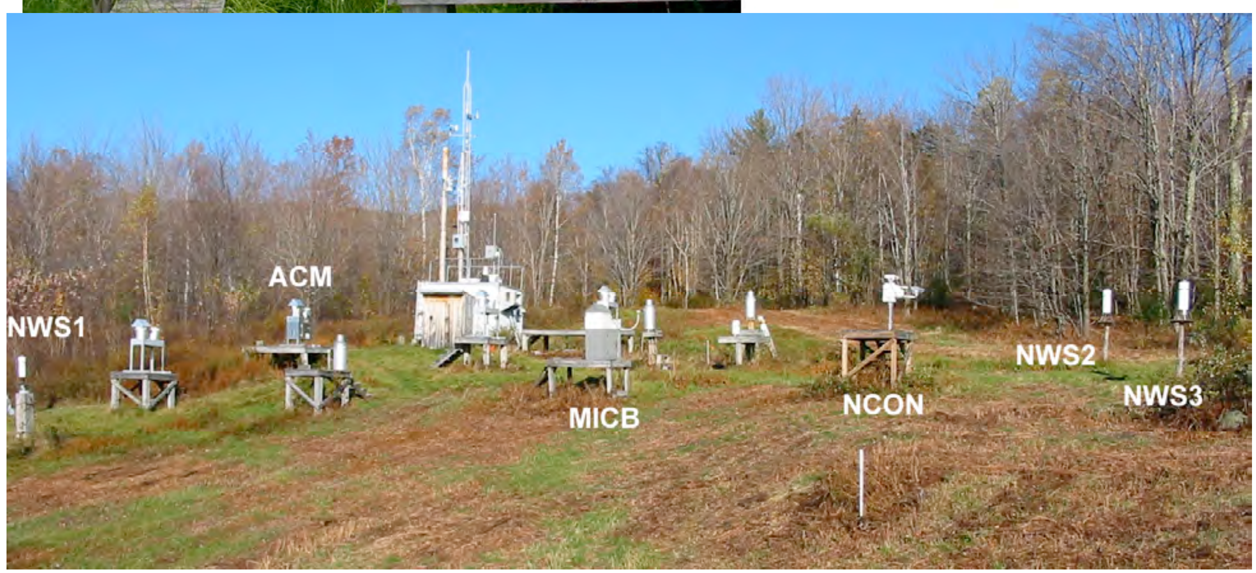
Funding Ended
- EPA-ORD (through 2007)

Integration with MDN



- Join national network
- Integrate long-term Record with MICB collector
- Test / improve network collector for northern sites
- Select appropriate network collector for our site
- MDN “event” site





NCON sampler with unmelted snow in funnel

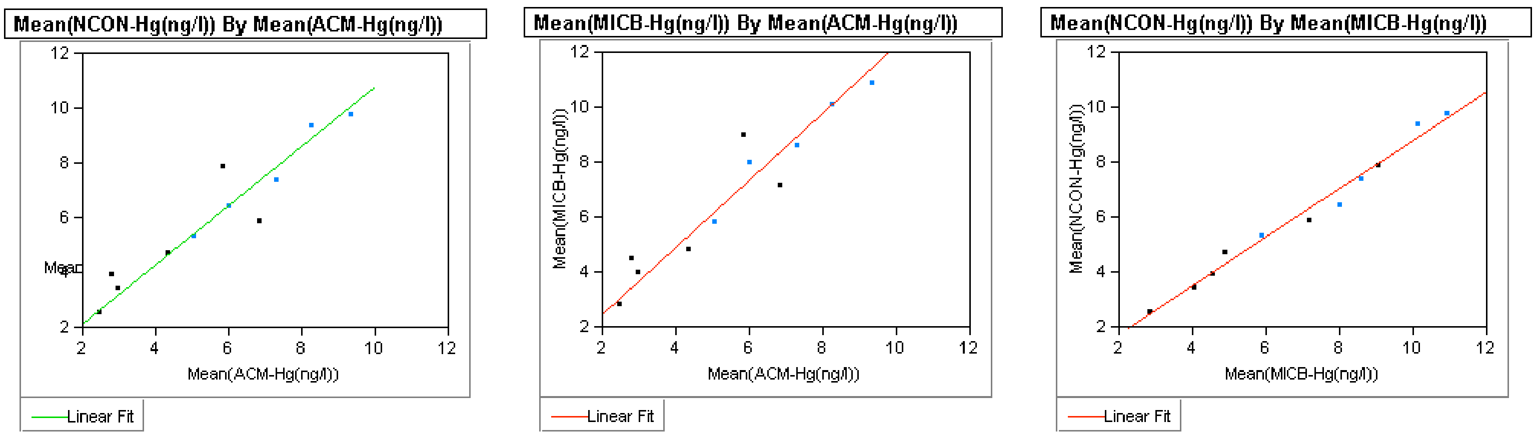
Precipitation Catch Relative to NWS 8-inch Gage

	ACM	NCON	MICB
snow	-48.3%	-66.0%	-46.4%
mix	-10.6%	-7.3%	-0.5%
rain	-1.2%	2.4%	2.7%
all	-5.0%	-2.2%	0.2%

Relative Monthly Collection Efficiency for Mercury

U s ing monthly precipitation-weighted means where the precipitation amount is on an NWS 8-inch gage basis for all collectors, the transfer functions are as follows:

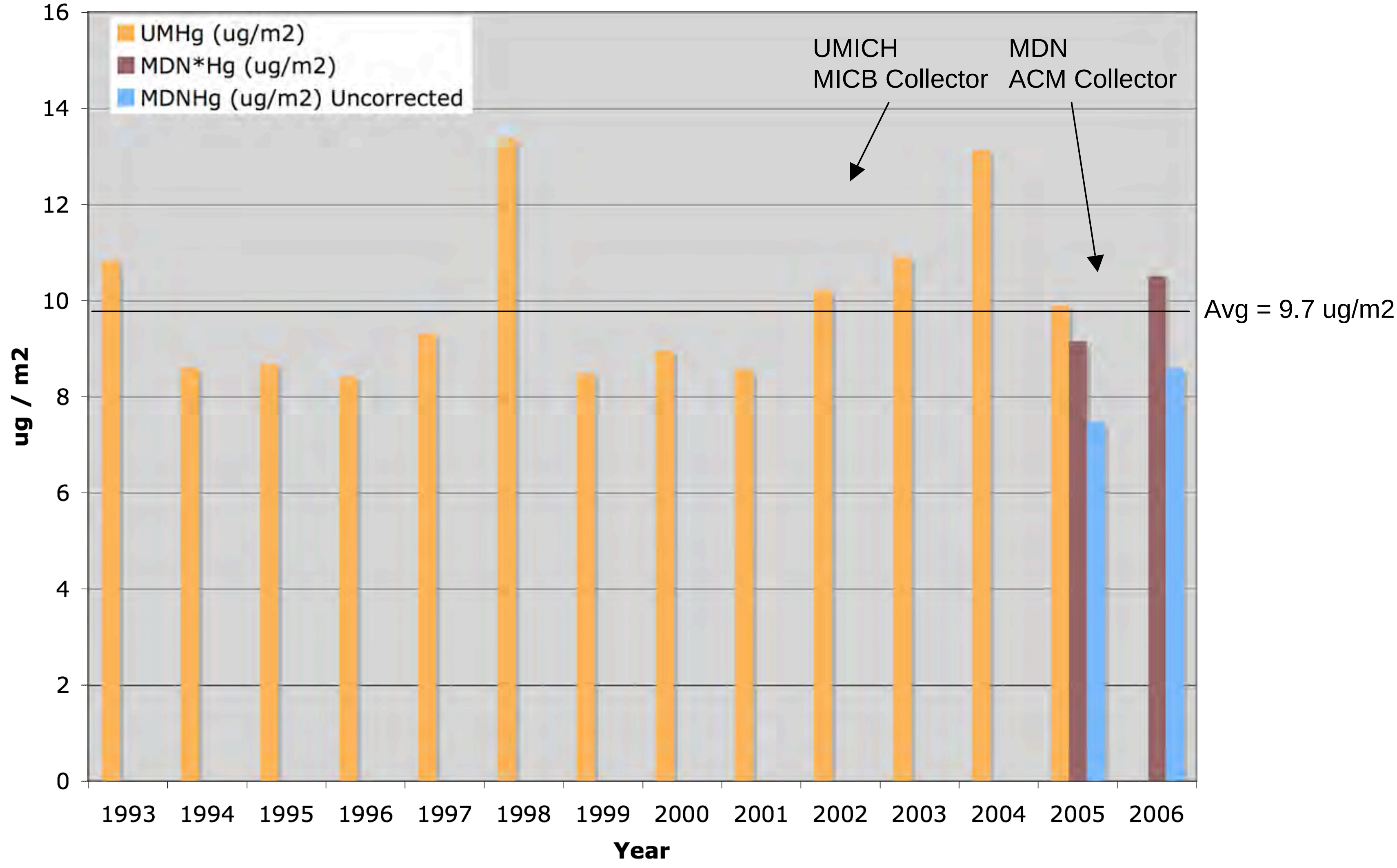
- NCON-basis = 1.0789 * ACM   % variance explained = 90%   (Figure 9a)
- NCON-basis = 0.8813 * MICB   % variance explained = 98%
- MICB-basis = 1.2232 * ACM   % variance explained = 90%   (Figure 9b)
- MICB-basis = 1.1320 * NCON   % variance explained = 98%   (Figure 9c)



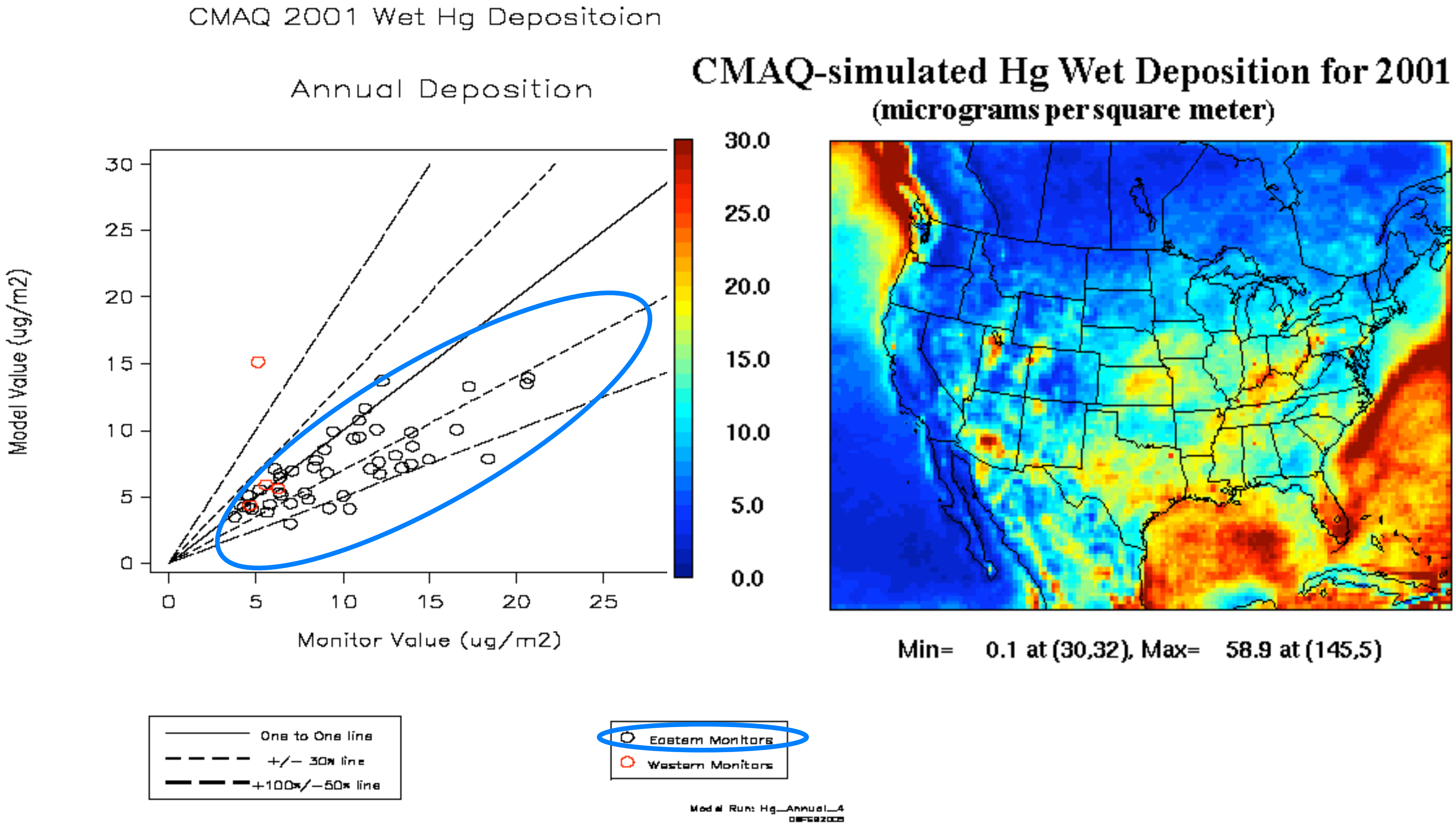
a) **b)** **c)**

Figure 9. Transfer functions for NWS precipitation-weighted mean monthly mercury concentration.

Annual Wet Deposition of Mercury at Underhill, Vermont



CMAQ applied to CAMR (TSD for CAMR, EPA, 2005)



CMAQ under predicts MDN by 27% (esp. east and northeast).

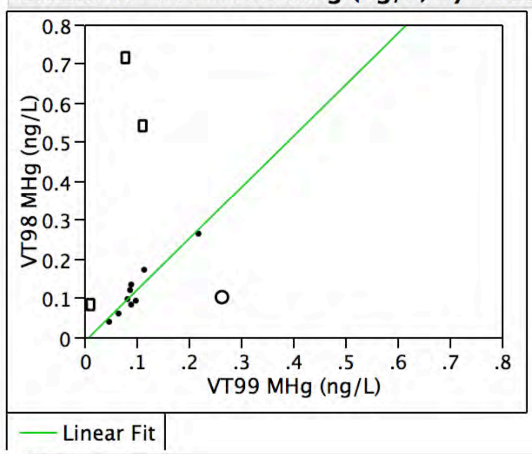
Our collector comparison at Underhill demonstrated that MDN under predicts wet deposition by at least 8% and possibly as much as 30%.

Wet Deposition May be a Significant Source of Methyl-Mercury to both Terrestrial and Aquatic Ecosystems

Methyl-Hg in wet deposition = 133 – 312 ng/m^2/y   (1.3% – 3.1% THg)

10/28/07 10:29 AM
Data Table=Underhill_methylHg-deposition

Bivariate Fit of VT98 MHg (ng/L) By VT99 MHg (ng/L)



Linear Fit

VT98 MHg (ng/L) = -0.013131 + 1.3142259 VT99 MHg (ng/L)

Summary of Fit

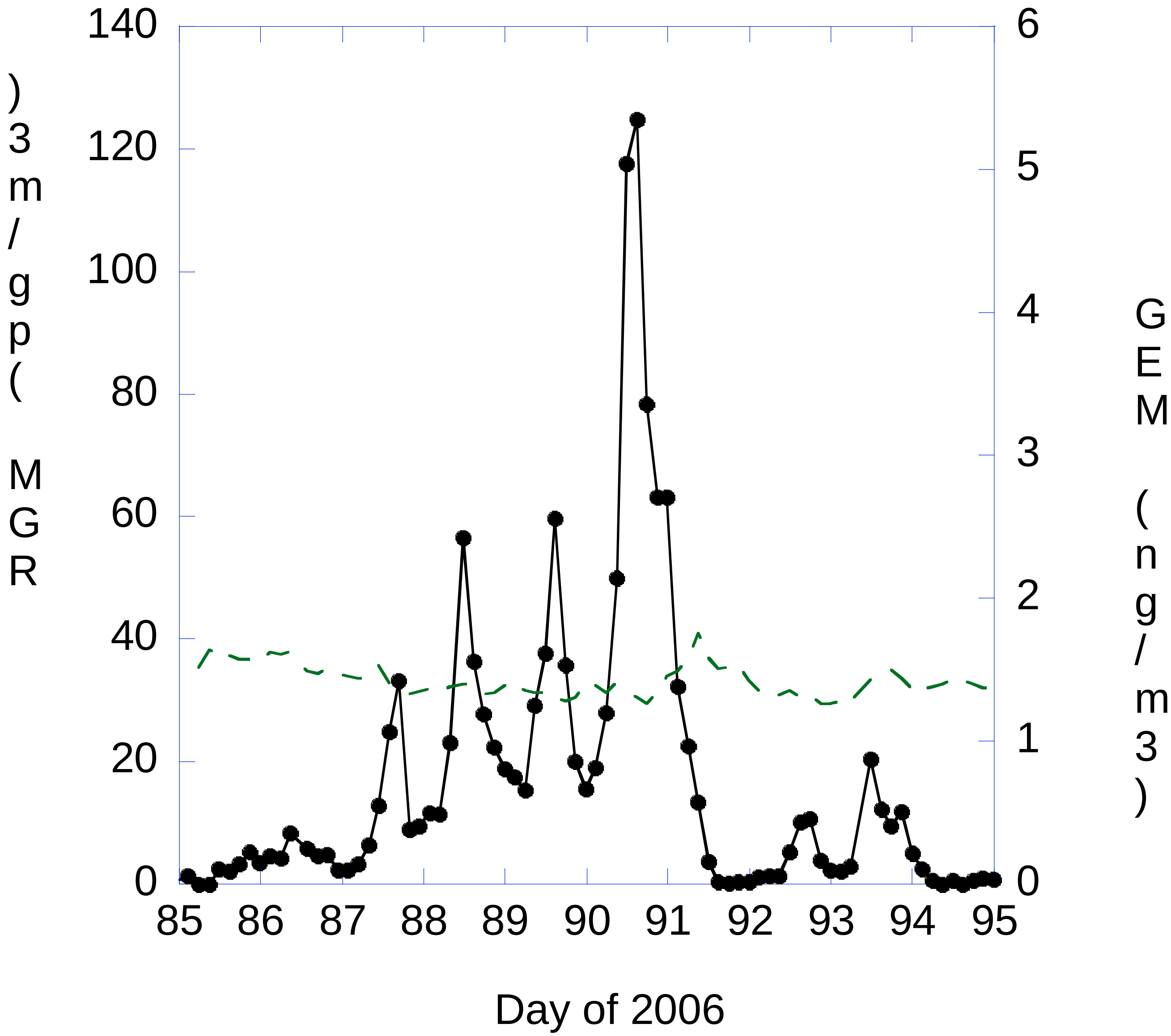
RSquare	0.896135
RSquare Adj	0.881298
Root Mean Square Error	0.023236
Mean of Response	0.118
Observations (or Sum Wgts)	9

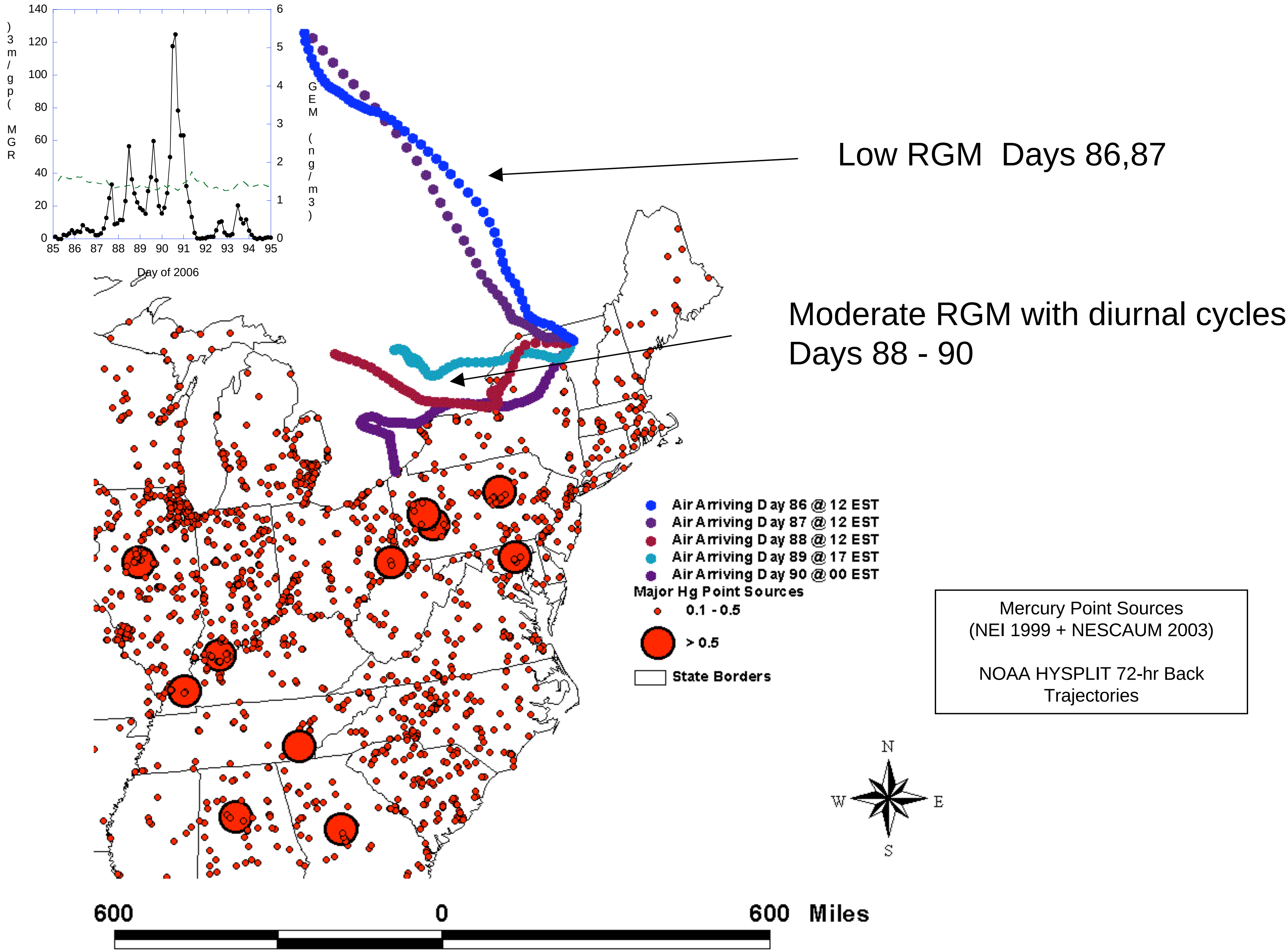
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.03260857	0.032609	60.3954
Error	7	0.00377943	0.000540	**Prob > F**
C. Total	8	0.03638800		0.0001*

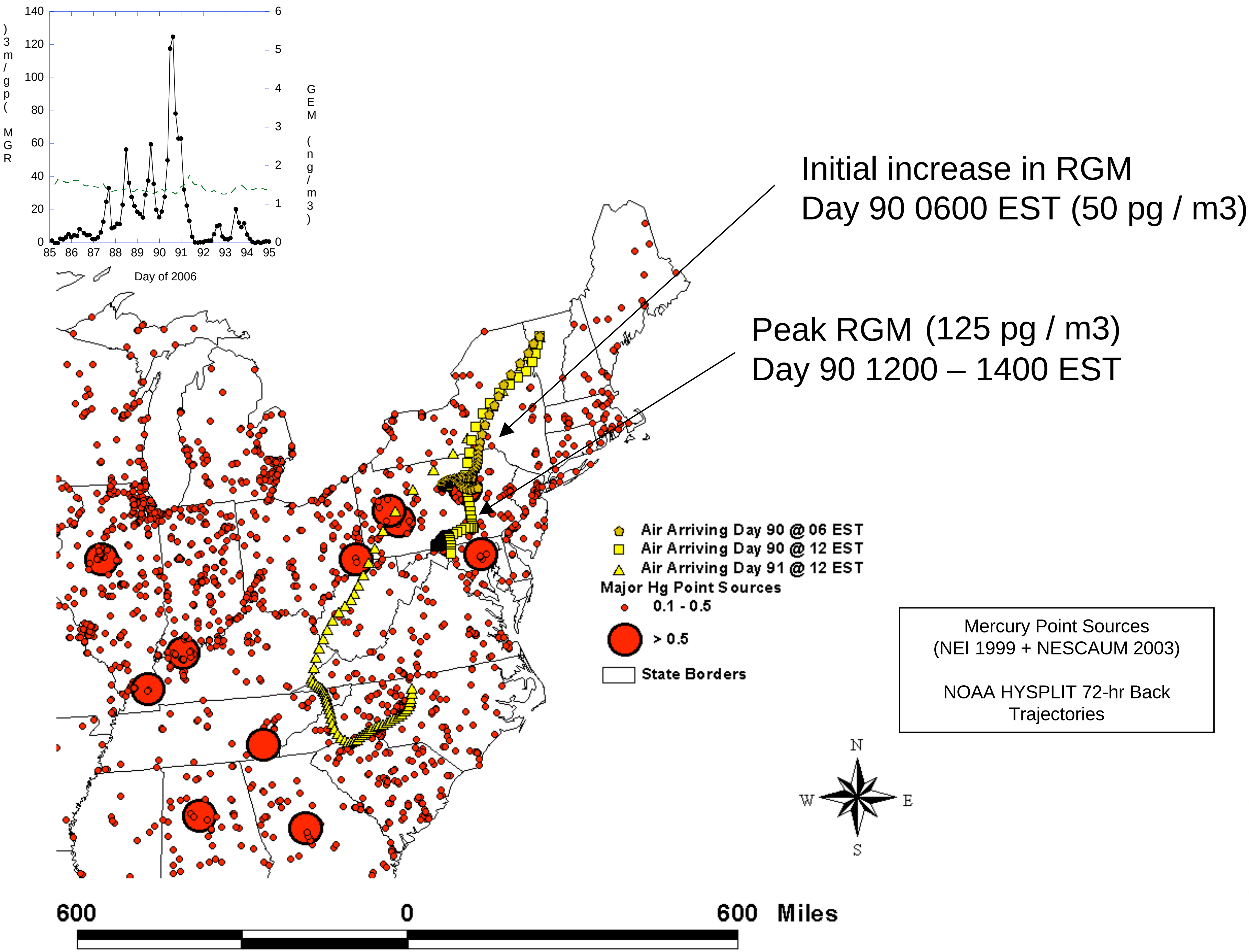
Parameter Estimates

Major Spring RGM Transport Event

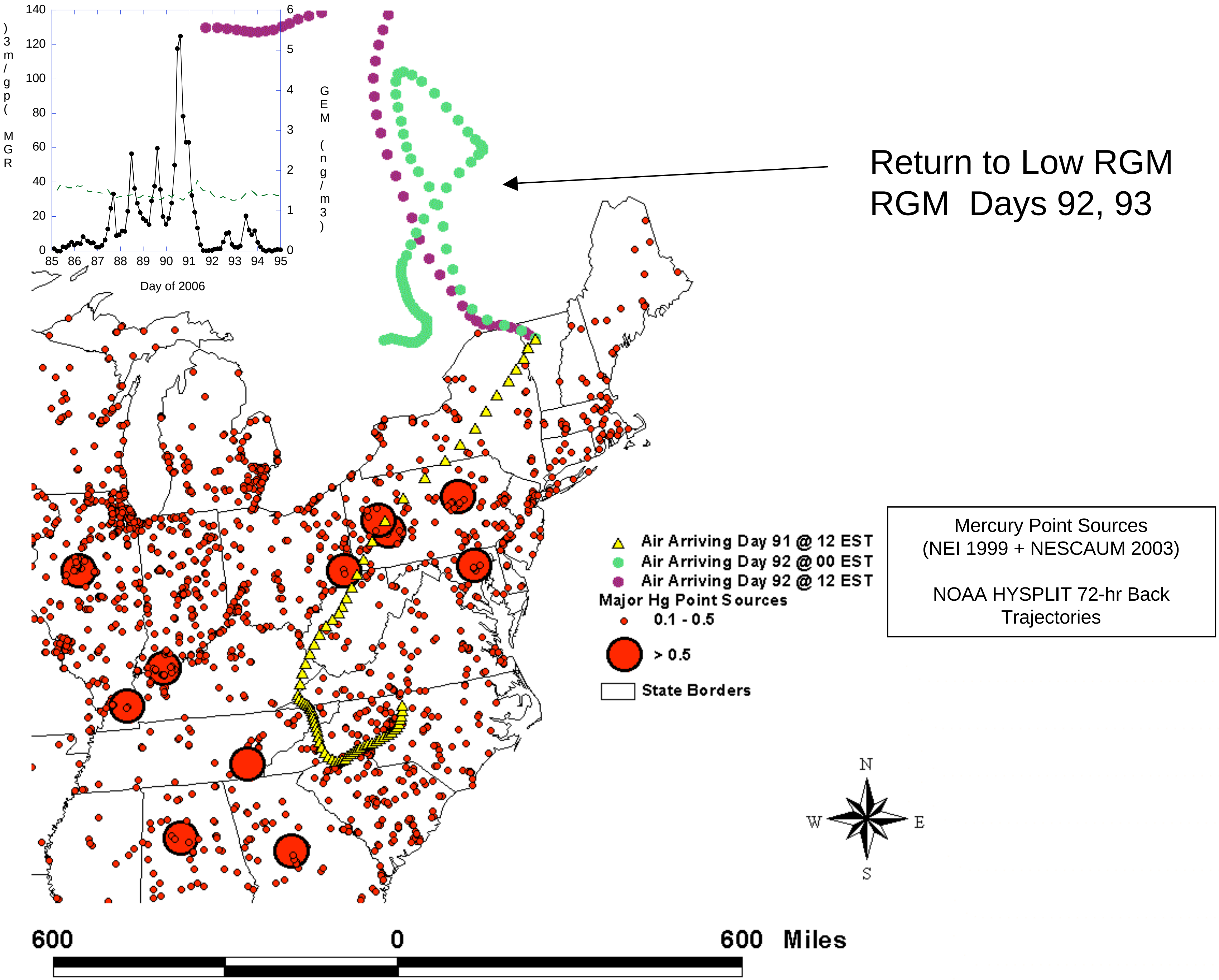




RGM (pg/m3)
GEM (ng/m3)
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
85
86
87
88
89
90
91
92
93
94
95
Day of 2006
Low RGM Days 86,87
Moderate RGM with diurnal cycles
Days 88 - 90
Air Arriving Day 86 @ 12 EST
Air Arriving Day 87 @ 12 EST
Air Arriving Day 88 @ 12 EST
Air Arriving Day 89 @ 17 EST
Air Arriving Day 90 @ 00 EST
Major Hg Point Sources
0.1 - 0.5
> 0.5
State Borders
Mercury Point Sources
(NEI 1999 + NESCAUM 2003)
NOAA HYSPLIT 72-hr Back
Trajectories
N
W
E
S
600
0
600
Miles

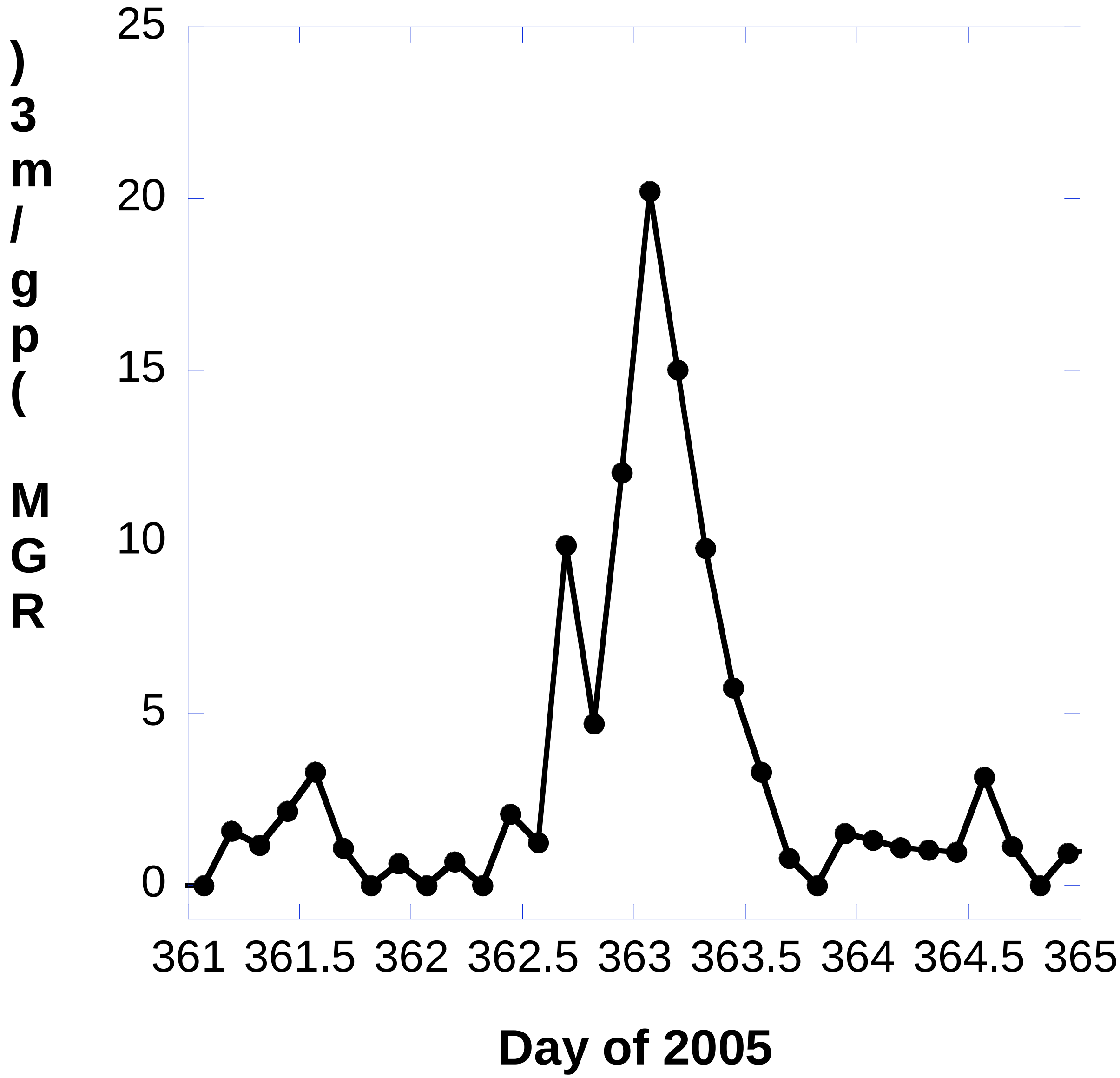


RGM (pg/m3)
GEM (ng/m3)
140
120
100
80
60
40
20
0
6
5
4
3
2
1
0
85 86 87 88 89 90 91 92 93 94 95
Day of 2006
Initial increase in RGM
Day 90 0600 EST (50 pg / m3)
Peak RGM (125 pg / m3)
Day 90 1200 – 1400 EST
Air Arriving Day 90 @ 06 EST
Air Arriving Day 90 @ 12 EST
Air Arriving Day 91 @ 12 EST
Major Hg Point Sources
0.1 - 0.5
> 0.5
State Borders
Mercury Point Sources
(NEI 1999 + NESCAUM 2003)
NOAA HYSPLIT 72-hr Back
Trajectories
N
W
E
S
600
0
600 Miles



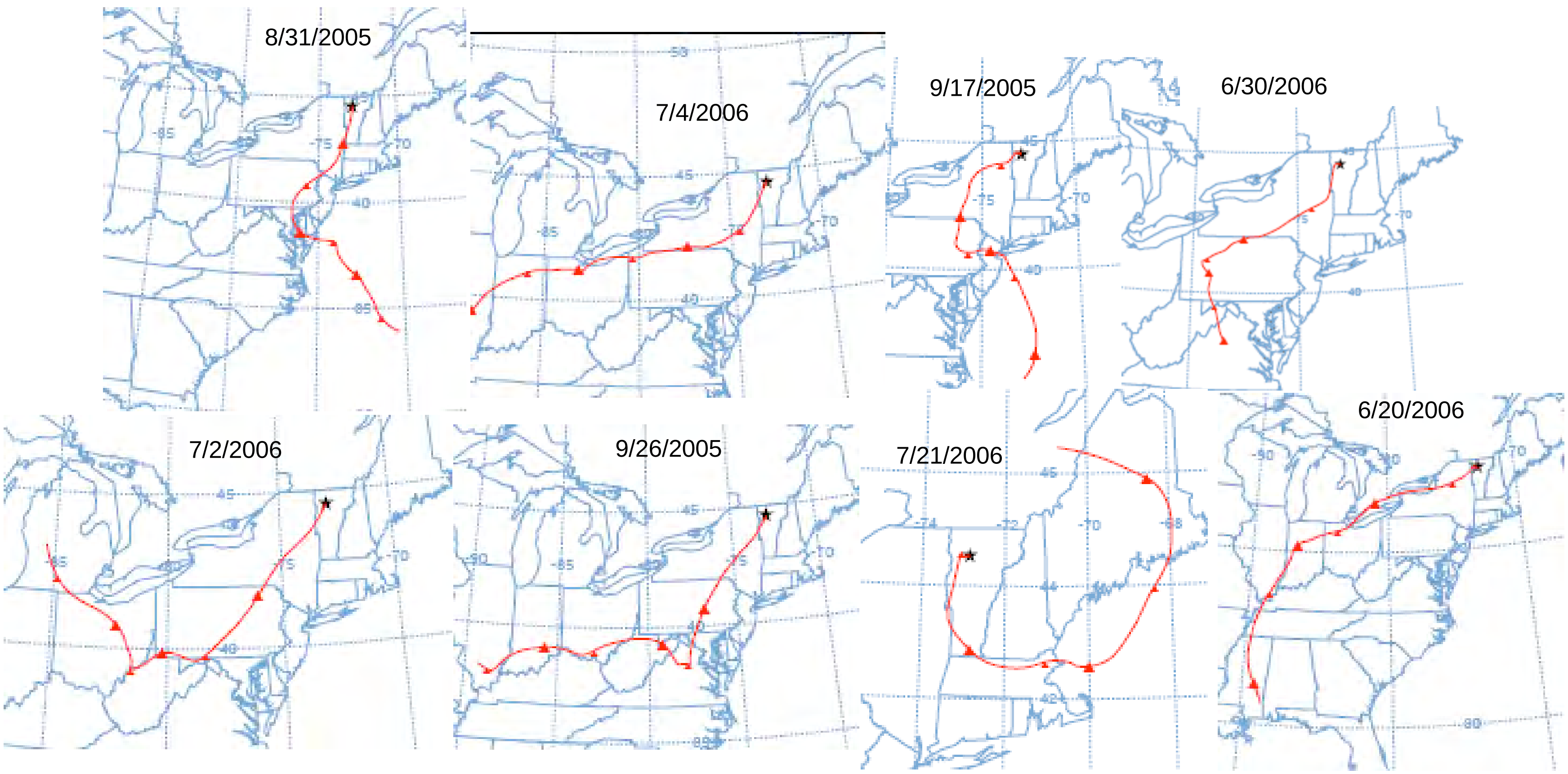
RGM (pg/m3)
GEM (ng/m3)
Day of 2006
Return to Low RGM
RGM Days 92, 93
Air Arriving Day 91 @ 12 EST
Air Arriving Day 92 @ 00 EST
Air Arriving Day 92 @ 12 EST
Major Hg Point Sources
0.1 - 0.5
> 0.5
State Borders
Mercury Point Sources
(NEI 1999 + NESCAUM 2003)
NOAA HYSPLIT 72-hr Back
Trajectories
N
W
E
S
600
0
600 Miles

RGM Transport Events Occur in All Seasons

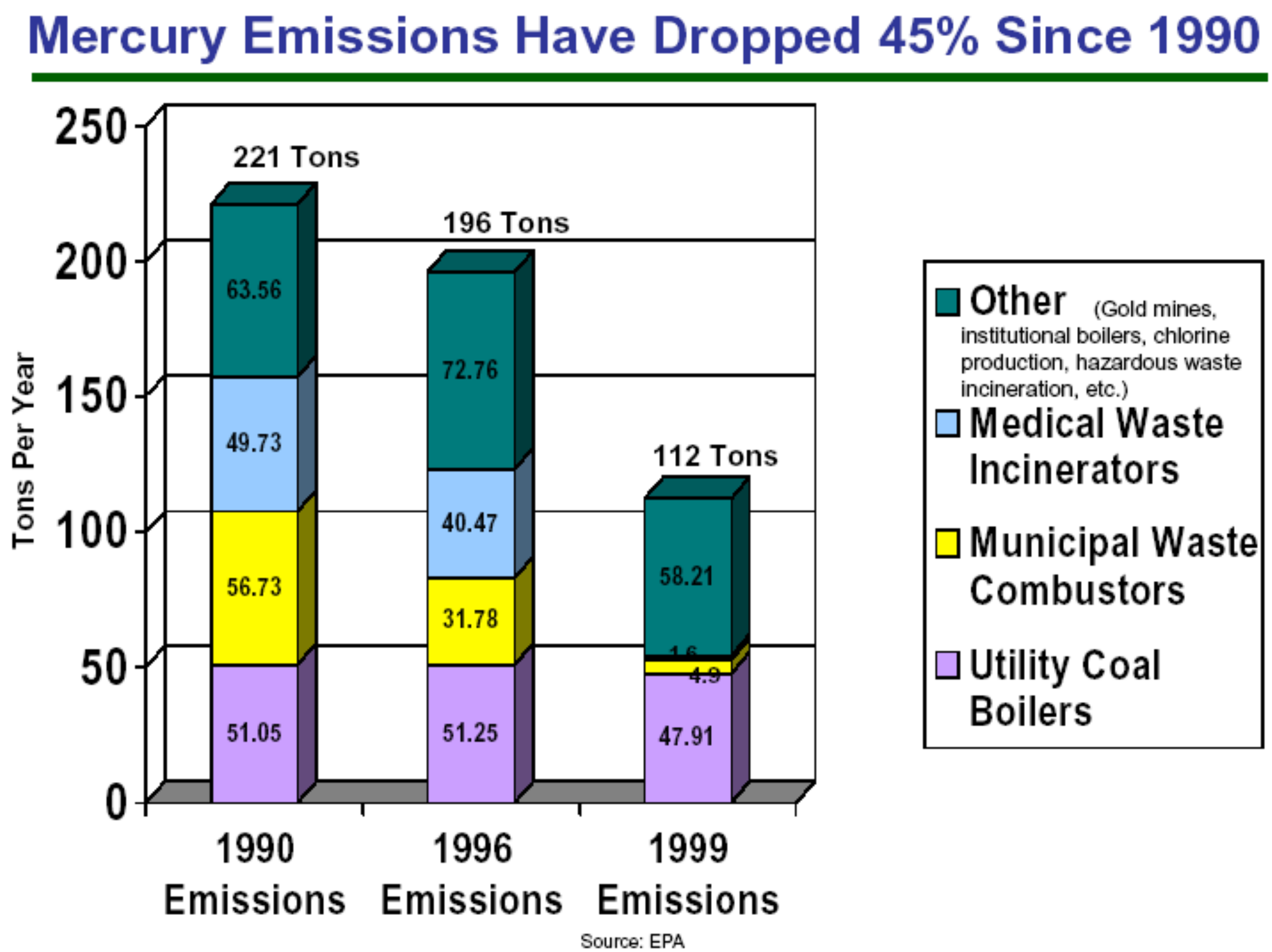


The same source regions are associated with elevated wet Hg deposition events

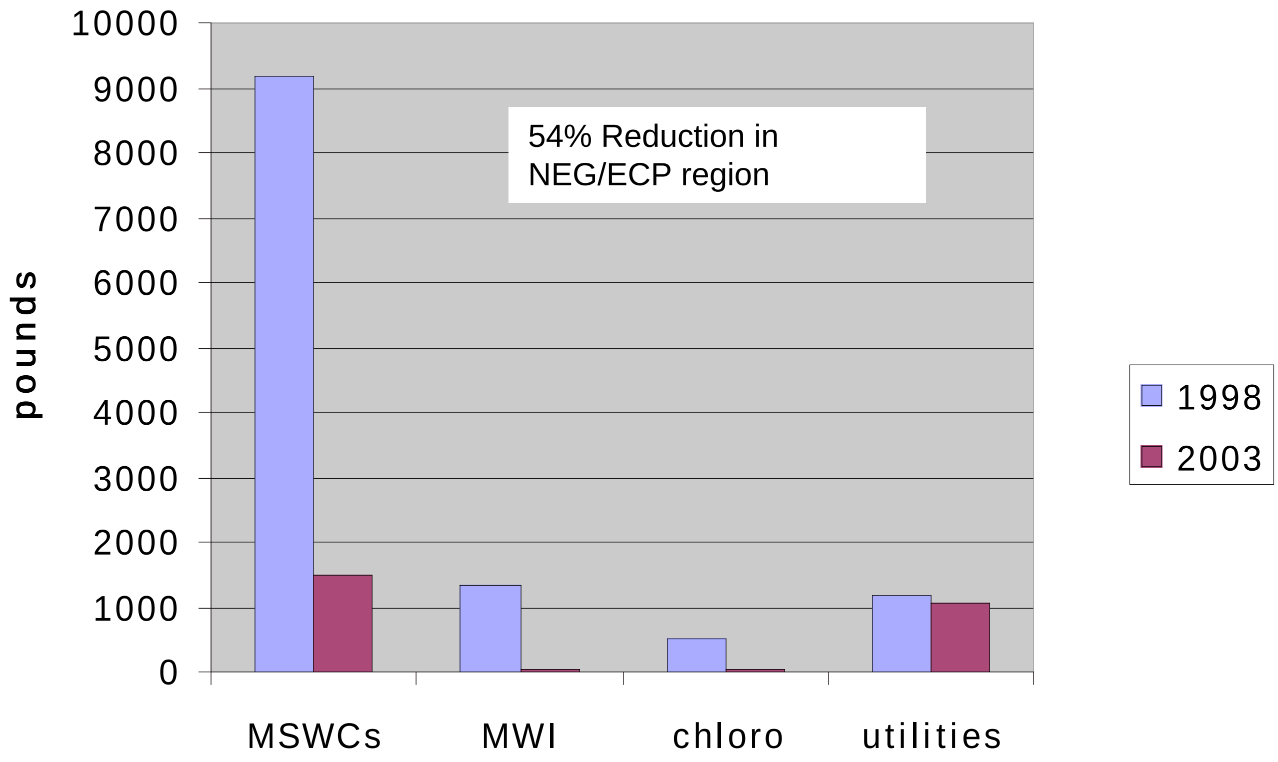
For the year ending 7/31/2006 the 9 highest deposition events (top 10%) were responsible for 35% of the annual wet deposition. Air arriving at Underhill during precipitation transited the major EGU source regions except for one event. The 7th ranked deposition event involved air transiting a high emission region in northeast MA and southeast NH.



Large US National emissions reductions from MWIs and MWCs, with litte change in EGU emissions

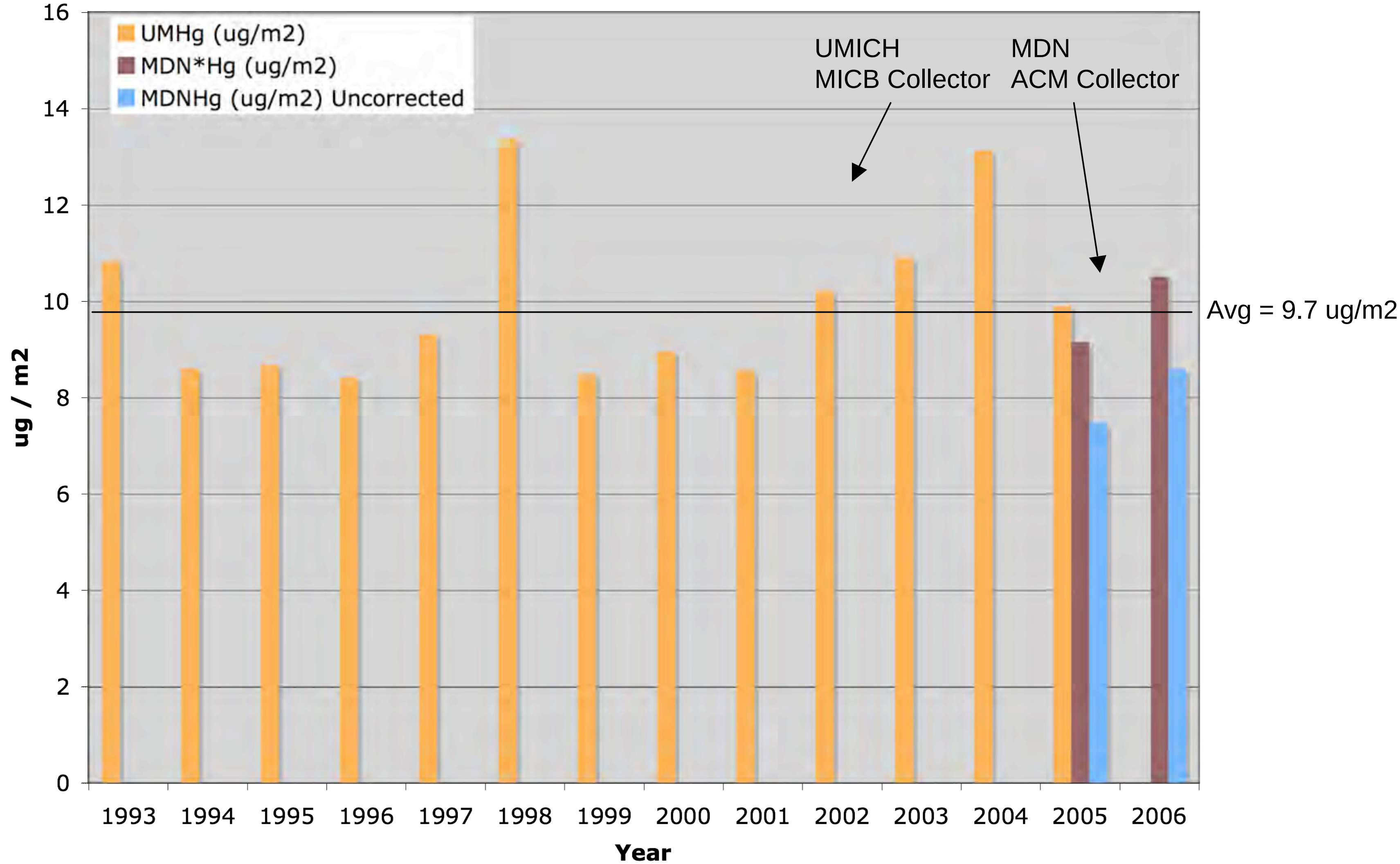


MWC and MWI emissions reductions have been even more substantial in the Northeast, also with little change in EGU emissions

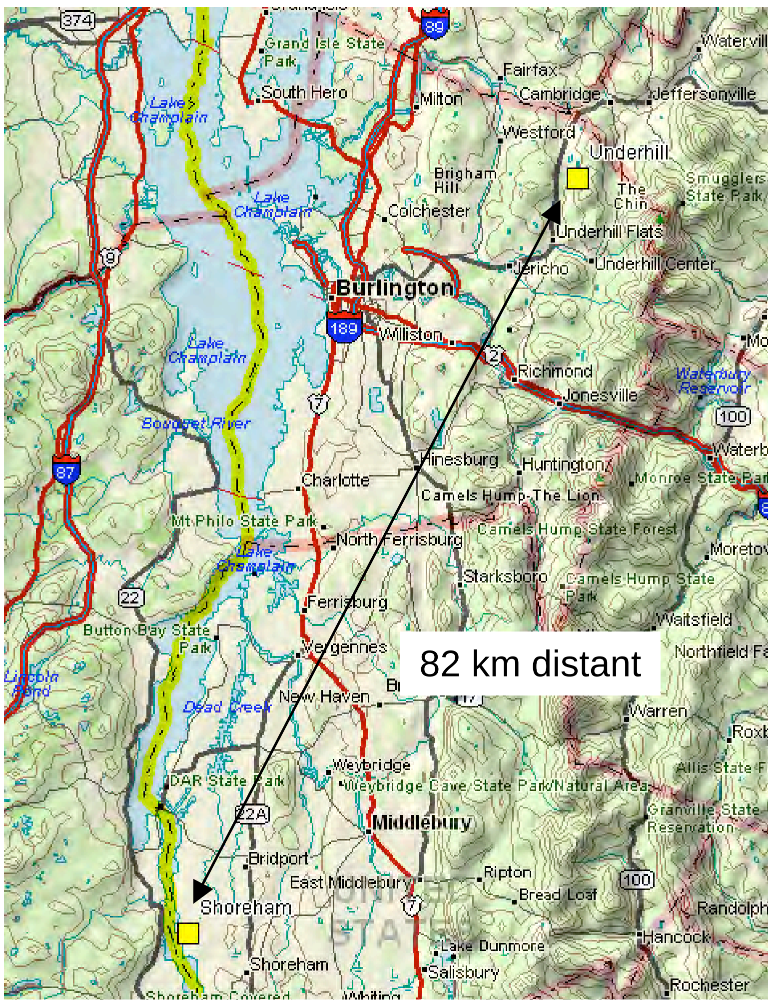


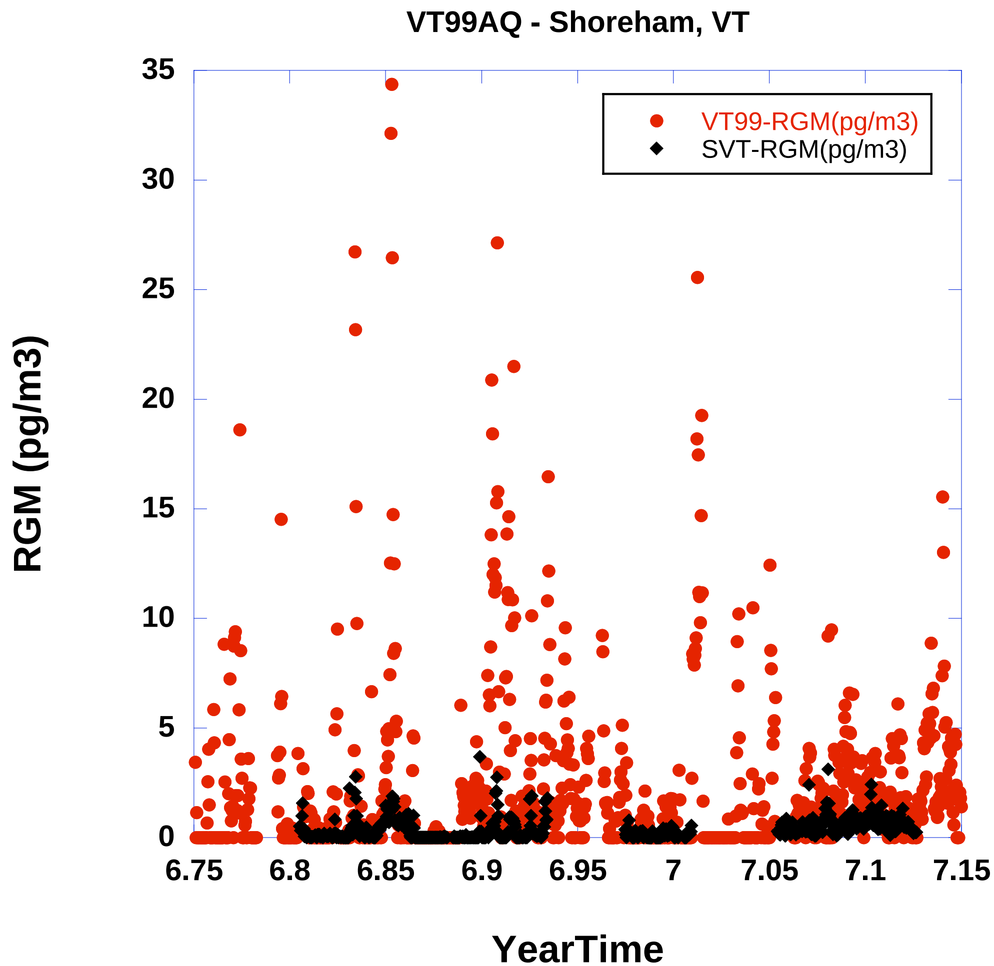
From C. Mark Smith, MADP – NESCAUM 2004 Mercury Conference, Portland ME

Annual Wet Deposition of Mercury at Underhill, Vermont



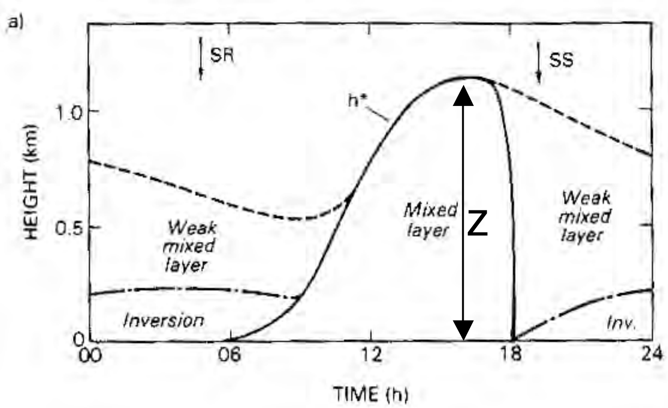
Mid- and High-elevation Forests May Experience Greater RGM Exposure Than Low-elevations

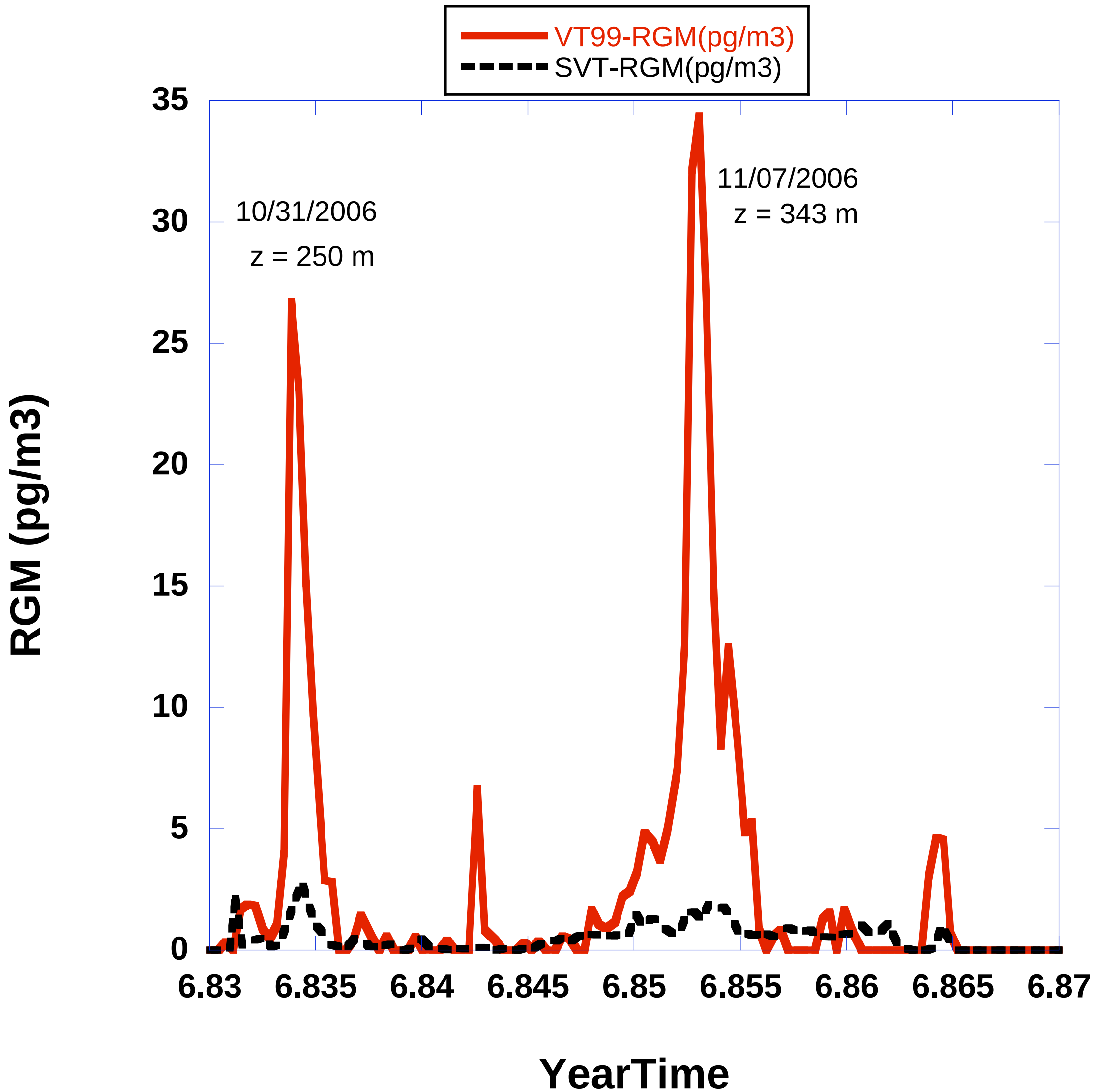




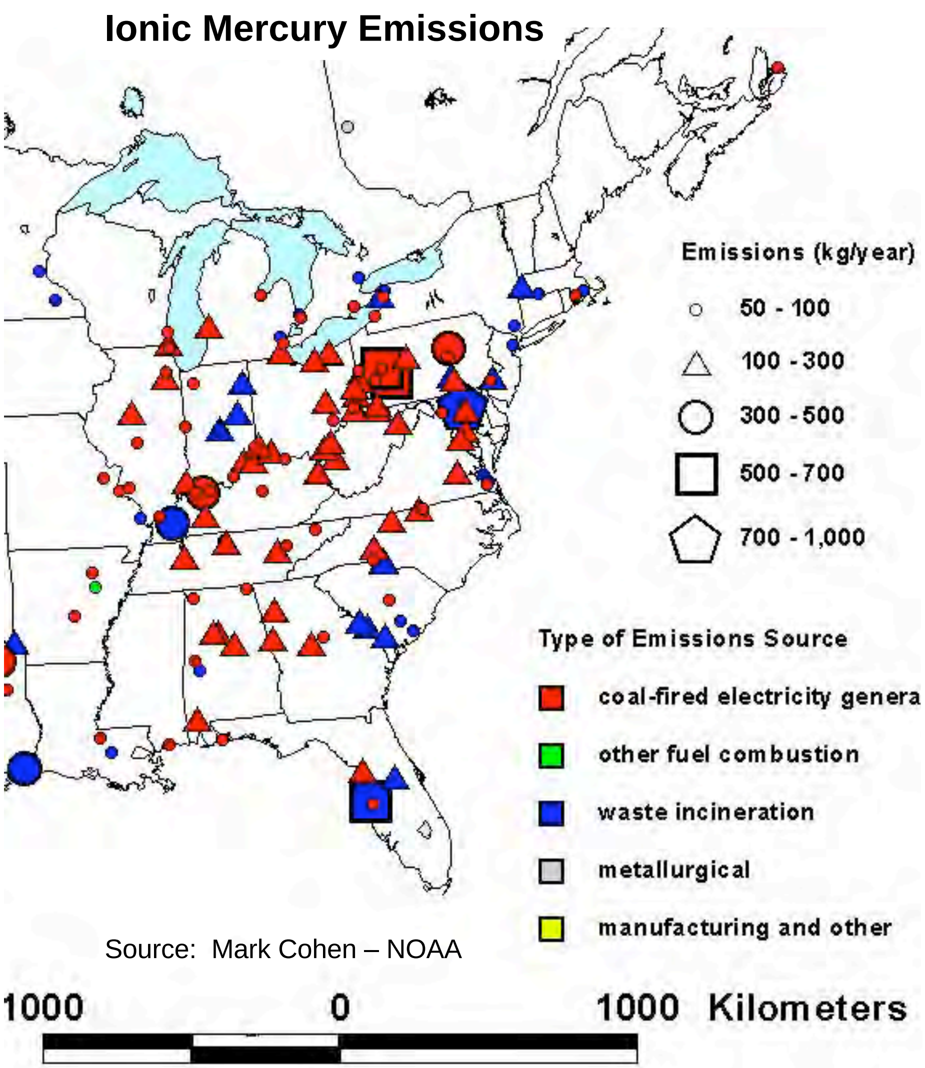
During Winter
Shoreham, VT (20 meters) is a surface layer measurement
Underhill, VT (400 meters) is frequently above the mixed layer

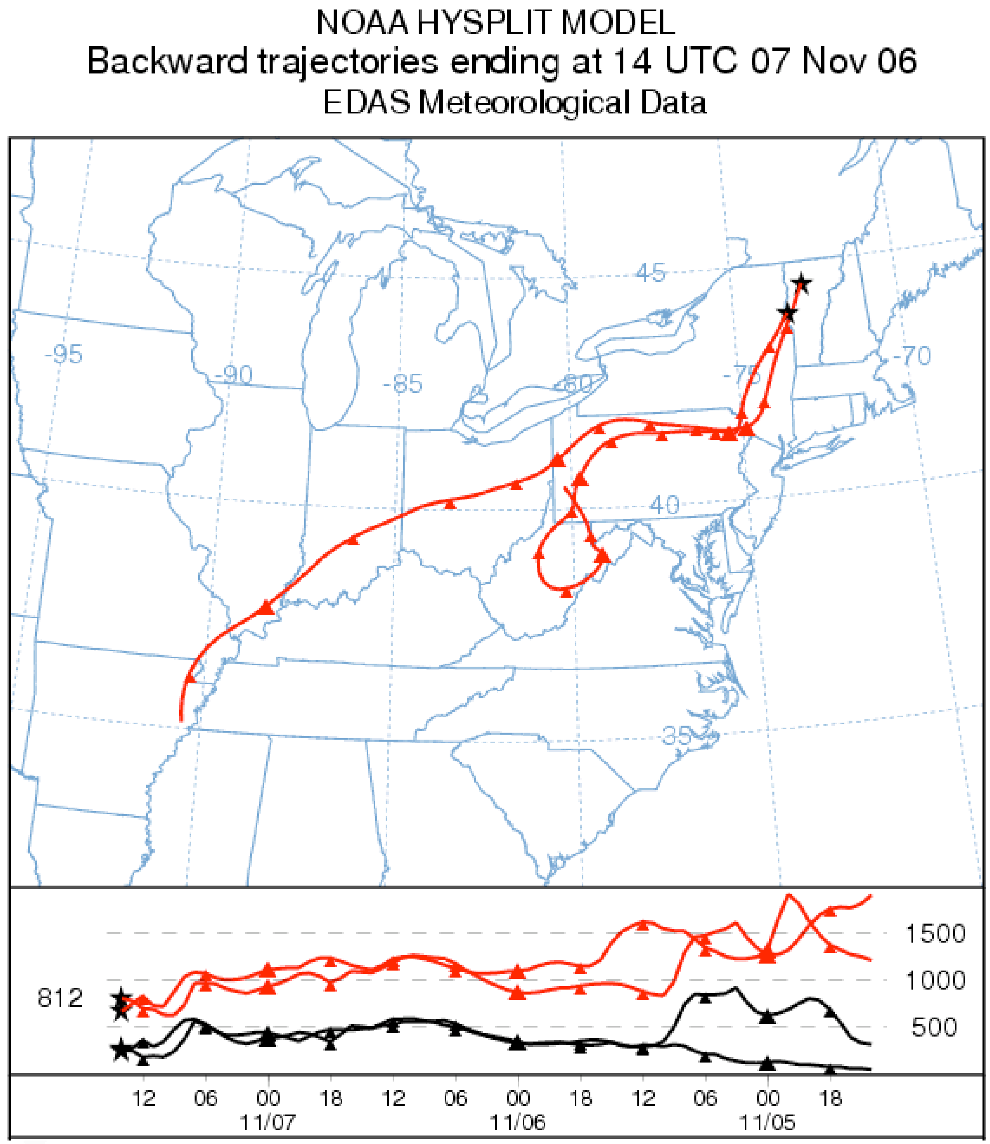
From Oke, 1987
Boundary Layer Climates





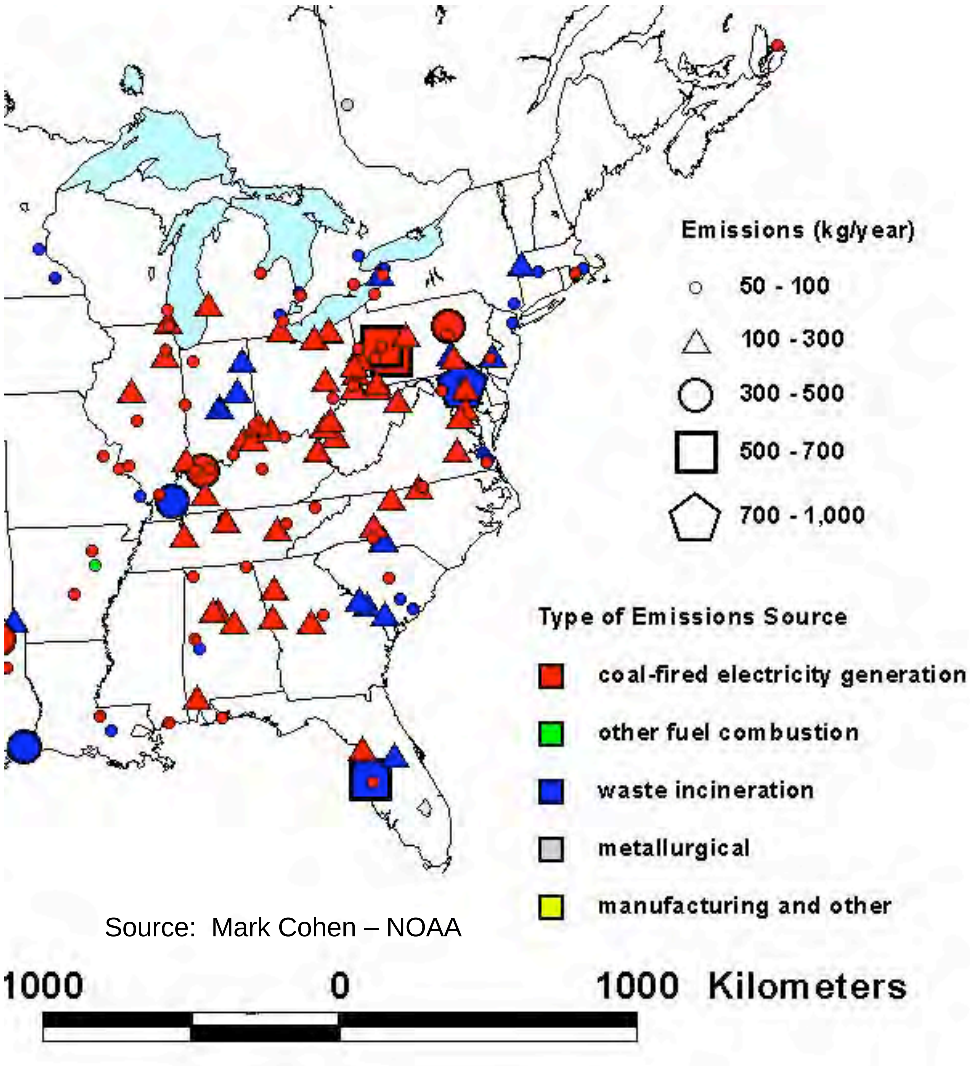
2006-11-07 Trajectories for air arriving at 500 meters agl



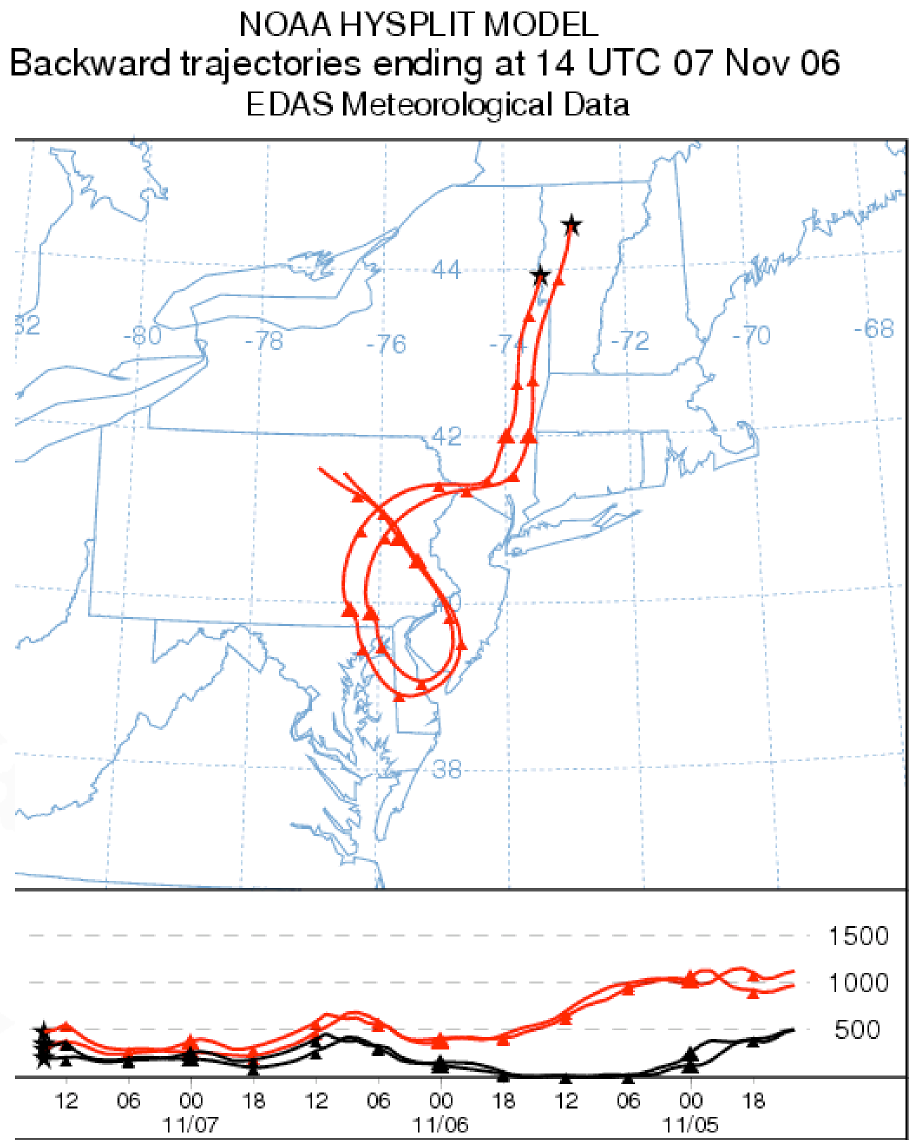


2006-11-07 Trajectories for air arriving at 150 meters agl

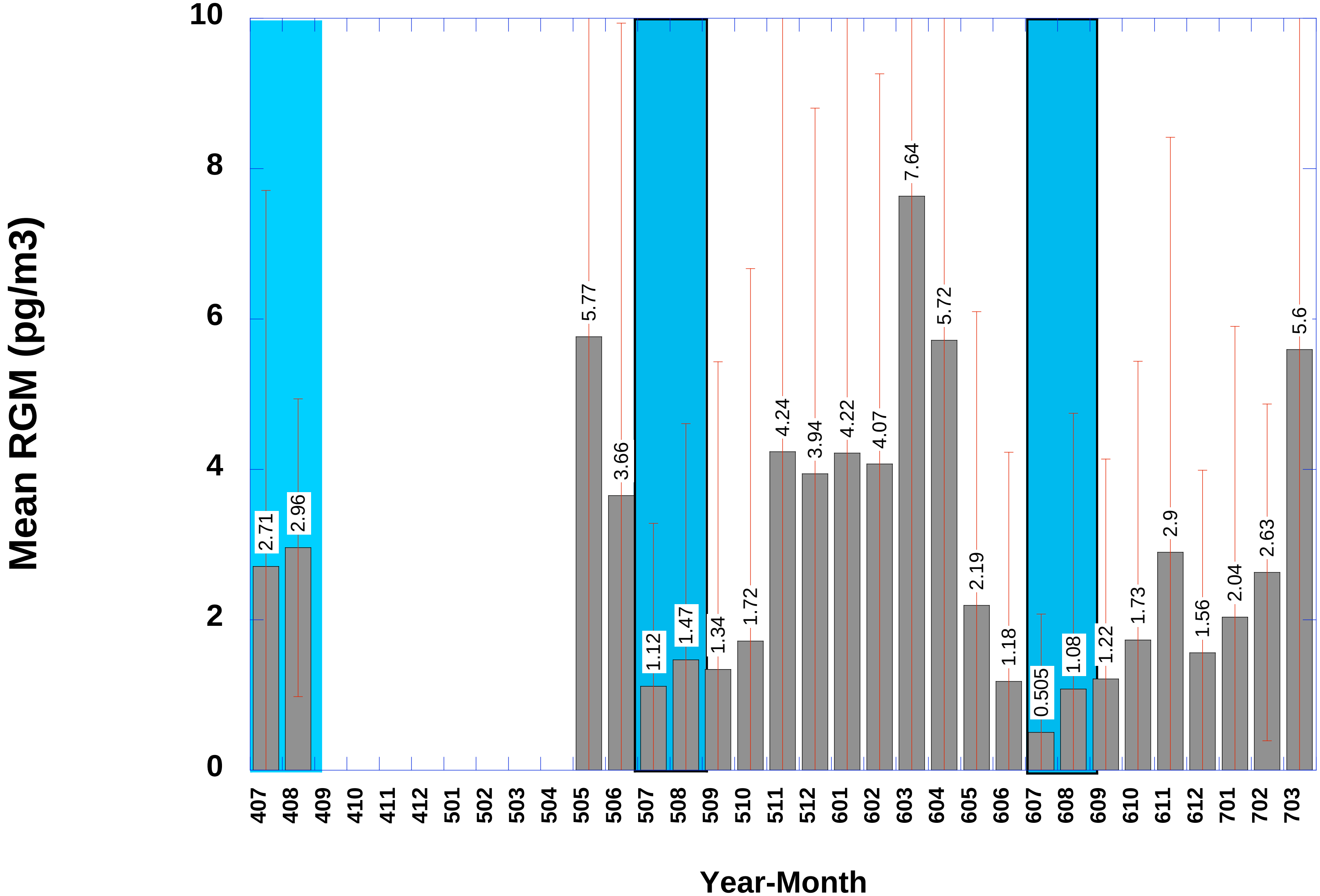
Ionic Mercury Emissions



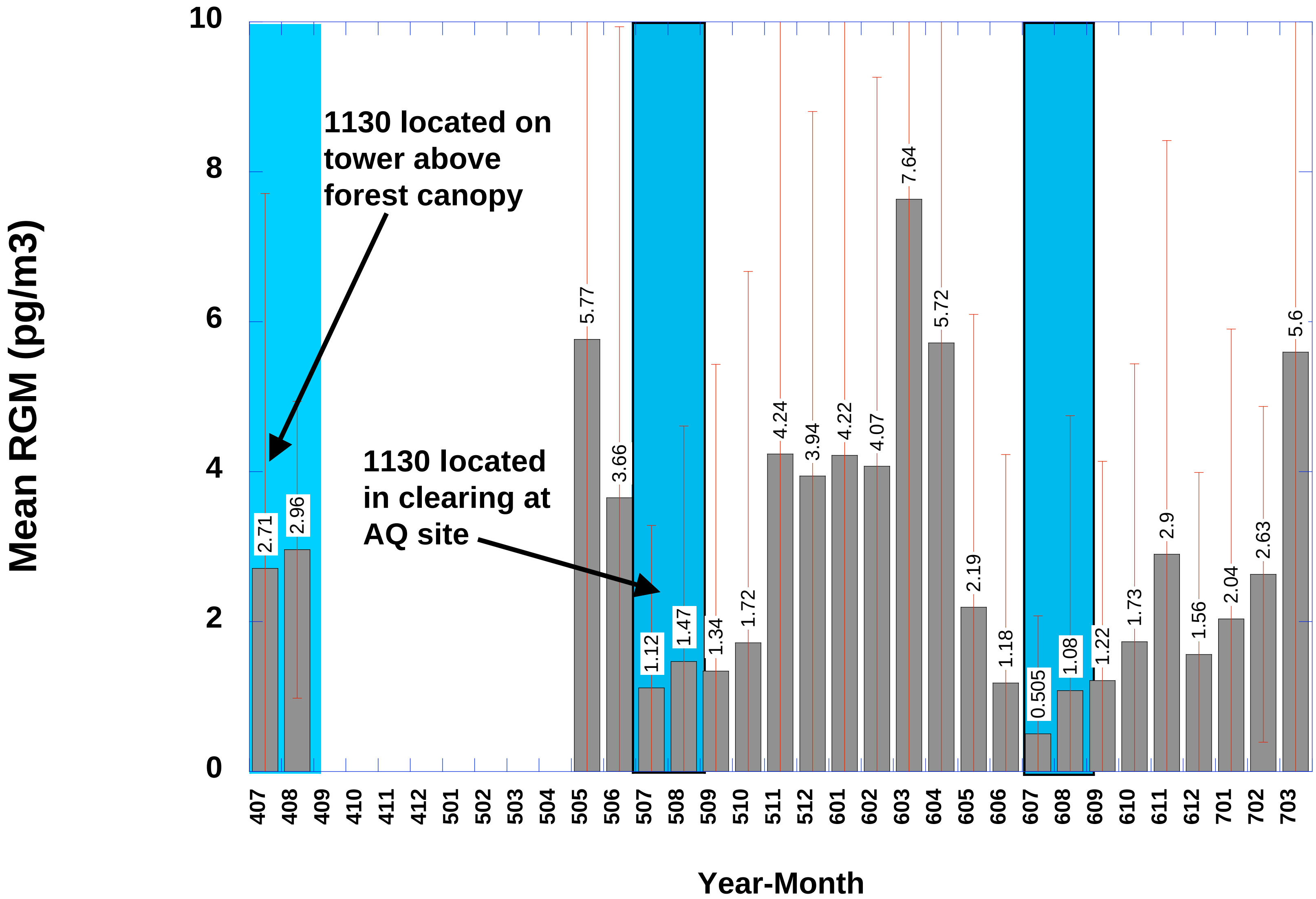
Source: Mark Cohen – NOAA



Seasonal variation in mixed layer depth may explain some of the seasonal variation in RGM concentrations at Underhill, VT



Seasonal variation in forest canopy leaf area may also explain some of the seasonal variation in RGM concentrations at Underhill, VT



Summary

- We are completing a successful integration into MDN
  - No evidence yet of declines in Hg wet deposition
  - Wet MeHg deposition may be a significant source for ecosystems

- We have developed and operated an ambient mercury speciation program that serves as a flagship site for the MTN
  - ambient air and precipitation Hg observations from Underhill help establish the need to control Hg emission sources to our south and west
  - Mid- and high-elevations have greater RGM exposure than low elevations

- Both Wet and Dry observation programs provide critical data for:
  - estimating mercury loading to terrestrial and aquatic ecosystems
  - multiple projects that depend on deposition information
  - evaluation of air pollution models