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

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Hg from other sources: local, regional & more distant

emissions of Hg(0), Hg(II), Hg(p)

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 from other sources: local, regional & more distant

emissions of Hg(0), Hg(II), Hg(p)

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

- Cooperative Oxford Lab (38.678°N, 76.173°W)
- Wye Research and Education Center (38.9131°N, 76.1525°W)

Map showing locations:
- Baltimore, MD
- Washington, DC
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?
Oxford July 3, 2004 -- one day after Peak Concentration in RGM

1999 RGM Emissions (kg/yr)
- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 400
- 400 - 600
- 600 - 1000

Type of Emissions Source
- red: coal-fired electricity generation
- blue: waste incineration
- yellow: manufacturing
- gray: metallurgical
- green: other fuel combustion

BackTrajectory Starting Height = 1000 m

BackTrajectory Starting Height = 100 m

BackTrajectory Starting Height = 500 m
Measured Atmospheric Concentrations at Oxford MD, Summer 2004

Another peak RGM concentration period
Measured Atmospheric Hg Concentrations at Oxford, MD, June 25-30, 2004

RGM and Hg(p) concentration (pg/m³)

Hg(0) concentration (pg/m³)

RGM and Hg(p) concentration (pg/m³)

Hg(0) concentration (pg/m³)


0 50 100 150 200

1500 2000 2500 3000 3500
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
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

NOAA HYSPLIT MODEL
Backward trajectory ending at 12 UTC 27 Jun 04
EDAS Meteorological Data

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

NOAA HYSPLIT MODEL
Backward trajectory ending at 15 UTC 27 Jun 04
EDAS Meteorological Data

Oxford monitoring site

Local time (UTC – 4)

RGM and Hg(p) concentration (pg/m3)
symbol color indicates type of mercury source:
- red: coal-fired power plant
- blue: waste incinerator
- yellow: manufacturing and other
- green: other fuel combustion

symbol size is proportional to 1999 Hg(II) emissions rate:
- 150 kg/yr
- 100 kg/yr
- 50 kg/yr

Oxford monitoring site

NOAA HYSPLIT MODEL
Backward trajectory ending at 18 UTC 27 Jun 04
EDAS Meteorological Data

Local time (UTC – 4)
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

NOAA HYSPLIT MODEL
Backward trajectory ending at 21 UTC 27 Jun 04
EDAS Meteorological Data

Oxford monitoring site

RGM and Hg(p) concentration (pg/m^3)

Local time (UTC – 4)

Meters AGL
symbol color indicates type of mercury source
- coal-fired power plant
- waste incinerator
- manufacturing and other
- other fuel combustion

globe size is proportional to 1999 Hg(II) emissions rate
- 150 kg/yr
- 100 kg/yr
- 50 kg/yr

NOAA HYSPLIT MODEL
Backward trajectory ending at 00 UTC 28 Jun 04
EDAS Meteorological Data

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
1999 RGM emissions near Oxford, Maryland

Symbol color indicates type of mercury source:
- red: coal
- blue: incinerator
- gray: metals
- yellow: manuf/other
- green: other fuel

Symbol size and shape indicates 1999 emissions of Hg(II) (kg/yr):
- circle: 10 - 20
- triangle: 20 - 50
- square: 50 - 100
- circle: 100 – 200

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

- 9 AM - 7 PM
- other times

Wind speed and 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)
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.

Large Incinerators: 3 medical waste, 1 MSW, 1 haz waste (Total Hg ~ 500 kg/yr)

Bremo

Beltsville monitoring site

Brunner Island

Large Incinerators: 3 medical waste, 1 MSW, 1 haz waste (Total Hg ~ 500 kg/yr)

Harford County MSW Incin

Brandon Shores and H.A. Wagner

100 miles from DC

Montgomery County MSW Incin

Dickerson

Arlington - Pentagon MSW Incin

Possum Point

Bremo

Eddystone

Chalk Point

Morgantown

Brunner Island

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

Measurement of ambient air concentrations
Measurement of wet deposition
atmospheric deposition to the water surface

Series 3300 CEM - Continuous Speciated Mercury Data
Resolution: 2.5 min  Duration: 11 Days

Seri es 3300 CEM - C ontinuous Speciated M ercury D ata
R esol ution: 2 .5   m i n  D uration: 11   D ays

- HgT
- Hg0
- Hg2

25-Aug 20-Aug 27-Aug 28-Aug 30-Aug 31-Aug 01-Sep 02-Sep 03-Sep 04-Sep 05-Sep
Hg - (ug/m³)
0 2 4 6 8 10 12
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?
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

Overall Budget of Power Plant

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

Cost of Electricity

0.10/kw-hr → 0.10001/kw-hr
$1000/yr → $1000.10/yr
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Thanks!

For more information on this research:
http://www.arl.noaa.gov/ss/transport/cohen.html