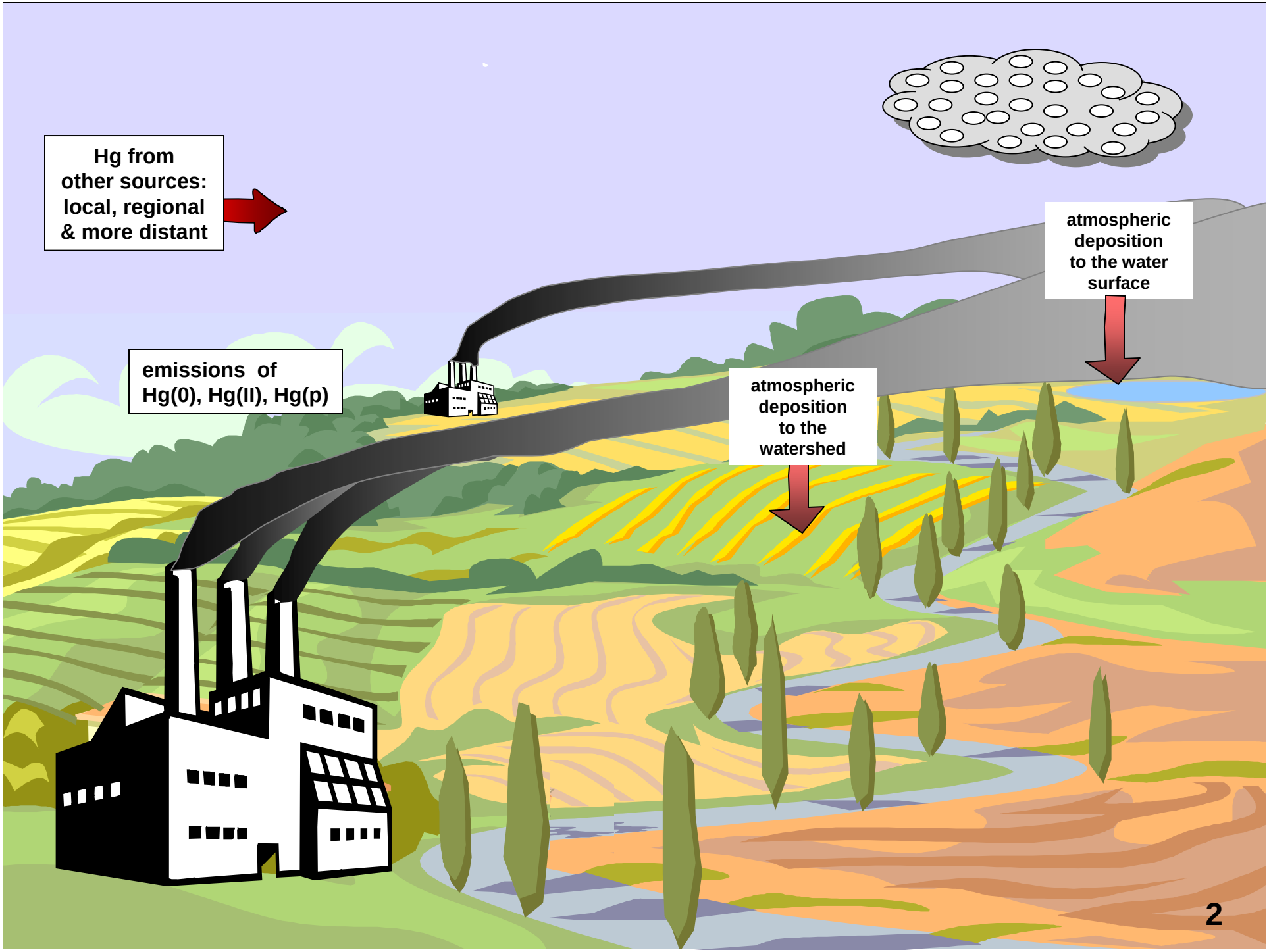
# Simulating the Atmospheric Fate and Transport of Mercury using the NOAA HYSPLIT Model

**Dr. Mark Cohen**
**NOAA Air Resources Laboratory**
**1315 East West Highway,**
**R/ARL, Room 3316**
**Silver Spring, Maryland, 20910, USA**
***mark.cohen@noaa.gov***
***http://www.arl.noaa.gov/ss/transport/cohen.html***

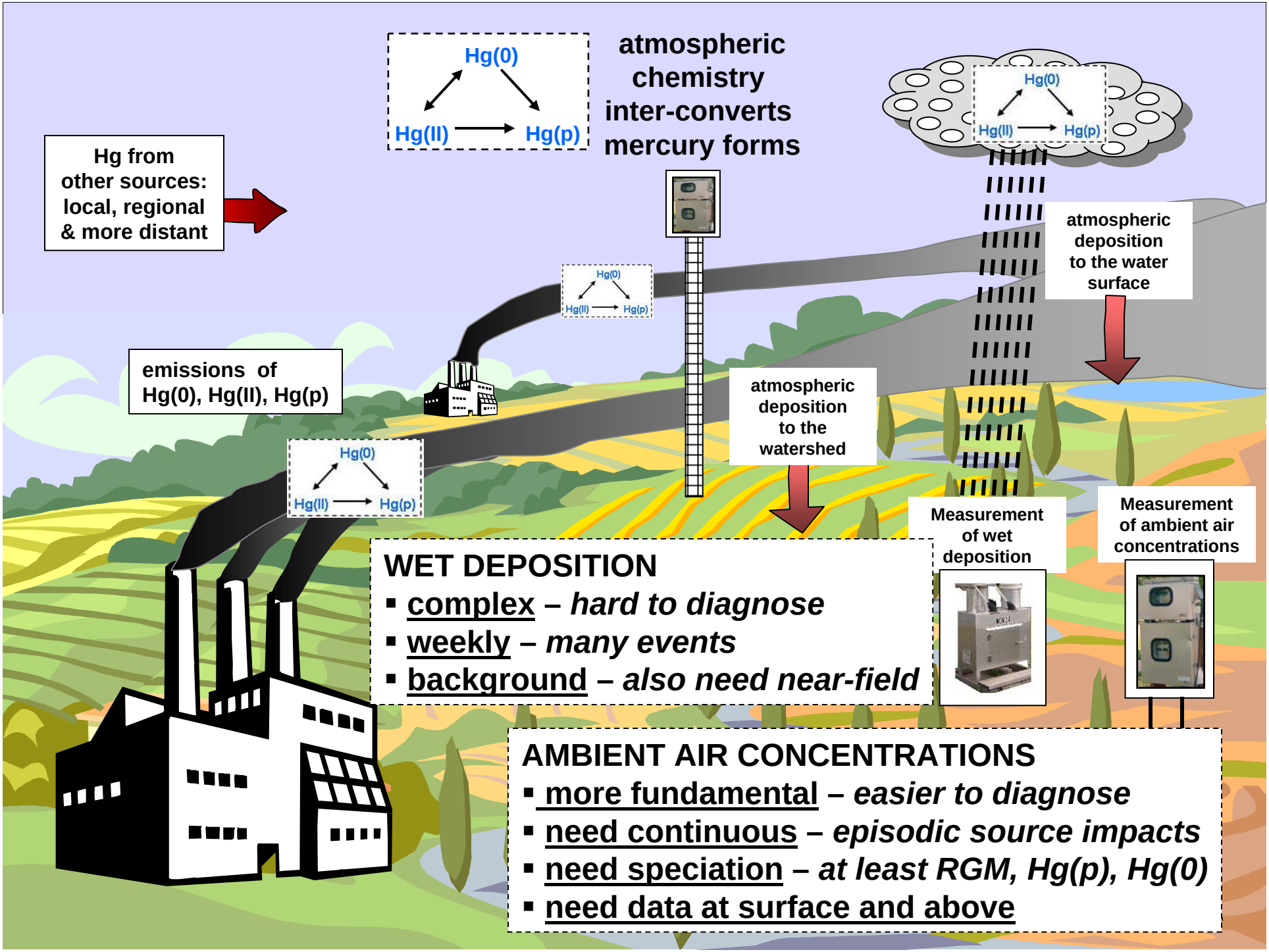

**Presentation S-1614 at Mercury 2006**
**Conference on Mercury as a Global Pollutant**
**Session S-EM-1: Bridging the Gap Between**
**Empirical Data and Multi-Media Modeling, August 8, 2006**

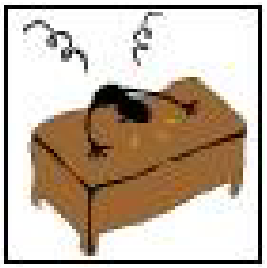

Hg from other sources: local, regional & more distant
emissions of Hg(0), Hg(II), Hg(p)
atmospheric deposition to the water surface
atmospheric deposition to the watershed

- ***policy development*** **requires:**
  - **source-attribution (*source-receptor* info)**
  - **estimated impacts of alternative future scenarios**

- **estimation of *source-attribution* & *future impacts* requires atmospheric models**

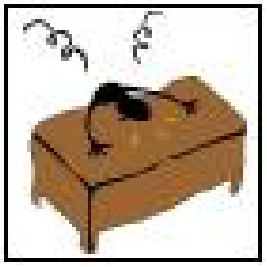
- ***atmospheric models*** **require:**
  - **knowledge of atmospheric chemistry & fate**
  - **emissions data**
  - **ambient data for “ground-truthing”**


Hg(0)
Hg(II)
Hg(p)
atmospheric chemistry inter-converts mercury forms
Hg from other sources: local, regional & more distant
emissions of Hg(0), Hg(II), Hg(p)
atmospheric deposition to the water surface
atmospheric deposition to the watershed
Measurement of wet deposition
Measurement of ambient air concentrations
WET DEPOSITION
▪ complex – hard to diagnose
▪ weekly – many events
▪ background – also need near-field
AMBIENT AIR CONCENTRATIONS
▪ more fundamental – easier to diagnose
▪ need continuous – episodic source impacts
▪ need speciation – at least RGM, Hg(p), Hg(0)
▪ need data at surface and above



**speciated ambient concentration data is scarce**

- *few measurement sites at ground level*
- *very few measurements aloft*



**therefore, atmospheric mercury models have not really been comprehensively evaluated yet**

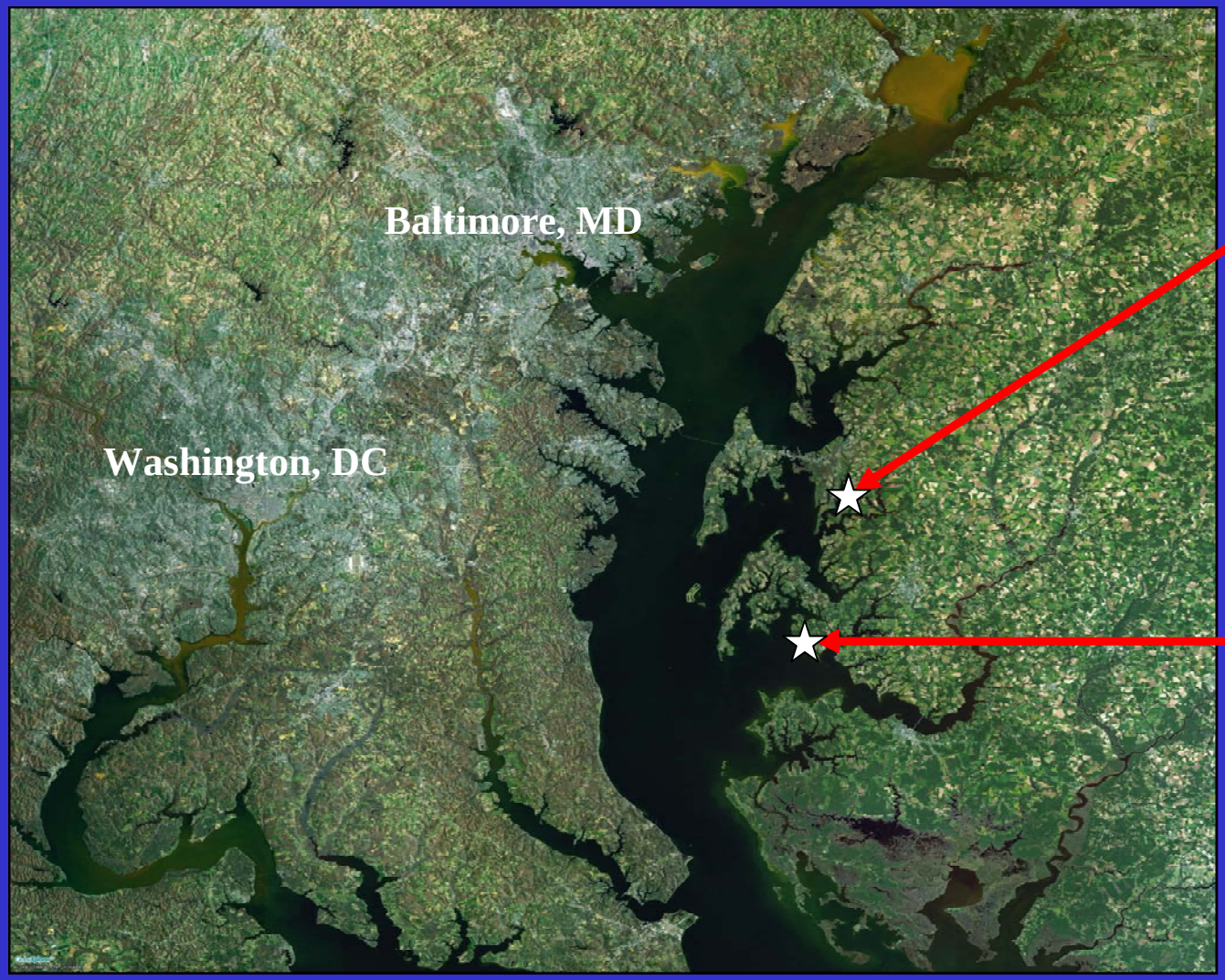
- *we don't really know how good or bad they are*

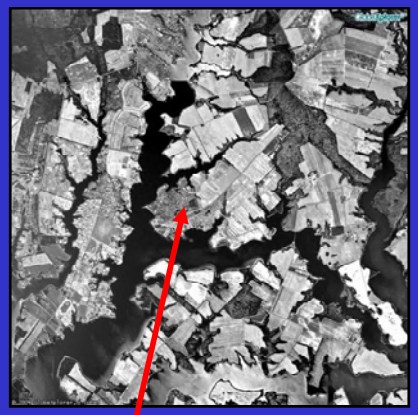
**collaboration between measurement and modeling community is key**

- *measurers need modelers to help interpret data*
- *modelers need measurements to evaluate models*

# NOAA measurements of ambient concentrations of speciated atmospheric mercury at Oxford Maryland, June-Aug 2004

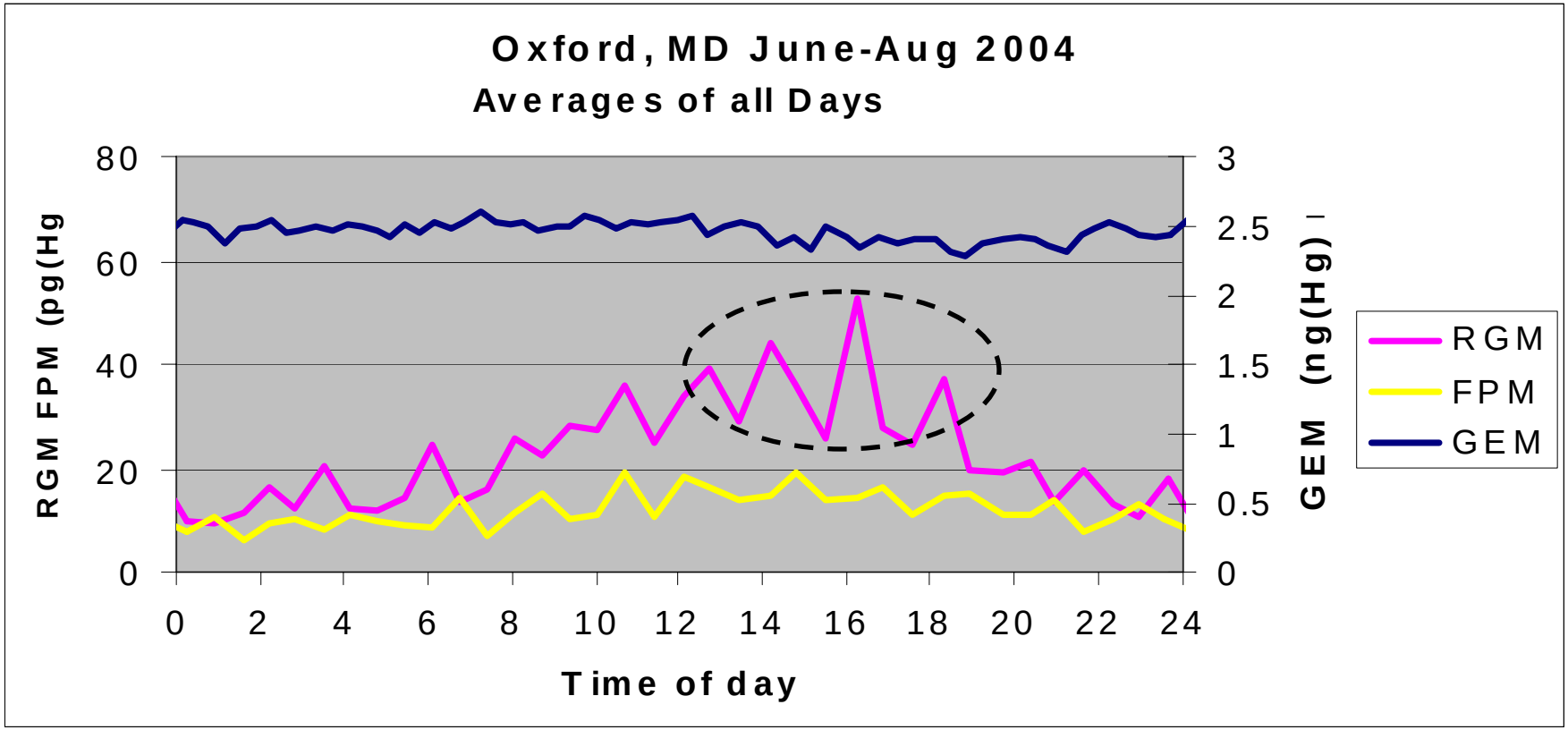
# Summer 2004 NOAA ARL Hg Measurement Sites



Wye Research and
Education Center
(38.9131EN, 76.1525EW)

Cooperative Oxford Lab
(38.678EN, 76.173EW)



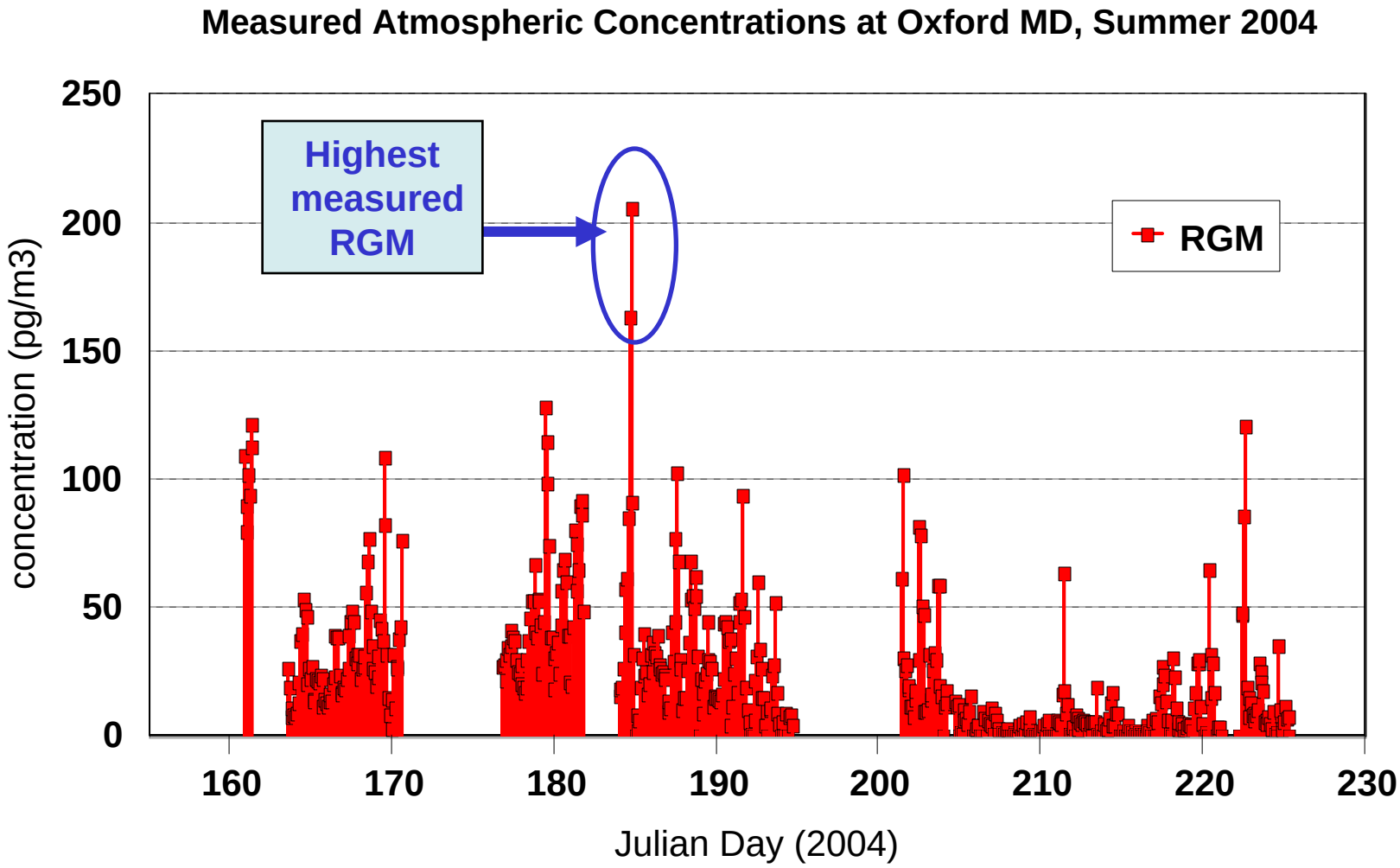

**peak of RGM in afternoon**

- ***to what extent due to atmospheric chemistry, i.e., in-situ production of RGM in atmosphere, through oxidation of Hg(0)?***

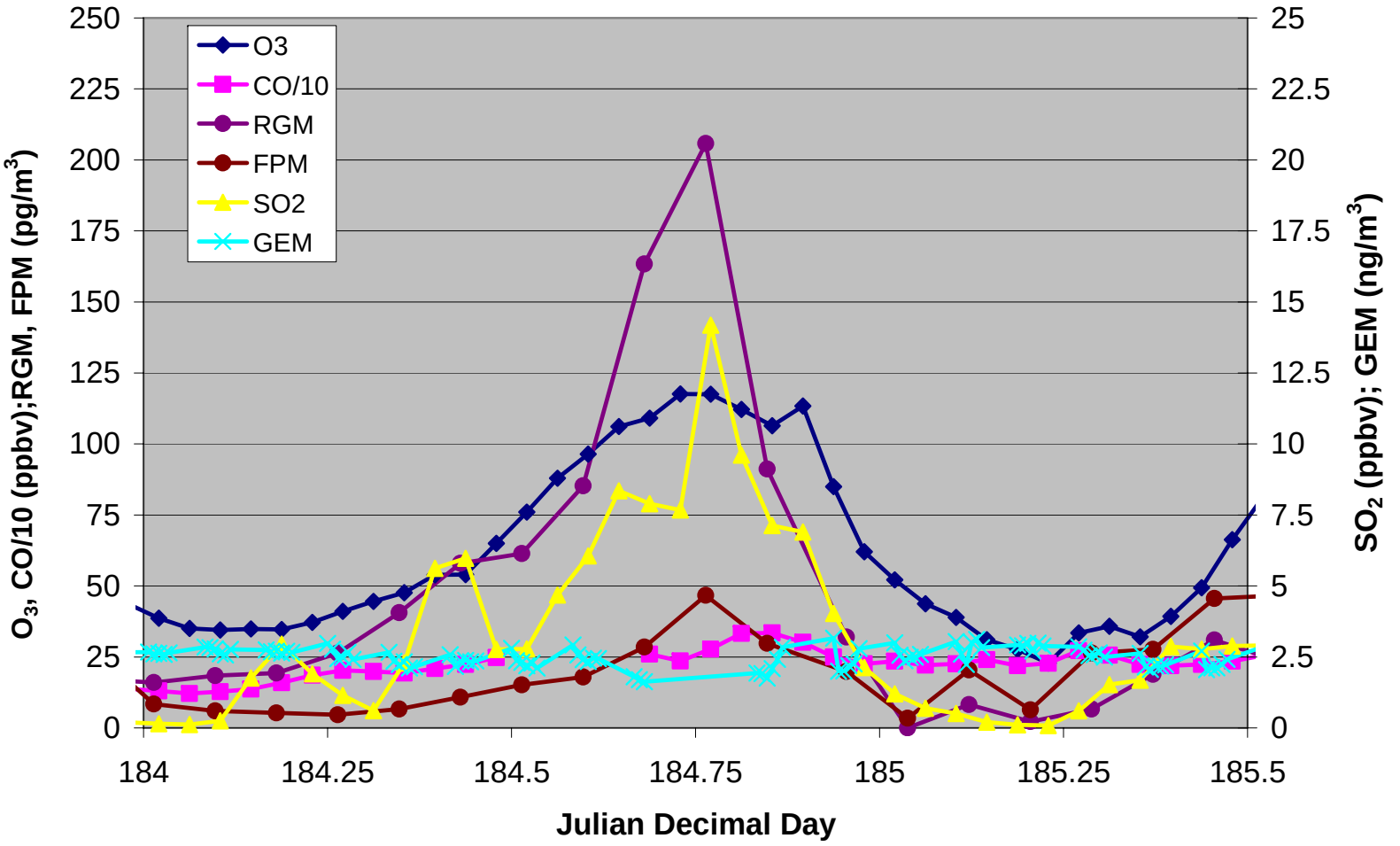
- ***to what extent due to atmospheric mixing, i.e.,***
  - ***Night: boundary layer very shallow, RGM quickly depleted via deposition;***
  - ***Day: boundary layer thicker, "continuous" supply of RGM mixed down to surface***

**peak of RGM in afternoon**

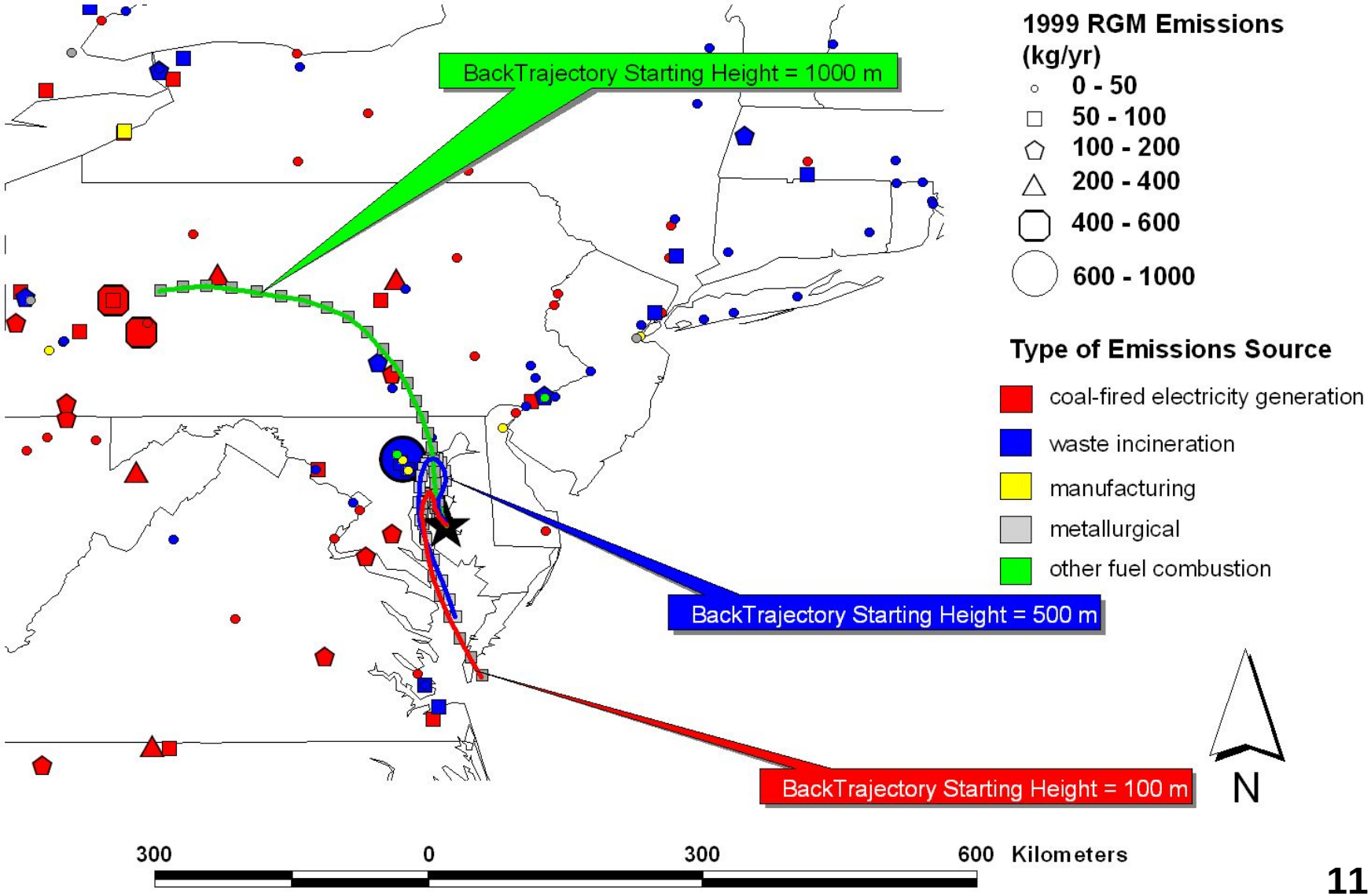
- ***to what extent due to local, regional, or more distant sources?***



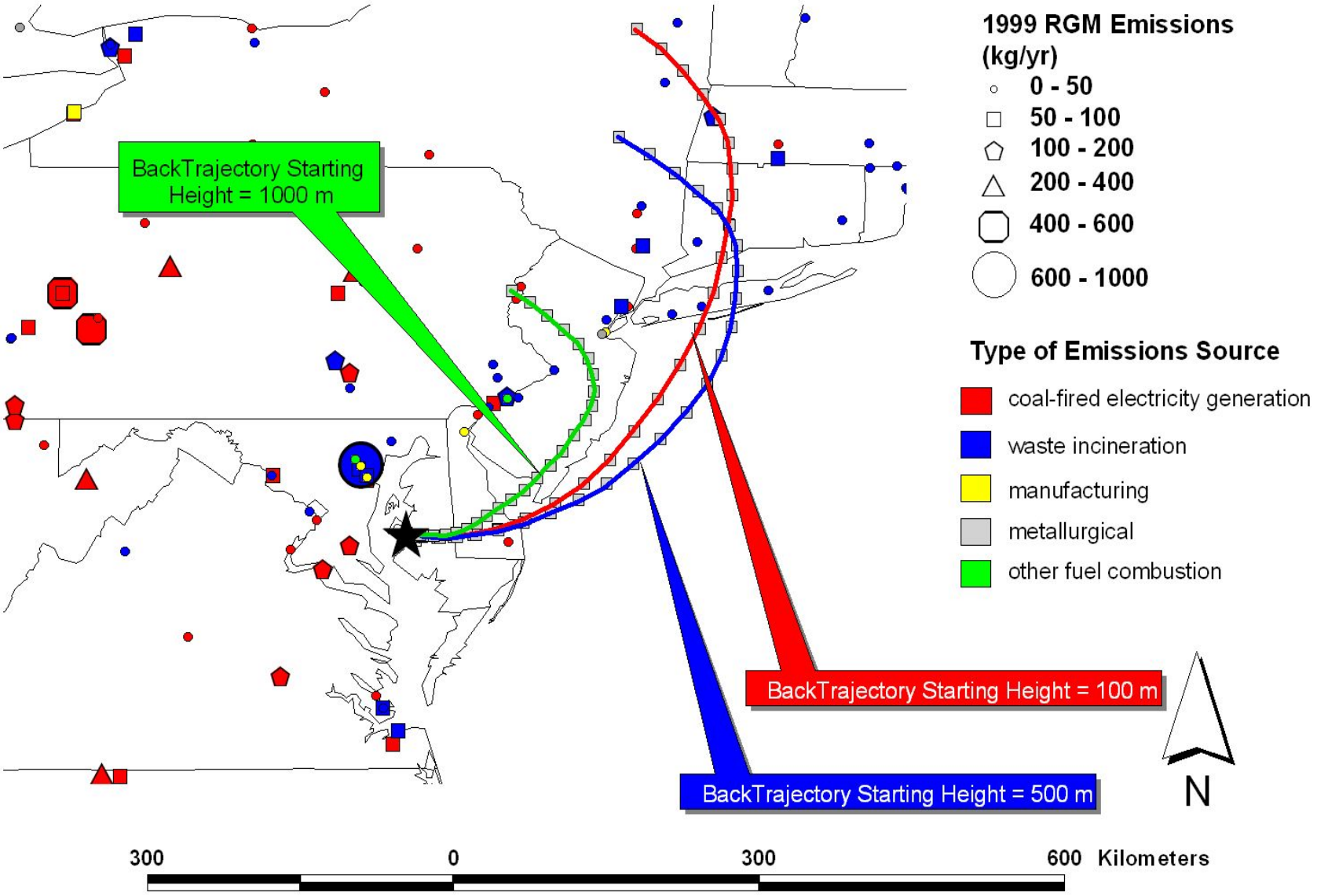
# Concentrations Measured at Oxford, MD

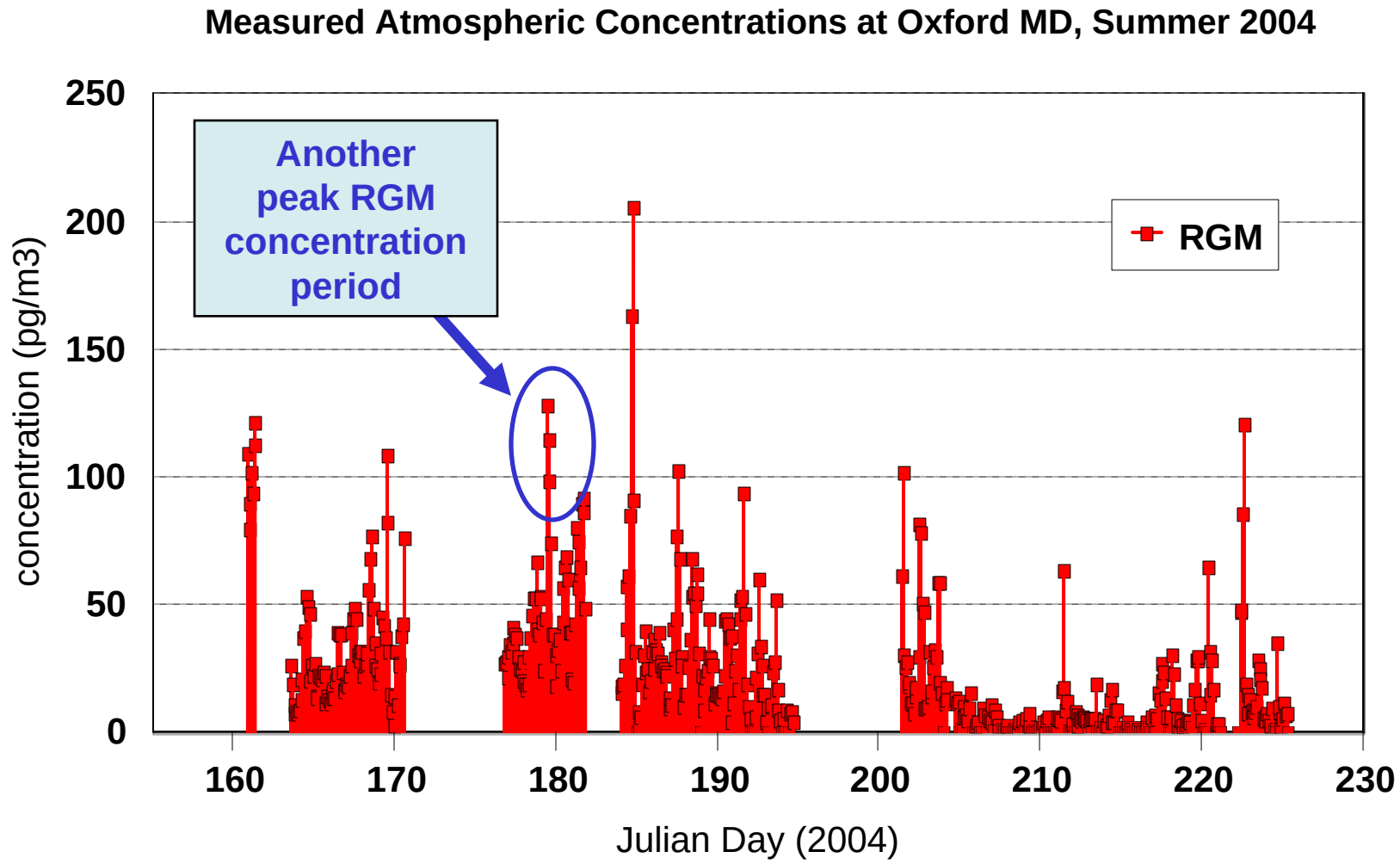


# Oxford July 2, 2004 Peak Concentration in RGM

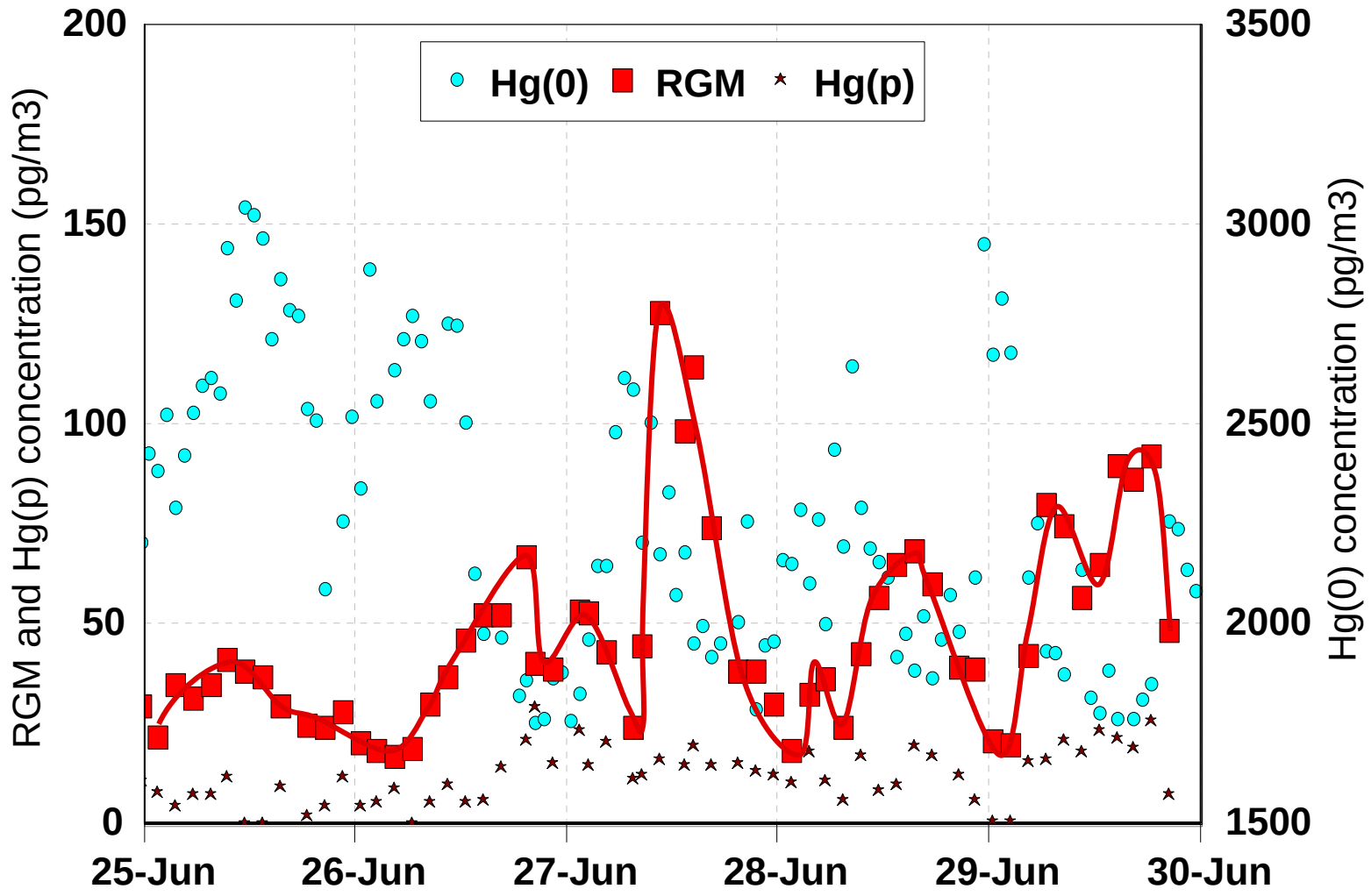


# Oxford July 3, 2004 -- one day after Peak Concentration in RGM

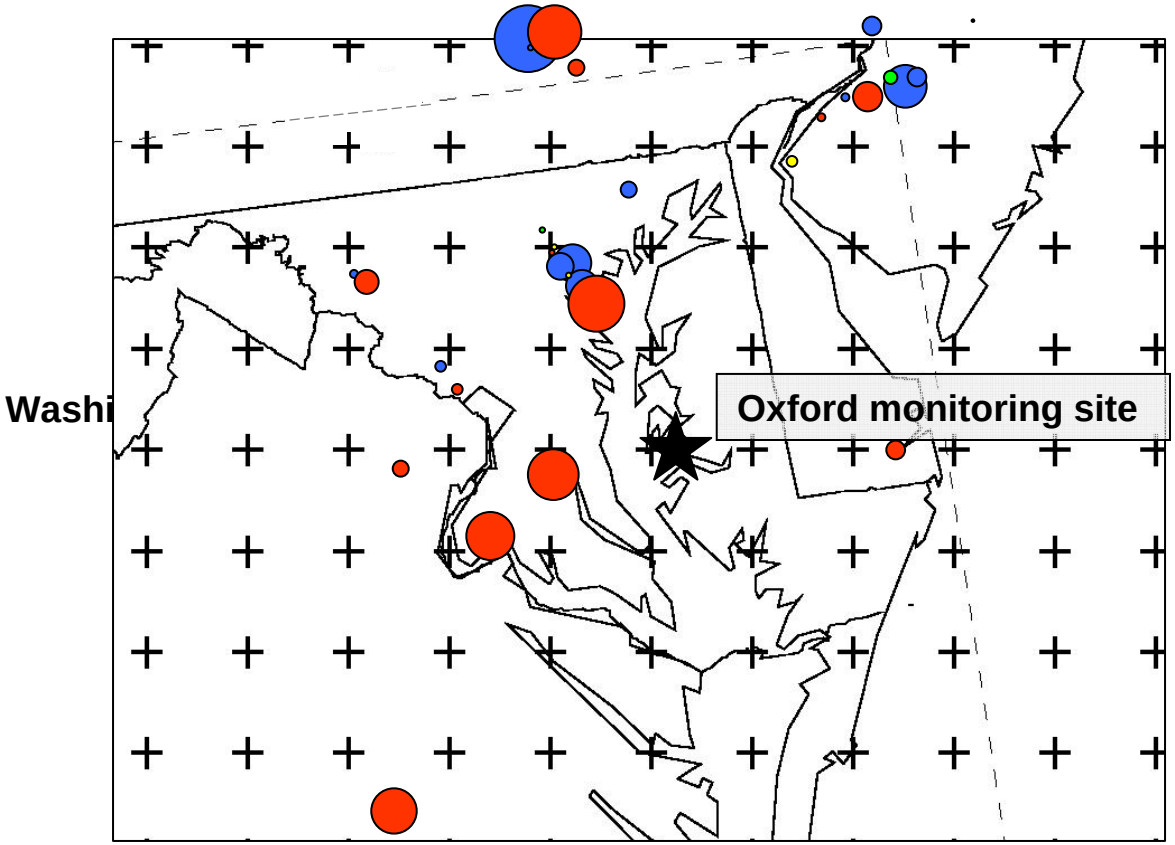



Measured Atmospheric Concentrations at Oxford MD, Summer 2004
Another peak RGM concentration period
RGM
concentration (pg/m3)
250
200
150
100
50
0
160
170
180
190
200
210
220
230
Julian Day (2004)

## Measured Atmospheric Hg Concentrations at Oxford, MD, June 25-30, 2004



# NOAA EDAS 40km meteorological data grid in the vicinity of the Oxford monitoring site

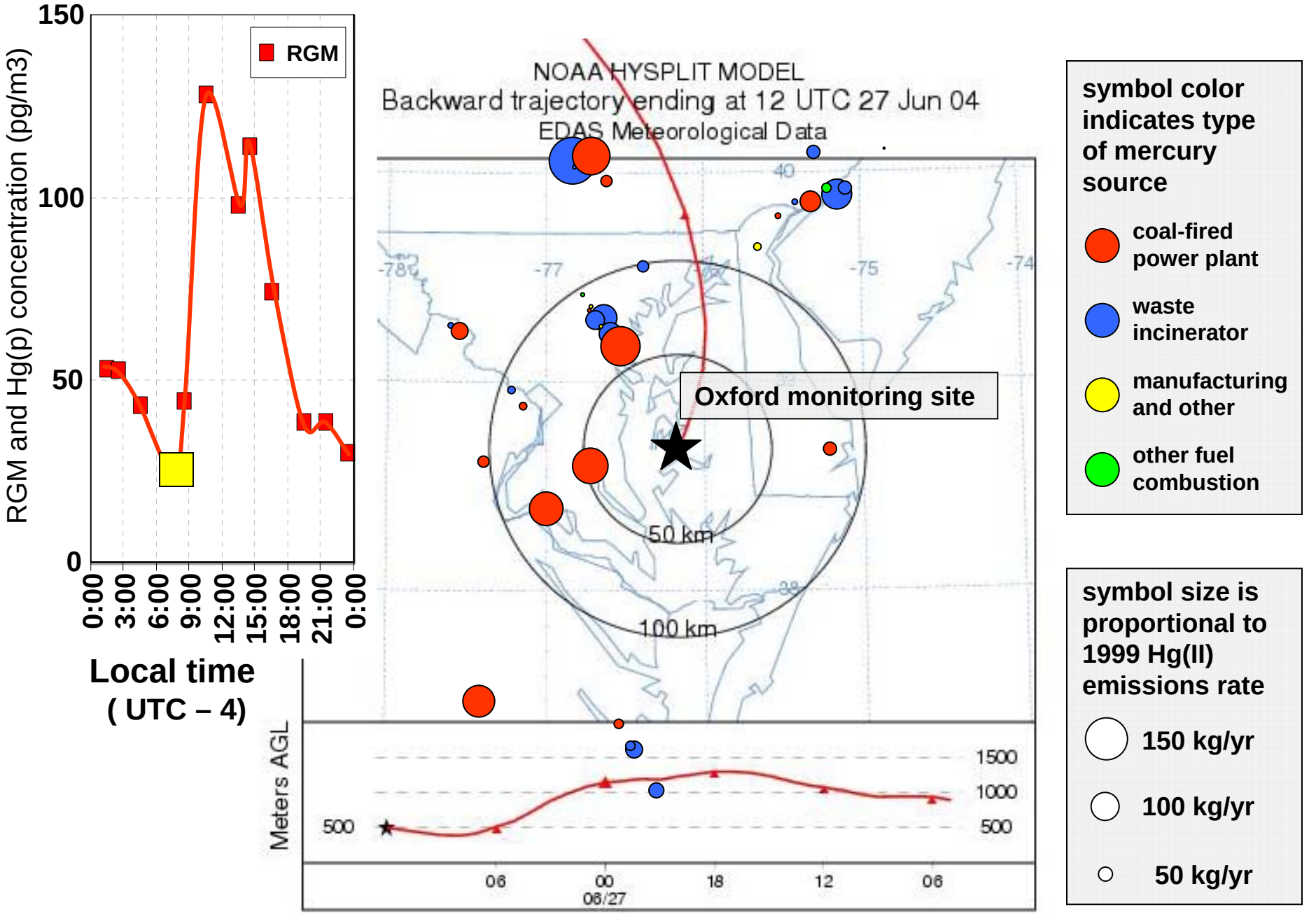


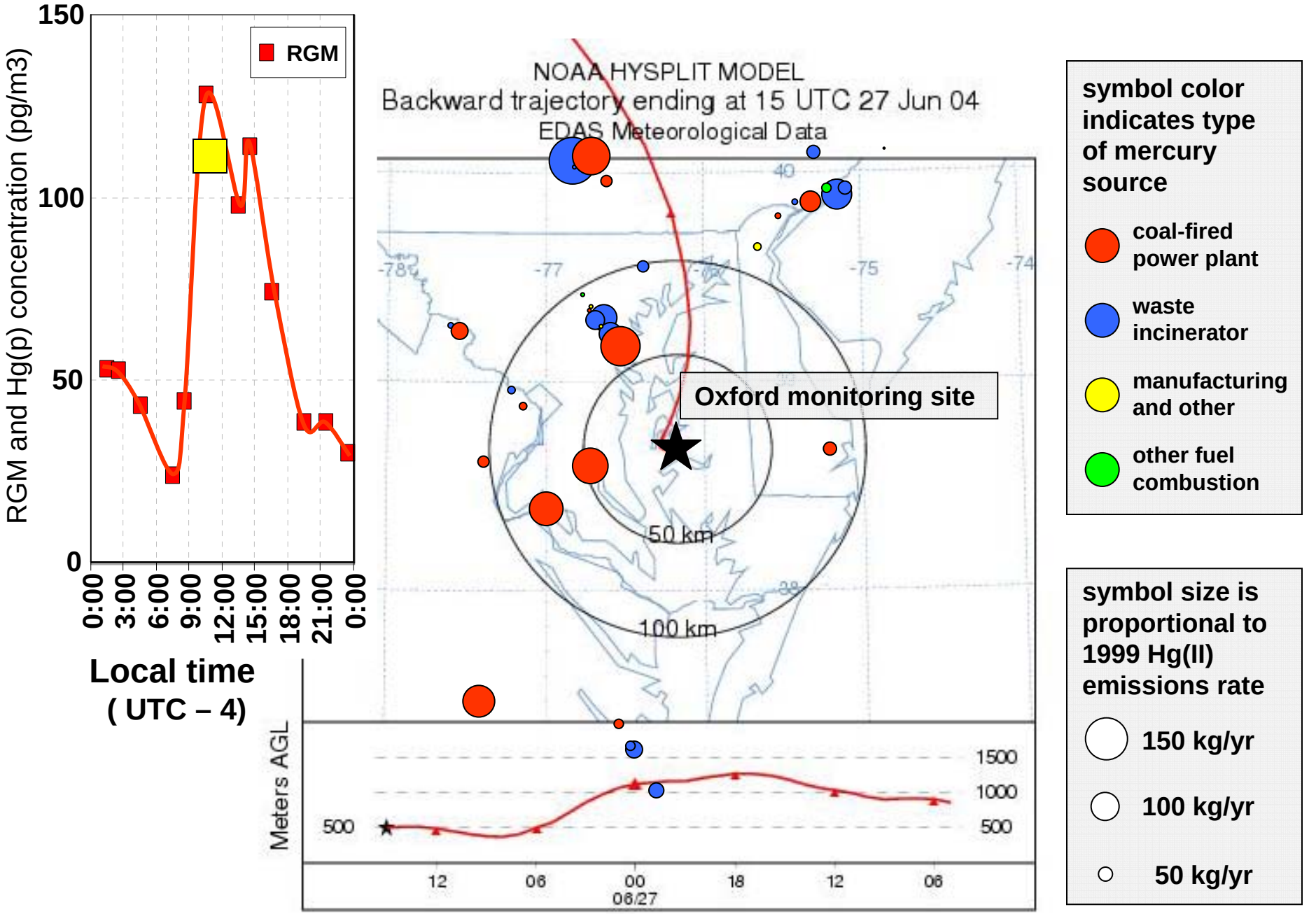

**symbol color indicates type of mercury source**

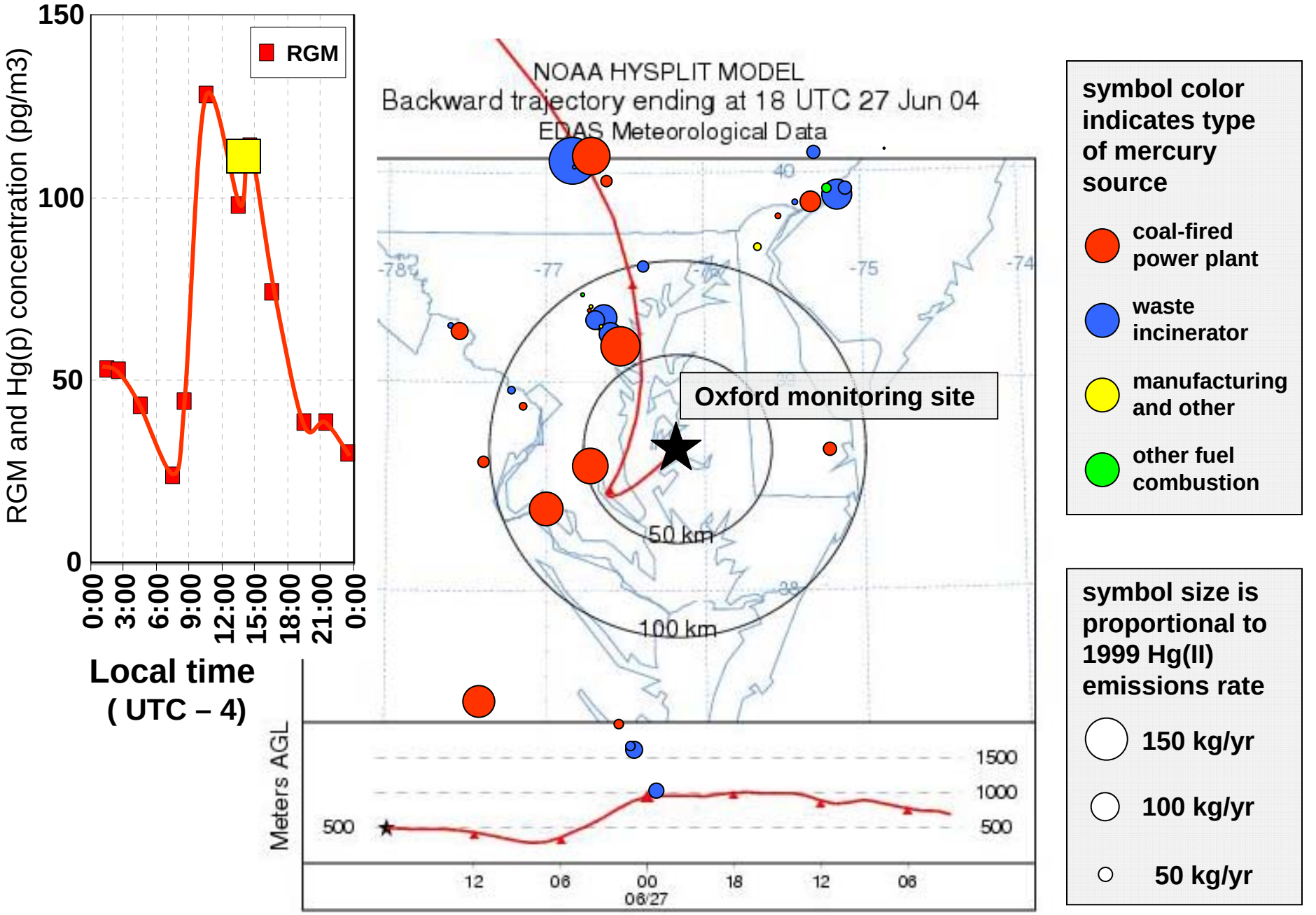
- coal-fired power plant
- waste incinerator
- manufacturing and other
- other fuel combustion

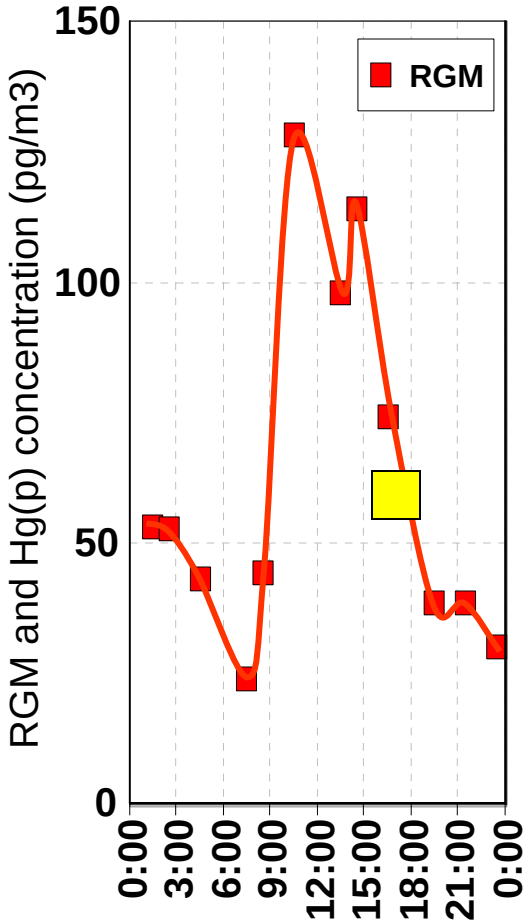
**symbol size is proportional to 1999 Hg(II) emissions rate**

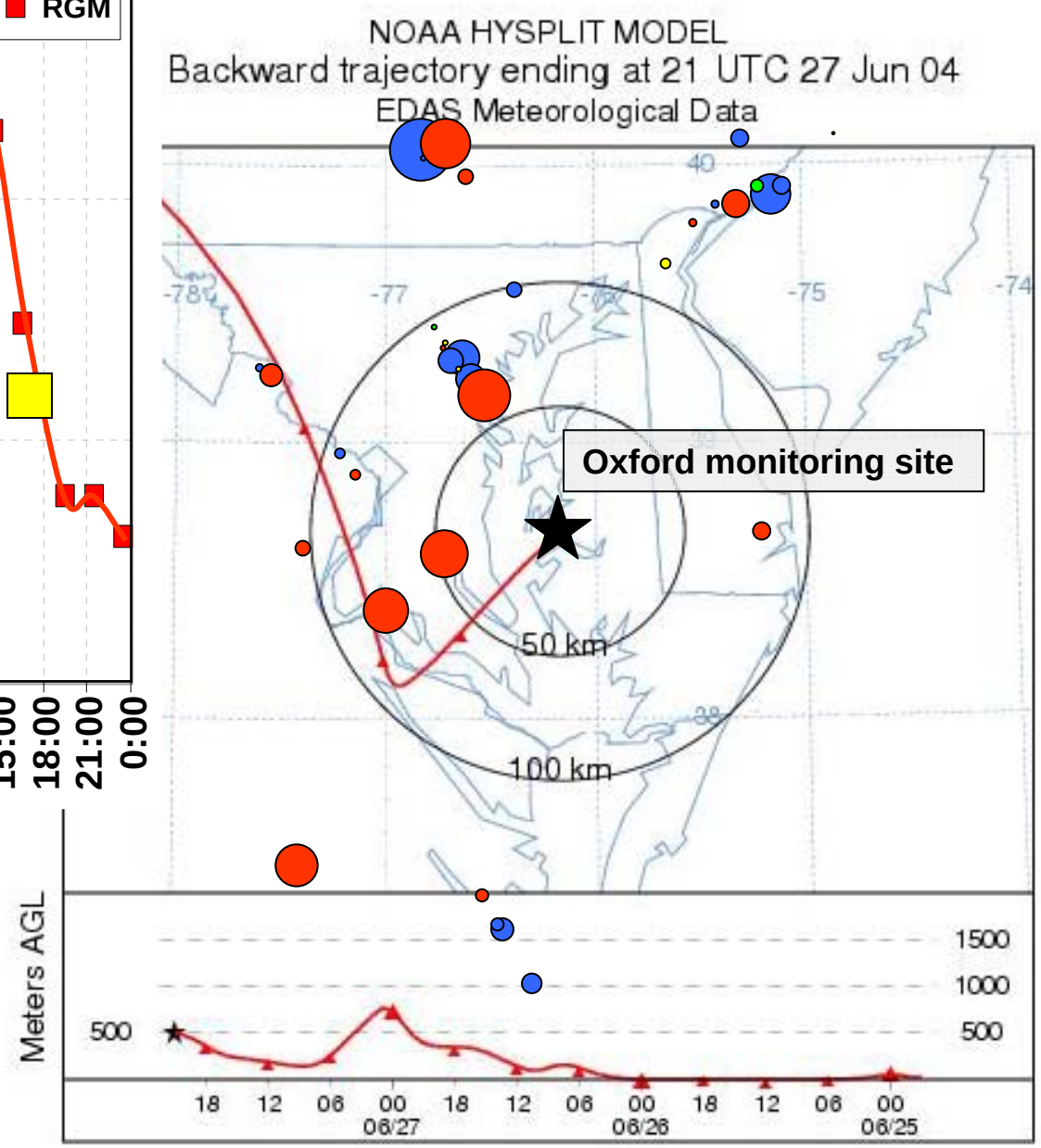
- 150 kg/yr
- 100 kg/yr
- 50 kg/yr


RGM and Hg(p) concentration (pg/m3)
150
100
50
0
RGM
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Local time
( UTC – 4)
NOAA HYSPLIT MODEL
Backward trajectory ending at 12 UTC 27 Jun 04
EDAS Meteorological Data
Oxford monitoring site
50 km
100 km
Meters AGL
1500
1000
500
500
06
00
06/27
18
12
06
symbol color indicates type of mercury source
coal-fired power plant
waste incinerator
manufacturing and other
other fuel combustion
symbol size is proportional to 1999 Hg(II) emissions rate
150 kg/yr
100 kg/yr
50 kg/yr


RGM and Hg(p) concentration (pg/m3)
150
100
50
0
RGM
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Local time
( UTC – 4)
NOAA HYSPLIT MODEL
Backward trajectory ending at 15 UTC 27 Jun 04
EDAS Meteorological Data
Oxford monitoring site
50 km
100 km
Meters AGL
1500
1000
500
500
12
06
00
06/27
18
12
06
symbol color indicates type of mercury source
coal-fired power plant
waste incinerator
manufacturing and other
other fuel combustion
symbol size is proportional to 1999 Hg(II) emissions rate
150 kg/yr
100 kg/yr
50 kg/yr


RGM and Hg(p) concentration (pg/m3)
150
100
50
0
RGM
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Local time
( UTC – 4)
NOAA HYSPLIT MODEL
Backward trajectory ending at 18 UTC 27 Jun 04
EDAS Meteorological Data
Oxford monitoring site
50 km
100 km
Meters AGL
1500
1000
500
500
12
06
00
06/27
18
12
06
symbol color indicates type of mercury source
coal-fired power plant
waste incinerator
manufacturing and other
other fuel combustion
symbol size is proportional to 1999 Hg(II) emissions rate
150 kg/yr
100 kg/yr
50 kg/yr



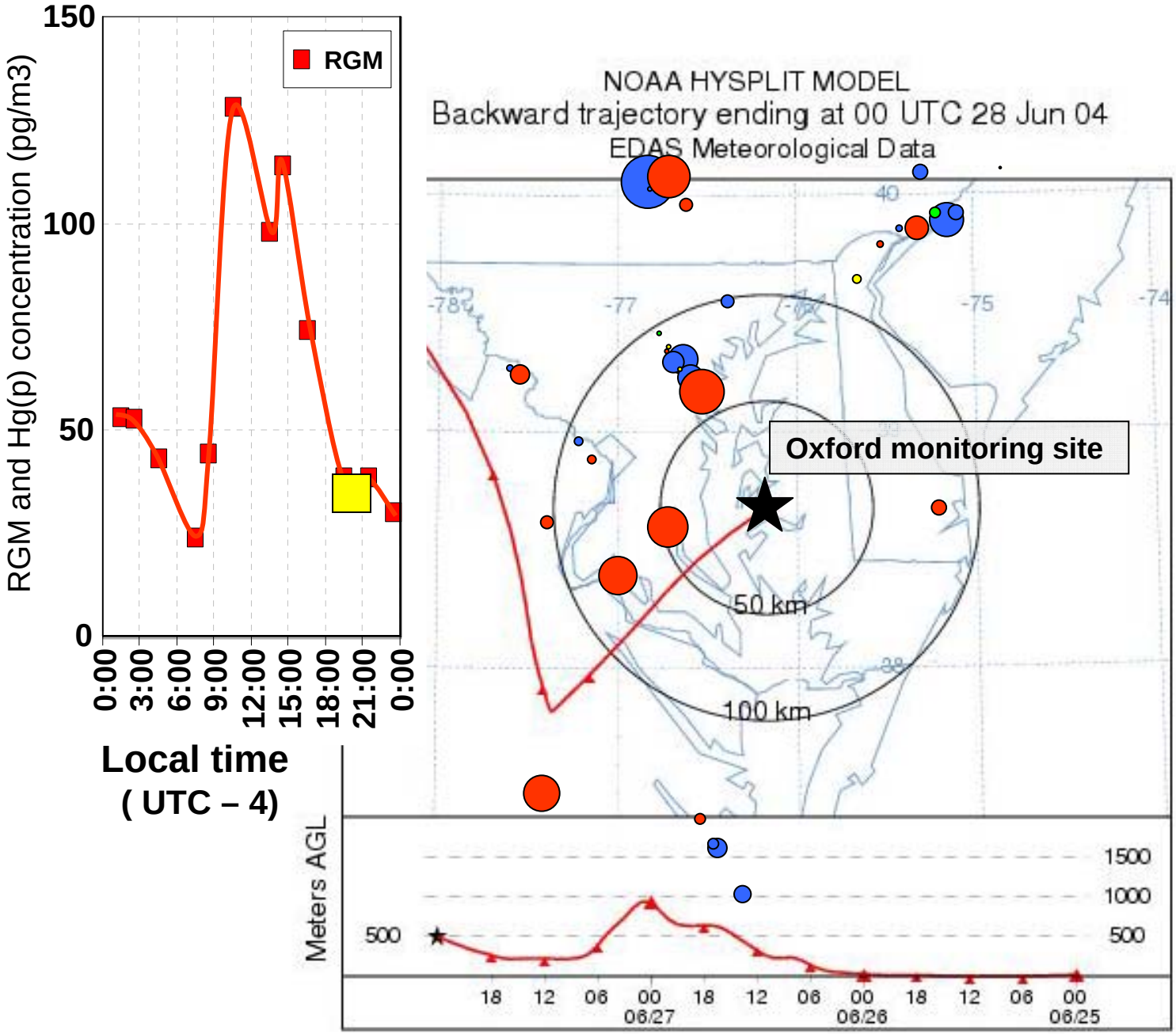



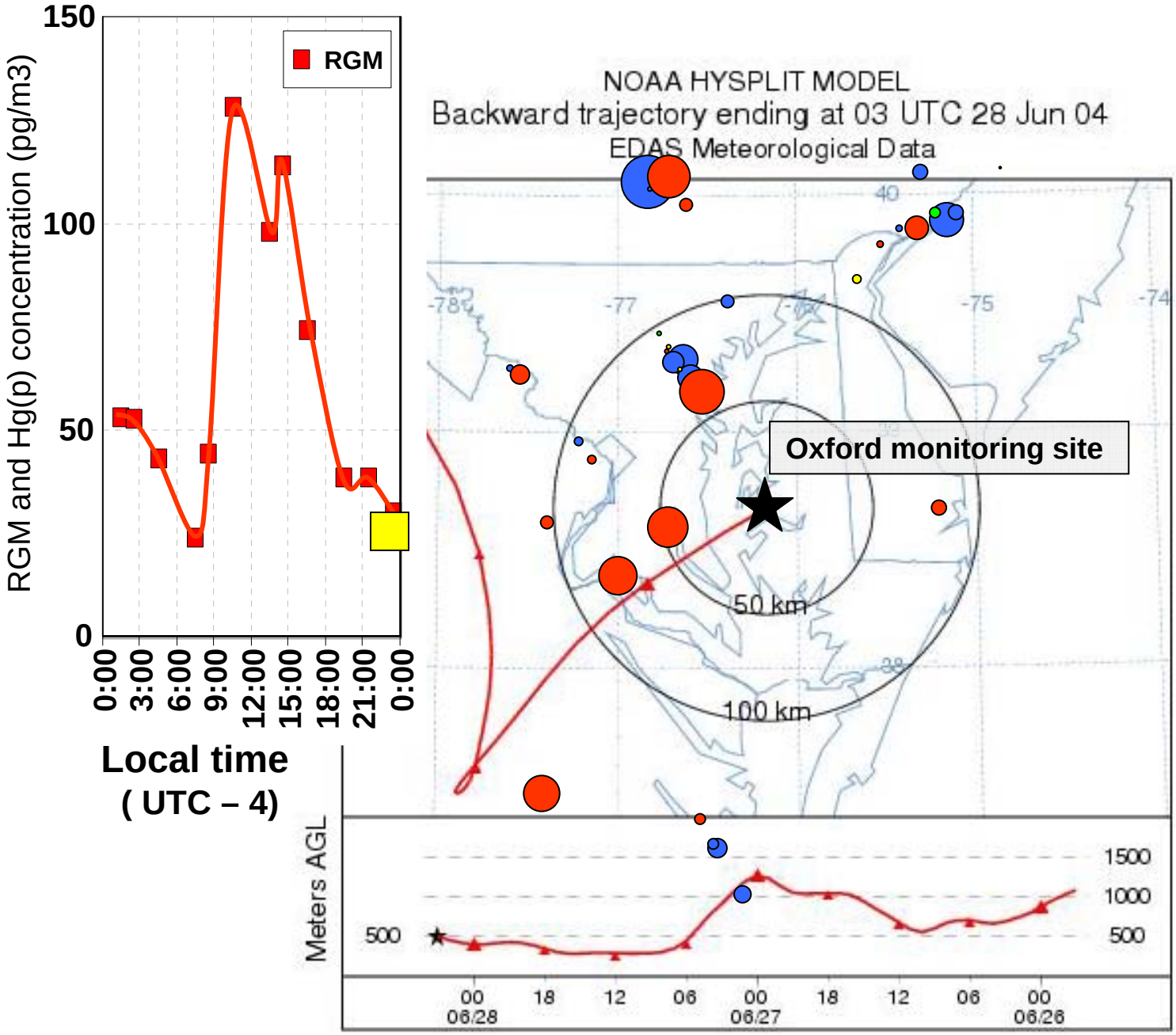

**symbol color indicates type of mercury source**

- coal-fired power plant
- waste incinerator
- manufacturing and other
- other fuel combustion

**symbol size is proportional to 1999 Hg(II) emissions rate**

- 150 kg/yr
- 100 kg/yr
- 50 kg/yr


RGM and Hg(p) concentration (pg/m3)
150
100
50
0
RGM
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Local time
( UTC – 4)
NOAA HYSPLIT MODEL
Backward trajectory ending at 00 UTC 28 Jun 04
EDAS Meteorological Data
Oxford monitoring site
50 km
100 km
Meters AGL
1500
1000
500
500
18
12
06
00
06/27
06/26
06/25
symbol color indicates type of mercury source
coal-fired power plant
waste incinerator
manufacturing and other
other fuel combustion
symbol size is proportional to 1999 Hg(II) emissions rate
150 kg/yr
100 kg/yr
50 kg/yr

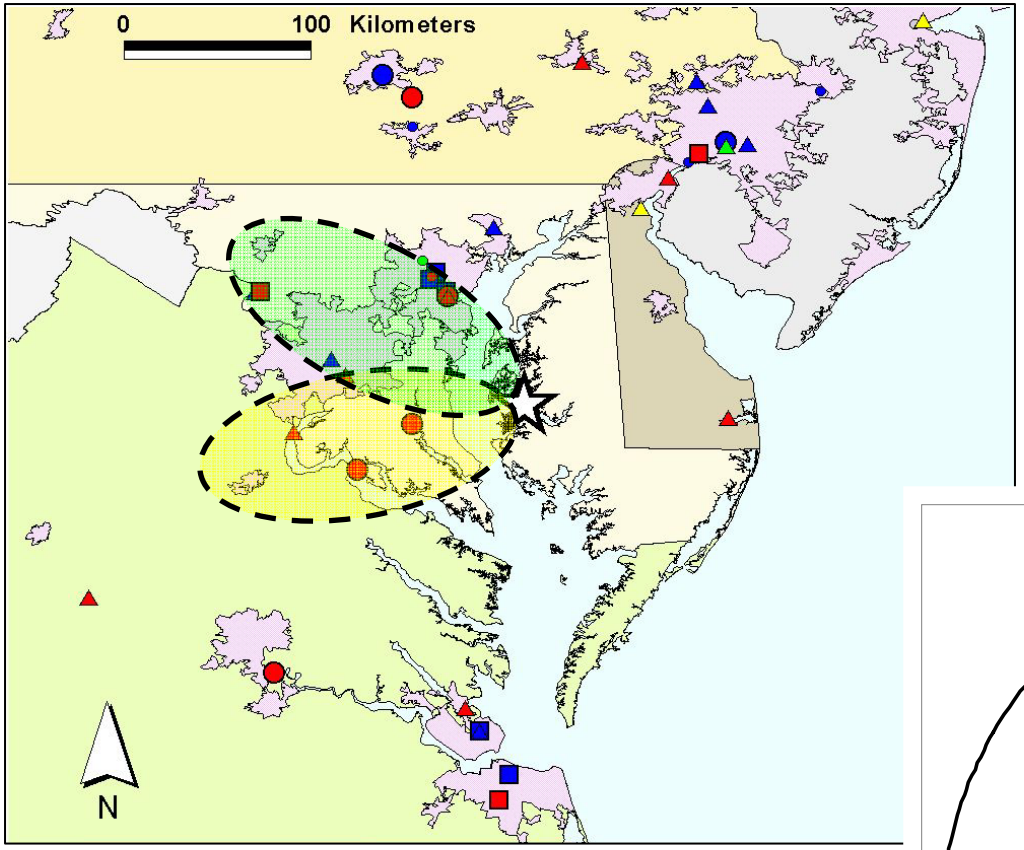



**symbol color indicates type of mercury source**

- coal-fired power plant
- waste incinerator
- manufacturing and other
- other fuel combustion

**symbol size is proportional to 1999 Hg(II) emissions rate**

- 150 kg/yr
- 100 kg/yr
- 50 kg/yr



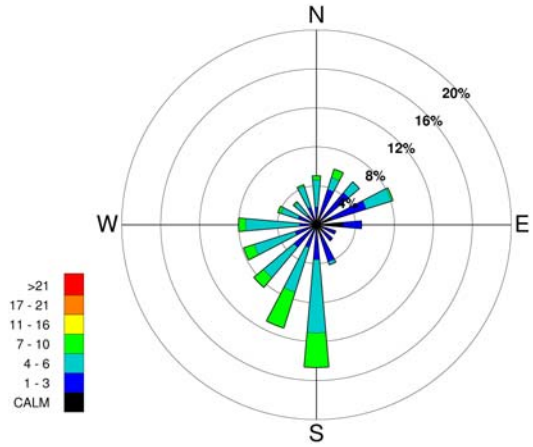

**1999 RGM emissions near Oxford, Maryland**

**Symbol color indicates type of mercury source**

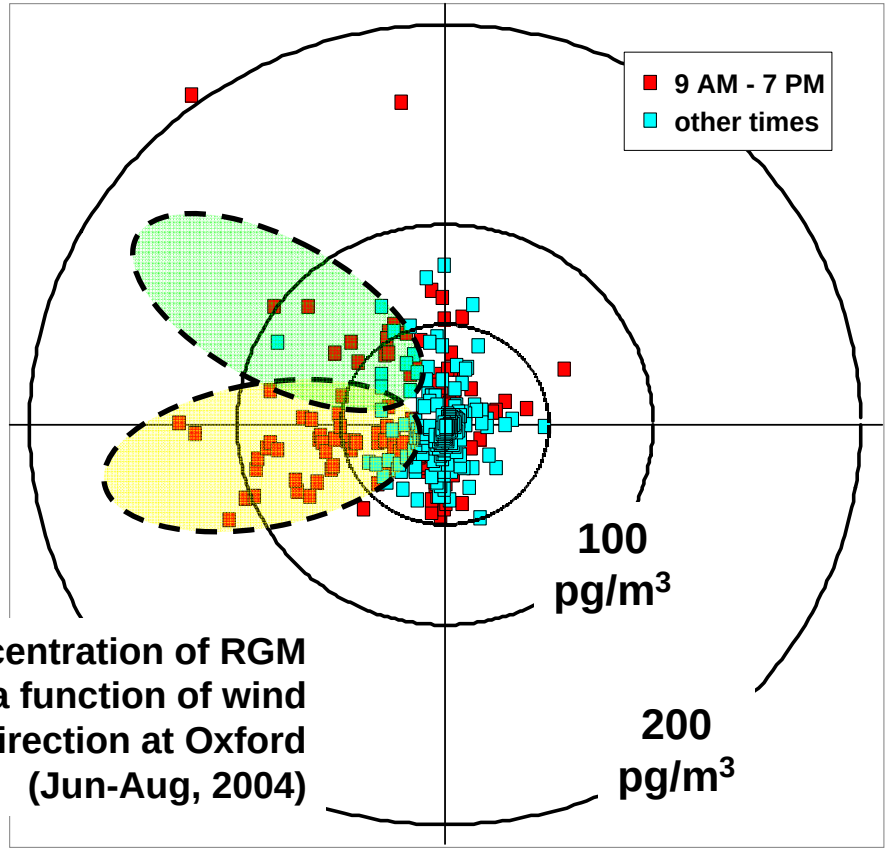
- coal
- incinerator
- metals
- manuf/other
- other fuel

**Symbol size and shape indicates 1999 emissions of Hg(II) (kg/yr)**

- 10 - 20
- 20 - 50
- 50 - 100
- 100 – 200



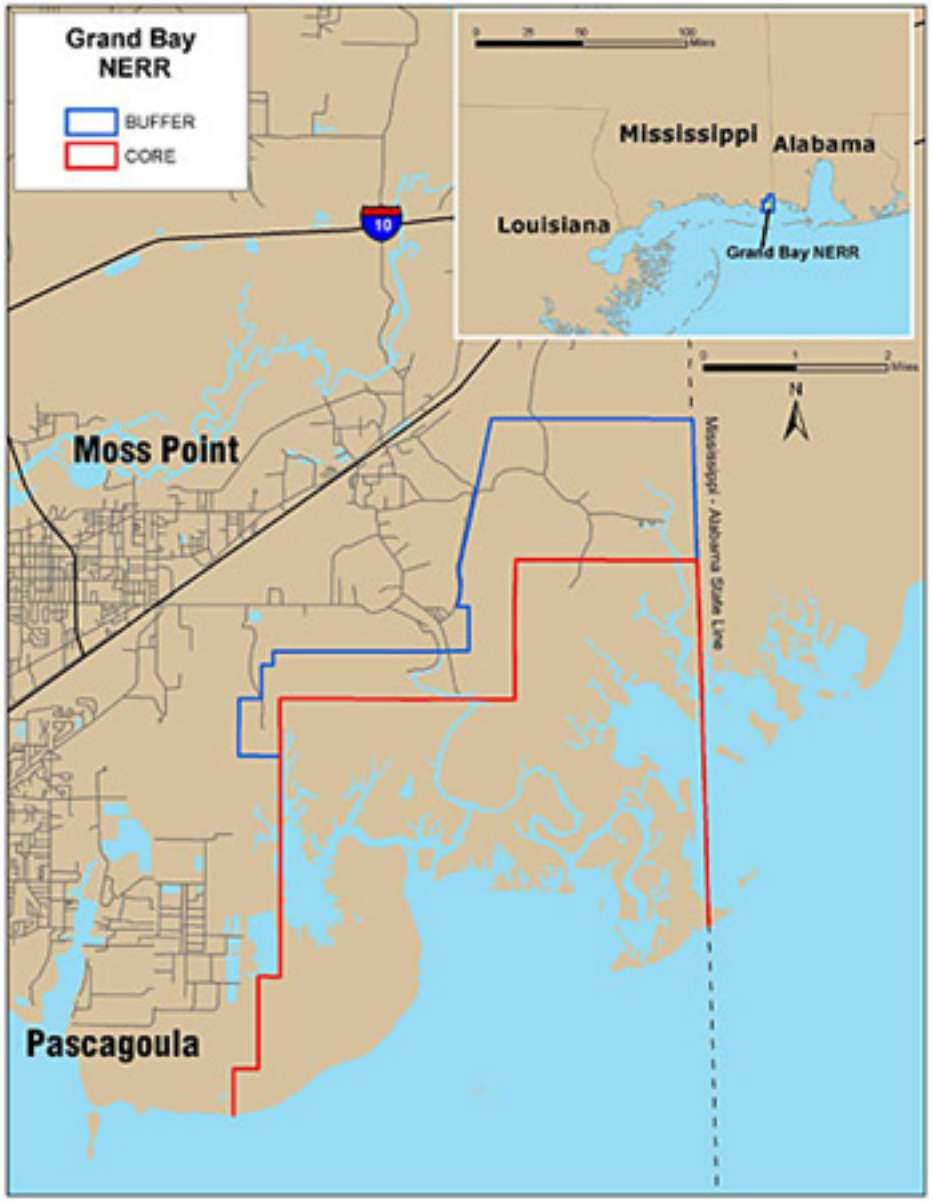

**Wind speed and direction at Oxford (Jun-Aug, 2004)**



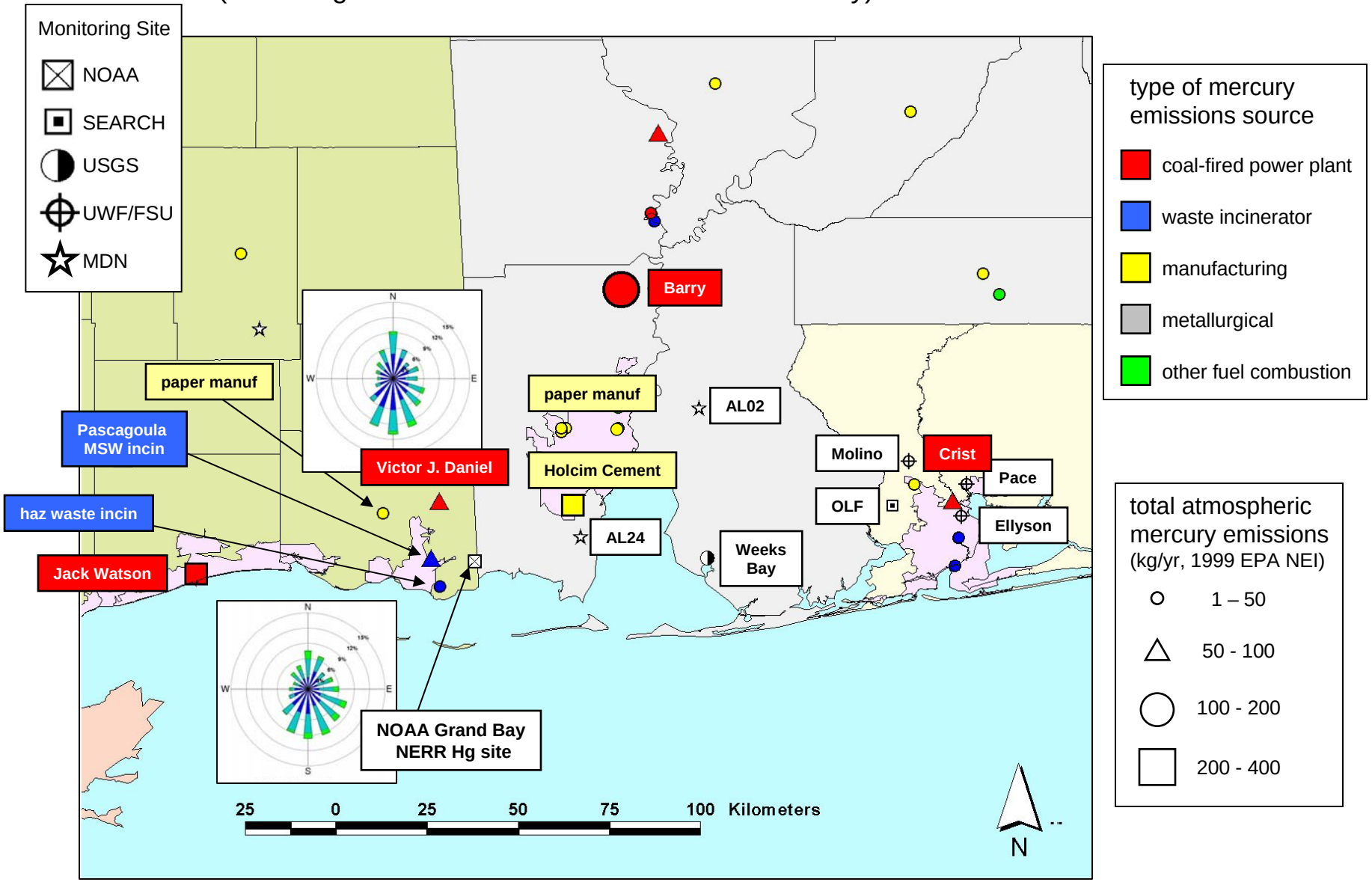

**Concentration of RGM as a function of wind direction at Oxford (Jun-Aug, 2004)**

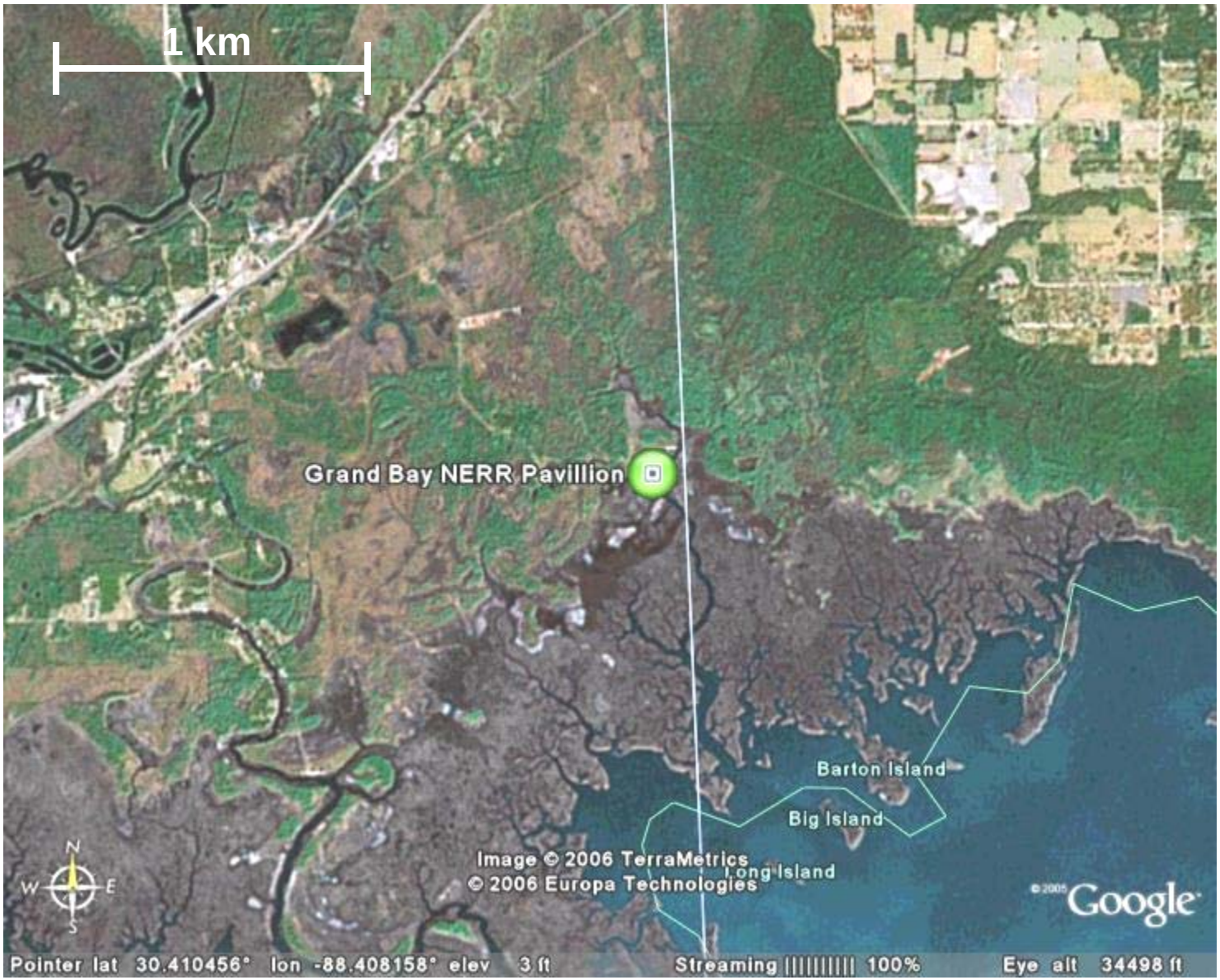
**NOAA measurements of ambient concentrations of speciated atmospheric mercury at the Grand Bay National Estuarine Research Reserve, Mississippi**

***to begin Fall 2006***



Location of the new NOAA Grand Bay NERR Atmospheric Mercury monitoring site, other atmospheric Hg monitoring sites, and major Hg point sources in the region (according to the EPA 1999 NEI emissions inventory)



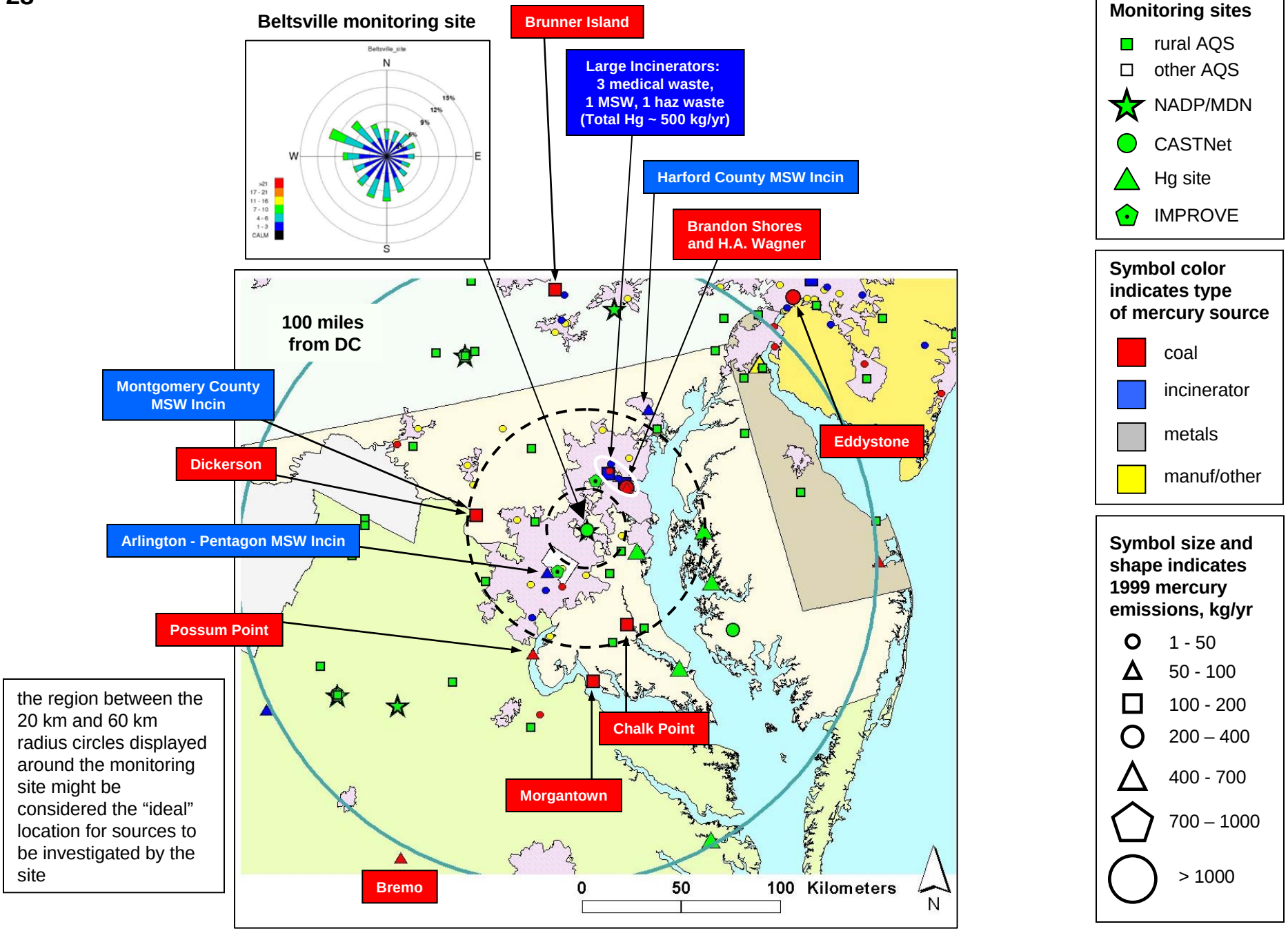

1 km
Grand Bay NERR Pavillion
Barton Island
Big Island
Long Island
Image © 2006 TerraMetrics
© 2006 Europa Technologies
Google
Pointer lat 30.410456° lon -88.408158° elev 3 ft
Streaming 100%
Eye alt 34498 ft

U.S. Fish and Wildlife Service
Pavilion at Grand Bay NERR

View looking south and west from the U.S. Fish
and Wildlife Service Pavilion at Grand Bay NERR

**EPA-NOAA**
**measurements of**
**ambient concentrations**
**of speciated**
**atmospheric mercury**
**at Beltsville Maryland**

***to begin Fall-Winter 2006***




the region between the 20 km and 60 km radius circles displayed around the monitoring site might be considered the "ideal" location for sources to be investigated by the site

**Monitoring sites**

- rural AQS
- other AQS
- NADP/MDN
- CASTNet
- Hg site
- IMPROVE

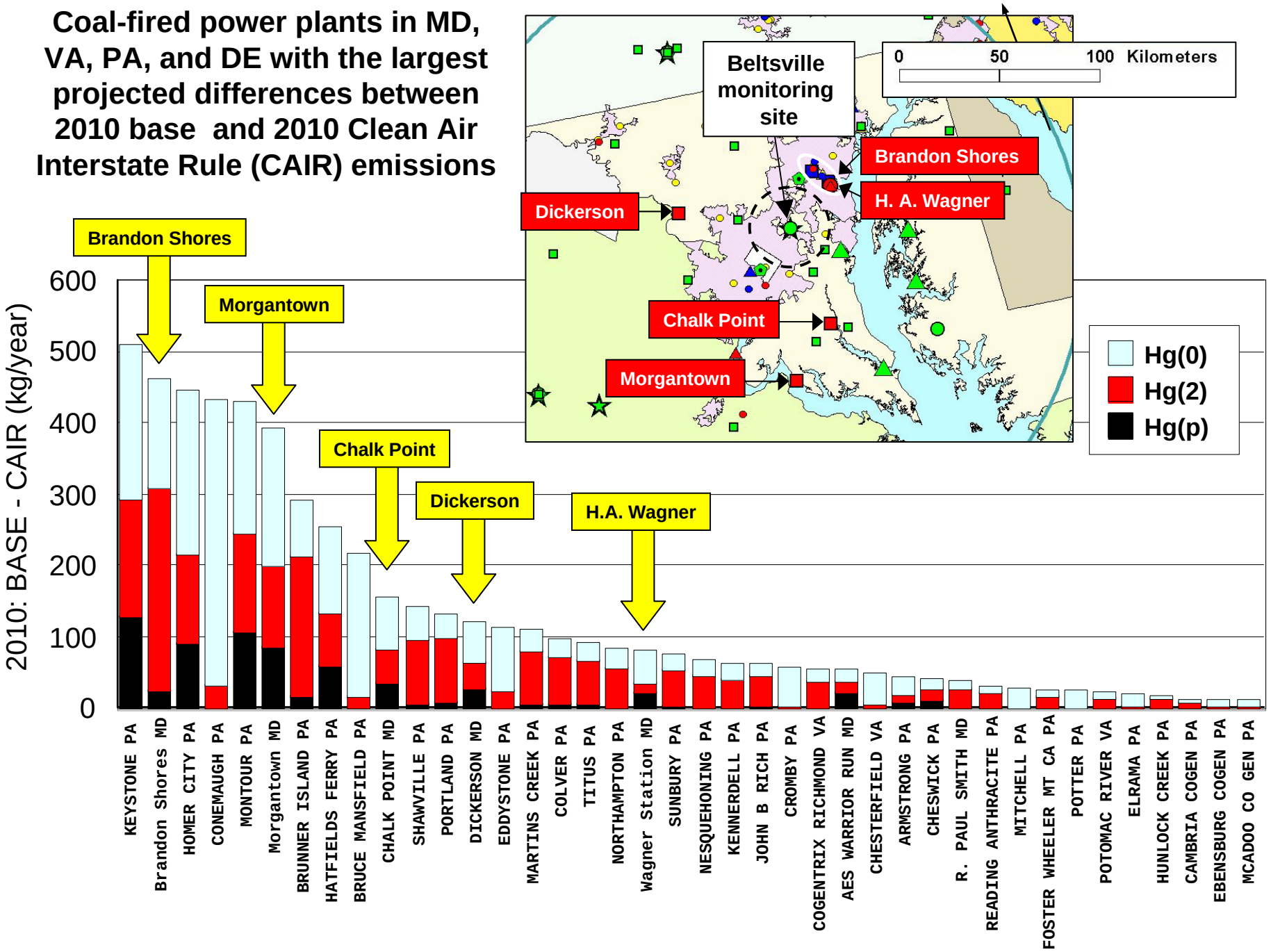
**Symbol color indicates type of mercury source**

- coal
- incinerator
- metals
- manuf/other

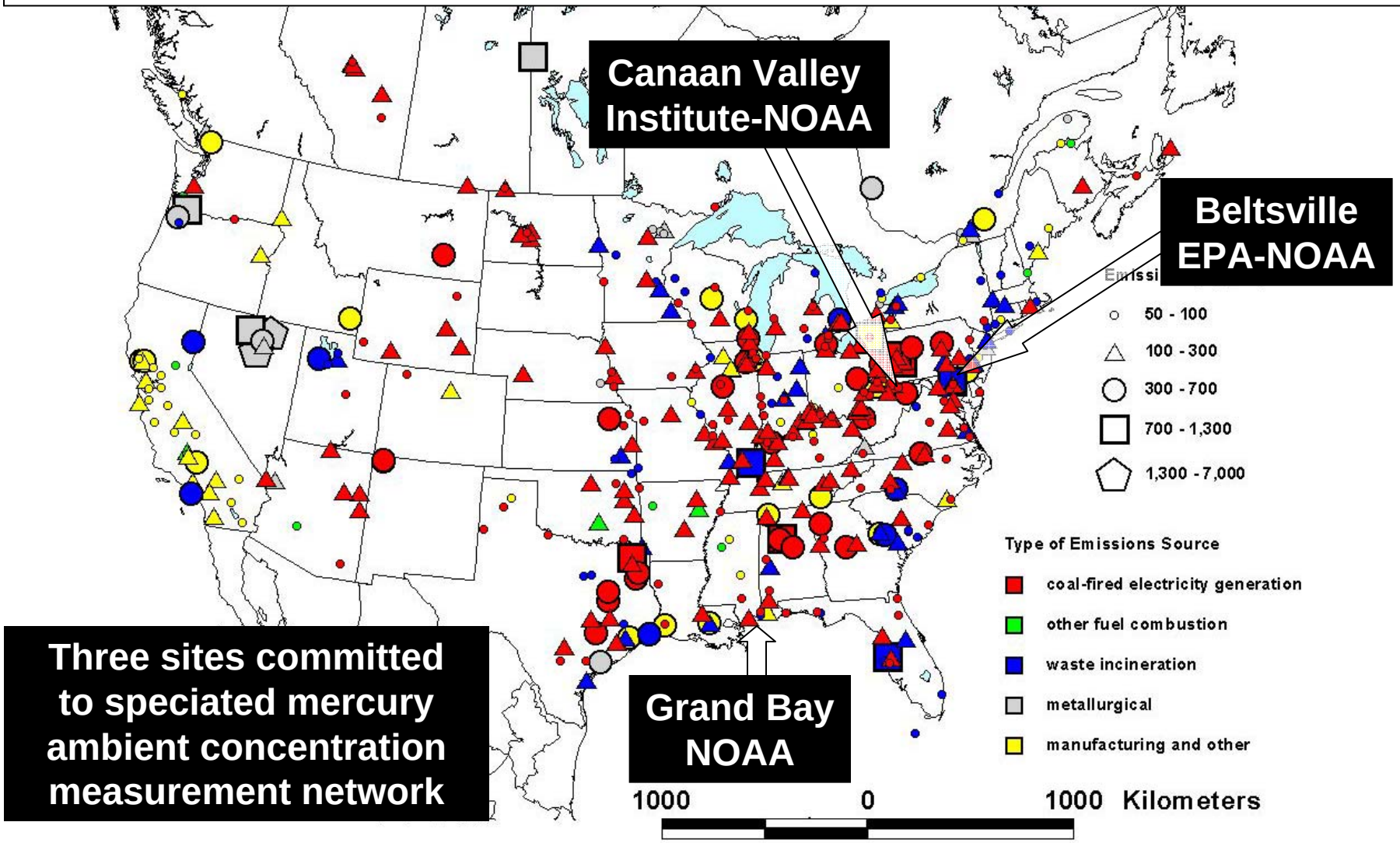
**Symbol size and shape indicates 1999 mercury emissions, kg/yr**

- 1 - 50
- 50 - 100
- 100 - 200
- 200 – 400
- 400 - 700
- 700 – 1000
- > 1000

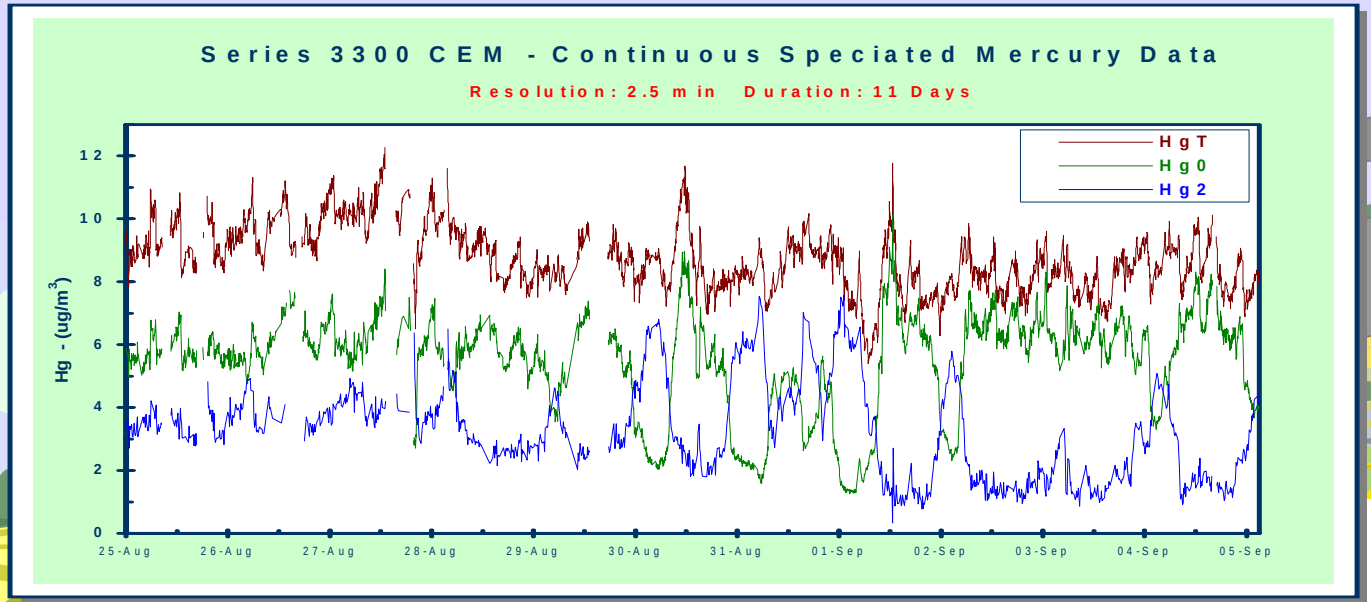
# Coal-fired power plants in MD, VA, PA, and DE with the largest projected differences between 2010 base and 2010 Clean Air Interstate Rule (CAIR) emissions

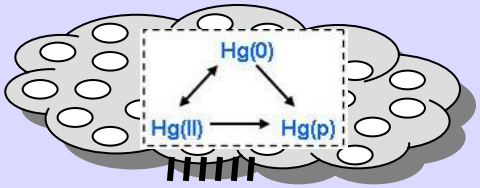


**Largest sources of total mercury emissions to the air in the U.S. and Canada, based on the U.S. EPA 1999 National Emissions Inventory and 1995-2000 data from Environment Canada**



**Hg from other sources: local, regional & more distant**

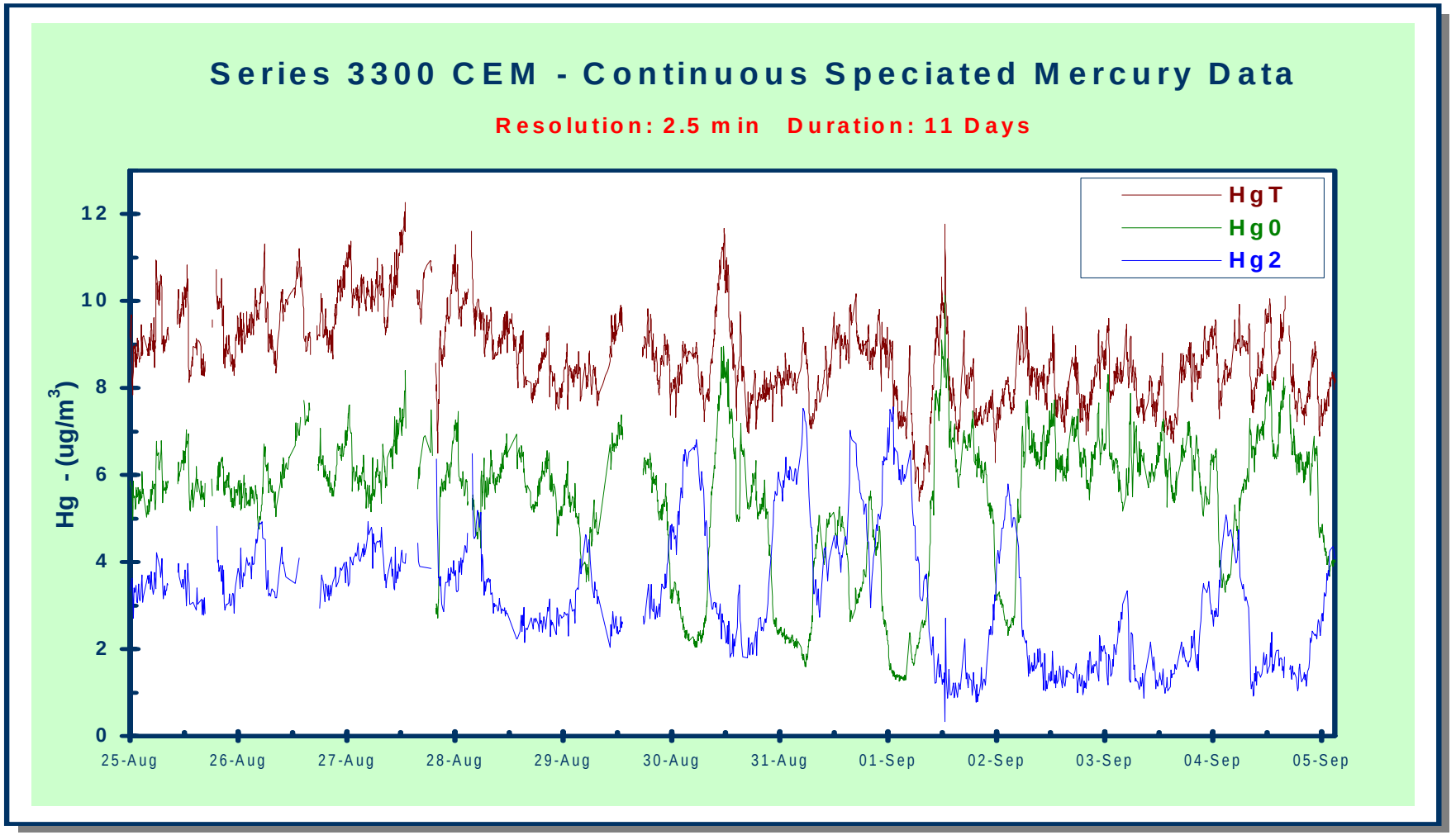



**atmospheric deposition to the water surface**

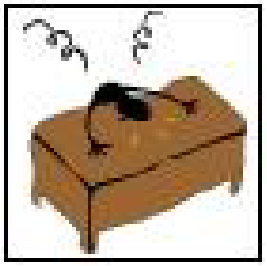
**Measurement of wet deposition**

**Measurement of ambient air concentrations**



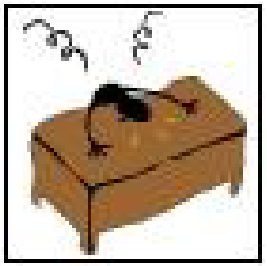

***Thanks to*** **Marty Keller, Senior Applications Engineer, Tekran Instruments Corporation, *for providing this graph!***

# Temporal Problems with Emissions Inventories



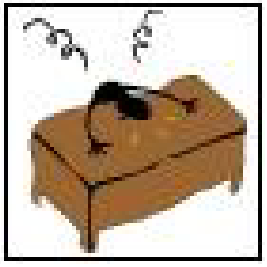
## Variations on time scales of minutes to hours

- *CEM's needed – and not just on coal-fired power plants*
- *CEM's must be speciated or of little use in developing critical source-receptor information*
- *Clean Air Mercury Rule only requires ~weekly total-Hg measurements, for purposes of trading*



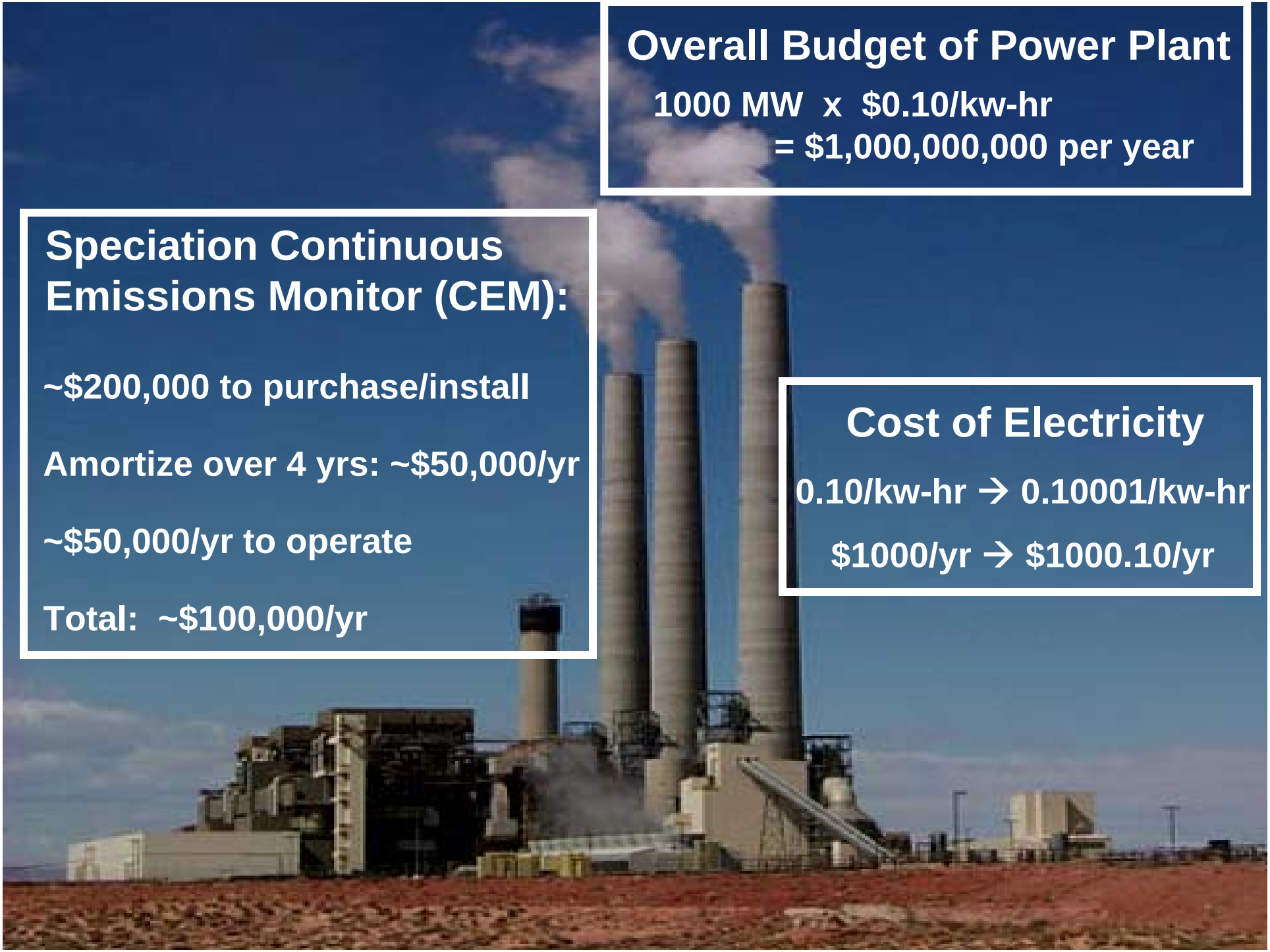
## We don't have information about major events

- *e.g., maintenance or permanent closures, installation of new pollution control devices, process changes*
- *Therefore, difficult to interpret trends in ambient data*



## Long delay before inventories released

- *2002 inventory is being released this year in U.S.; till now, the latest available inventory was for 1999*
- *How can we use new measurement data?*



## Overall Budget of Power Plant

1000 MW x $0.10/kw-hr
= $1,000,000,000 per year

## Speciation Continuous Emissions Monitor (CEM):

~$200,000 to purchase/install

Amortize over 4 yrs: ~$50,000/yr

~$50,000/yr to operate

Total: ~$100,000/yr

## Cost of Electricity

0.10/kw-hr → 0.10001/kw-hr

$1000/yr → $1000.10/yr

## MANY THANKS TO:

- **Gary Foley, J. David Mobley, Elsie Sunderland, Chris Knightes (EPA); Panos Georgopolous and Sheng-Wei Wang (EOSHI Rutgers Univ); John McDonald (IJC):** *collaboration on multimedia Hg modeling*

- **David Schmeltz, Gary Lear, John Schakenbach, Scott Hedges, Rey Forte (EPA):** *collaboration on Hg models and /measurements, including new EPA-NOAA Hg monitoring site at Beltsville, MD.*

- **David Ruple, Mark Woodrey (Grand Bay NERR), Susan White , Gary Matlock, Russell Callender, Jawed Hameedi (NOAA), and Durwin Carter (U.S. Fish and Wildlife Service):** *collaboration at NOAA Grand Bay NERR atmospheric monitoring site*

- **Anne Pope and colleagues (EPA):** *U.S. mercury emissions inventory*

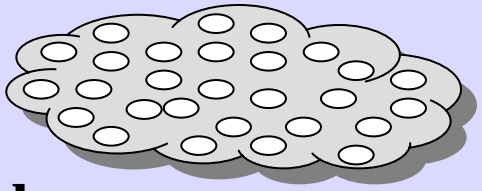
- **David Niemi, Dominique Ratte, Marc Deslauriers (Environment Canada):** *Canadian mercury emissions inventory data*

- **Mark Castro (Univ. Md, Frostburg), Fabien Laurier (Univ Md Ches Biol Lab), Rob Mason (Univ CT), Laurier Poissant (Envr Can):** *ambient Hg data for model evaluation*

- **Roland Draxler, Glenn Rolph, Rick Artz (NOAA):** *HYSPLIT model and met data*

- **Steve Brooks, Winston Luke, Paul Kelley (NOAA) :** *ambient Hg data*

# Thanks!



**For more information on this research:**

**http://www.arl.noaa.gov/ss/transport/cohen.html**