Organization of Course

INTRODUCTION

1. Course overview
2. Air Toxics overview
3. HYSPLIT overview

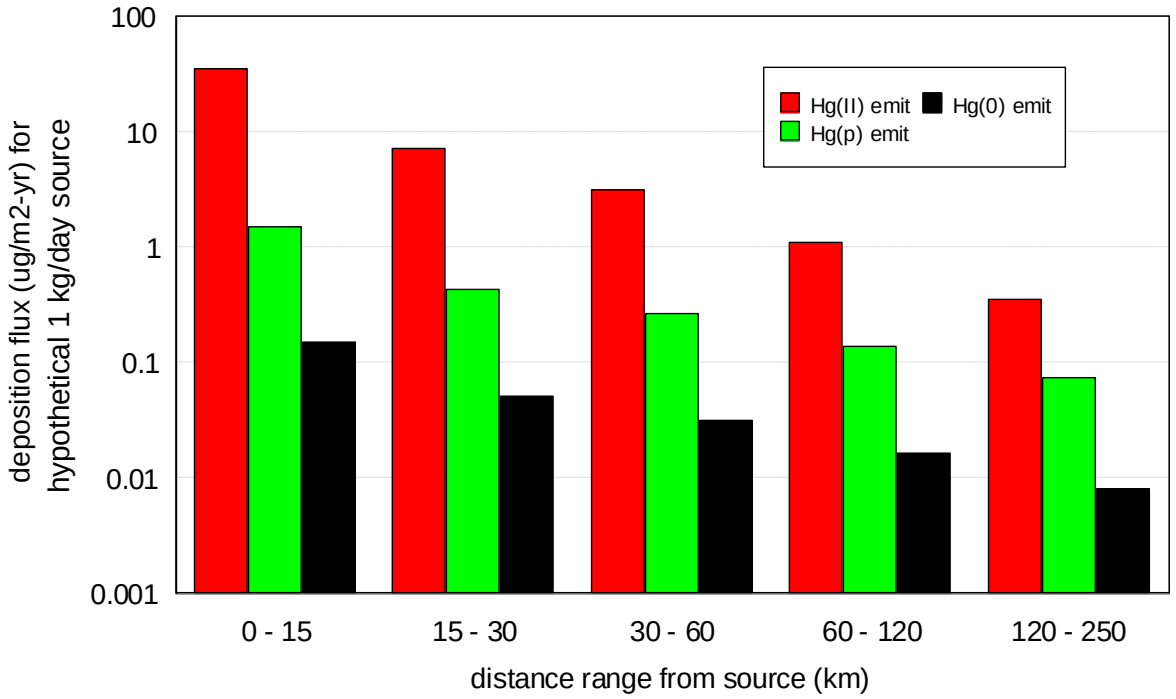
HYSPLIT Theory and Practice

4. Meteorology
5. Back Trajectories
6. Concentrations / Deposition
7. HYSPLIT-SV for semivolatiles (e.g, PCDD/F)
8. HYSPLIT-HG for mercury

Overall Project Issues & Examples

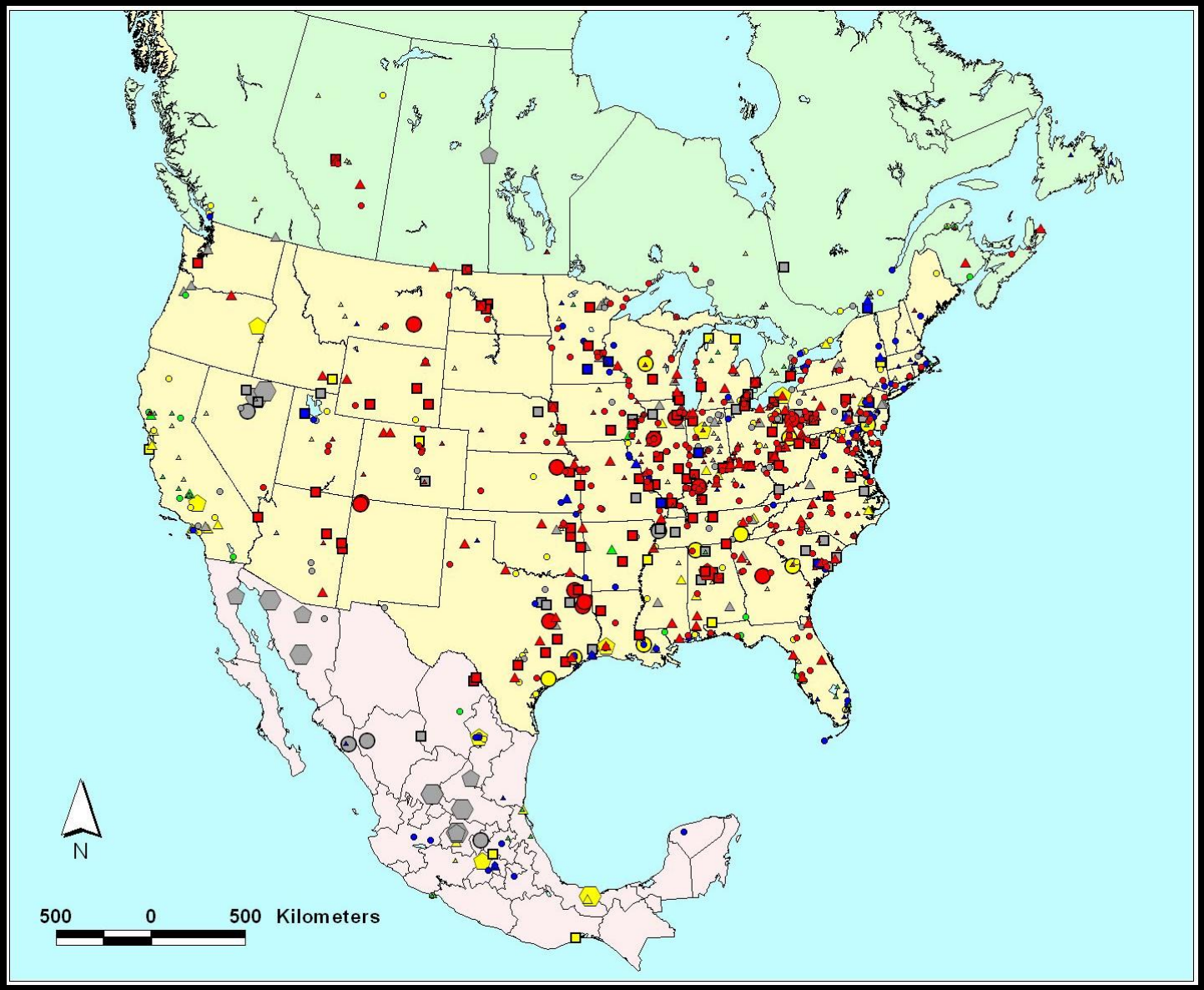
9. **Emissions Inventories**
10. Source-Receptor Post-Processing
11. Source-Attribution for Deposition
12. Model Evaluation
13. Model Intercomparison
14. Collaboration Possibilities

Mercury Emissions Inventories



For atmospheric modeling, MUST BE SPECIATED

Elemental Mercury -- Hg(0) -- Emissions to the Air



size/shape of symbol denotes amount of mercury emitted (kg/yr)

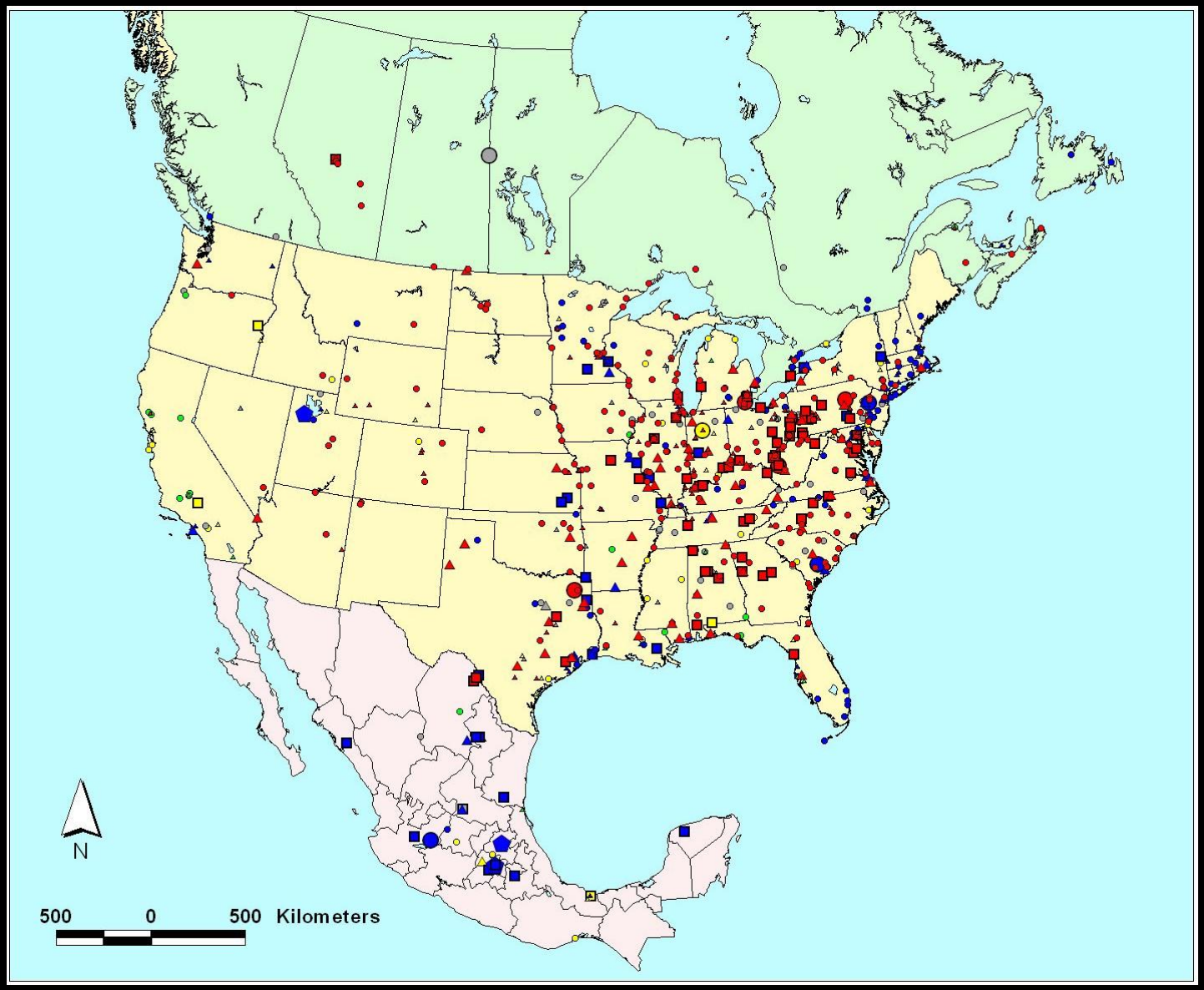
△	5 – 10
○	10 – 50
△	50 – 100
□	100 – 300
○	300 – 500
⬠	500 – 1000
⬡	1000 – 3500

color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
1999 Mexican data from inventory prepared by *Acosta y Asociados* for the Commission for Environmental Cooperation

Reactive Gaseous Mercury – RGM -- Emissions to the Air



size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5 – 10
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Particulate Mercury -- Hg(p) -- Emissions to the Air

size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5 – 10
○	10 – 50
△	50 – 100
□	100 – 300
○	300 – 500
⬠	500 – 1000
⬡	1000 – 3500

color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
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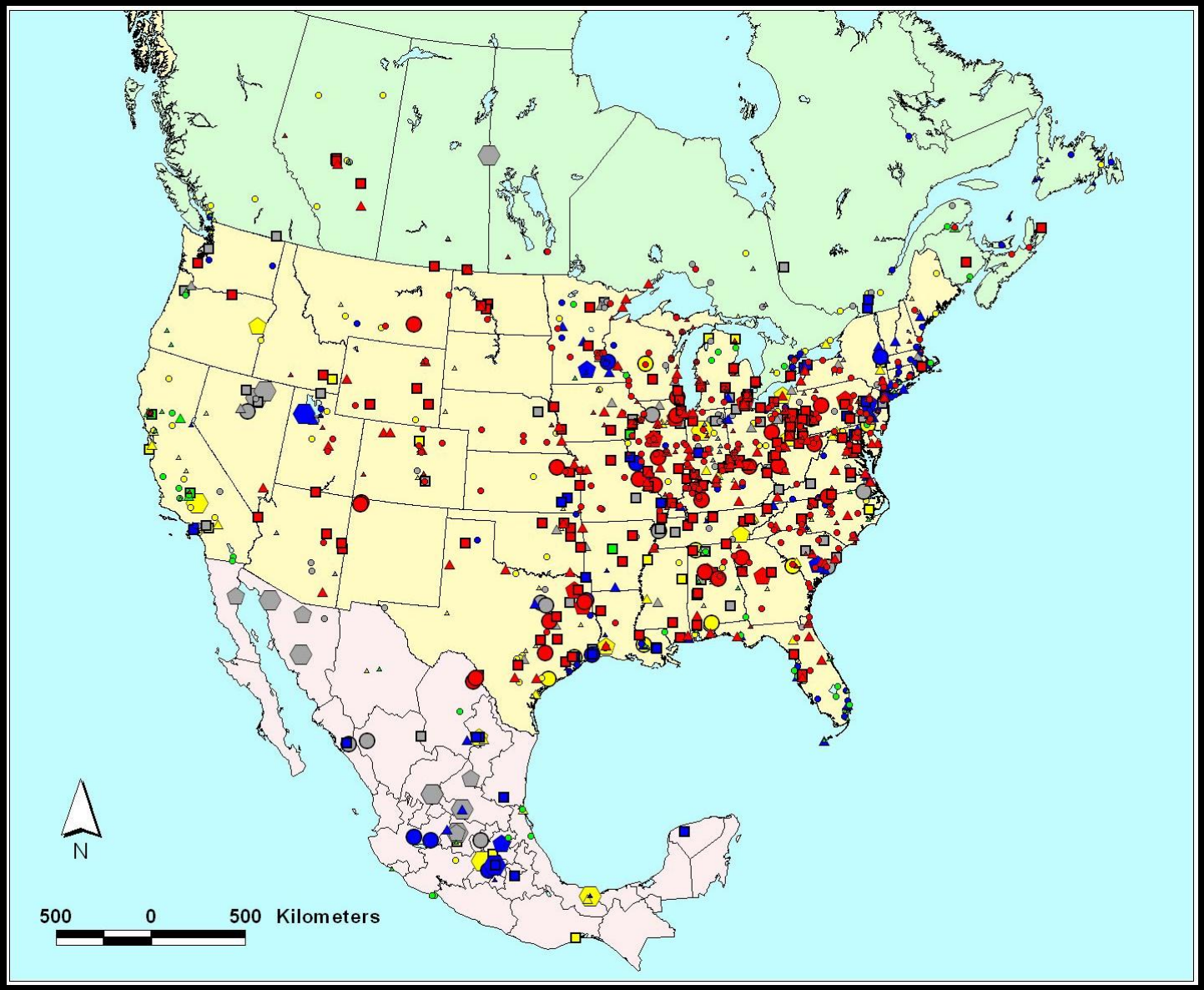
Total Mercury Emissions to the Air [Hg(0) + RGM + Hg(p)]



size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5 – 10
○	10 – 50
△	50 – 100
□	100 – 300
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color of symbol denotes type of mercury source

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- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
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Some events in the U.S. regulation and prevention of mercury emissions

1965

1970

1975

1980

1985

1990

1995

2000

2005

2010

1970's - 1990's: many mercury-cell chlor-alkali plants converted to alternate processes or closed due to regulatory and other pressures

Clean Air Act Amendments of 1990 – calls for Maximum Achievable Control Technology (MACT) to regulate hazardous air pollutants; *intent is to prohibit emissions trading for these air toxics*

1990's – Hg emissions from municipal and medical waste incinerators fall dramatically due to:

- **closure of *some* municipal waste incinerators and *many* medical waste incinerators**
- **MACT-related pollution control requirements**
- **reduction in mercury content of waste (e.g., battery legislation)**

2002 – Clear Skies Initiative for power plants introduced *(ultimately withdrawn)*

2005 – CAIR (Clean Air Interstate Rule) for power plants (Hg reduced as co-benefit of SO_2 & NO_x controls)

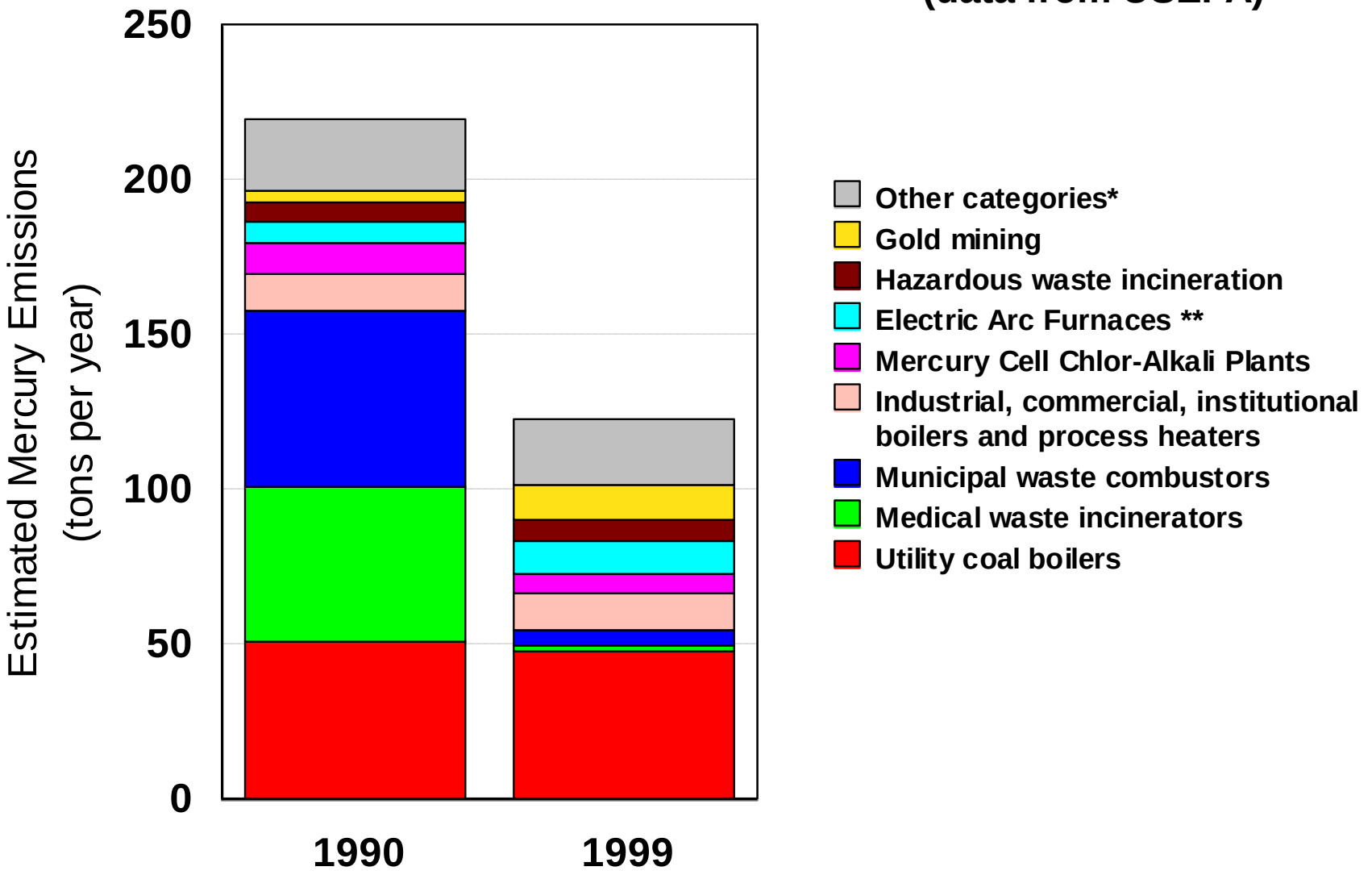
2005 – EPA meets court-ordered deadline and promulgates CAMR (Clean Air Mercury Rule) for power plants – *based on Hg emissions trading*

"Hot Spot" Controversy -- Many States sue EPA & propose / promulgate more strict regulations

2008 – CAMR and CAIR overturned... What is next?

Direct, Anthropogenic Mercury Emissions in the United States

(data from USEPA)

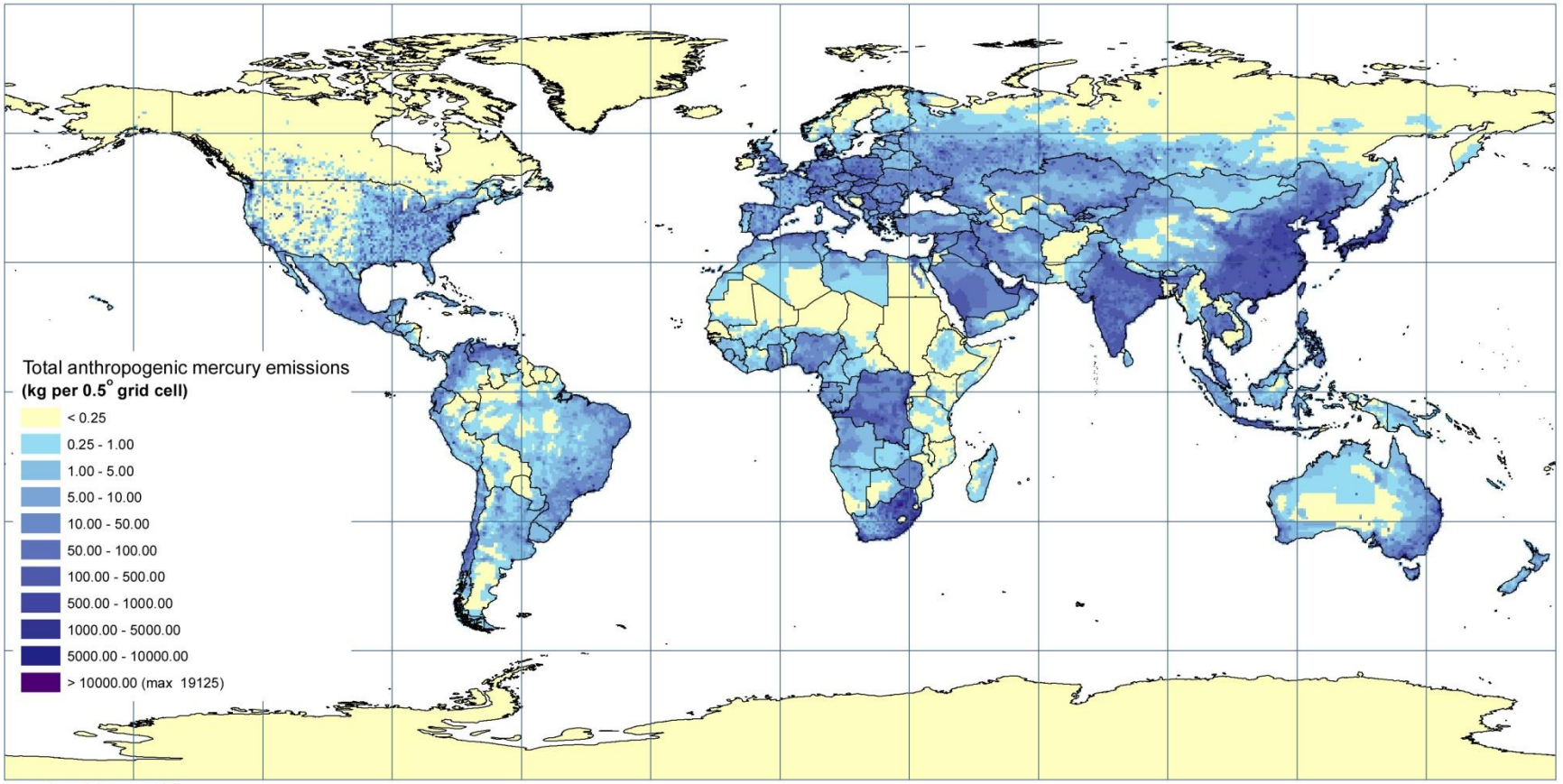


* Data for Lime Manufacturing are not available for 1990.

** Data for Electric Arc Furnaces are not available for 1999. The 2002 estimate (10.5 tons) is shown here.

Spatially Distributed Inventories of Global Anthropogenic Emissions of Mercury to the Atmosphere, 2000

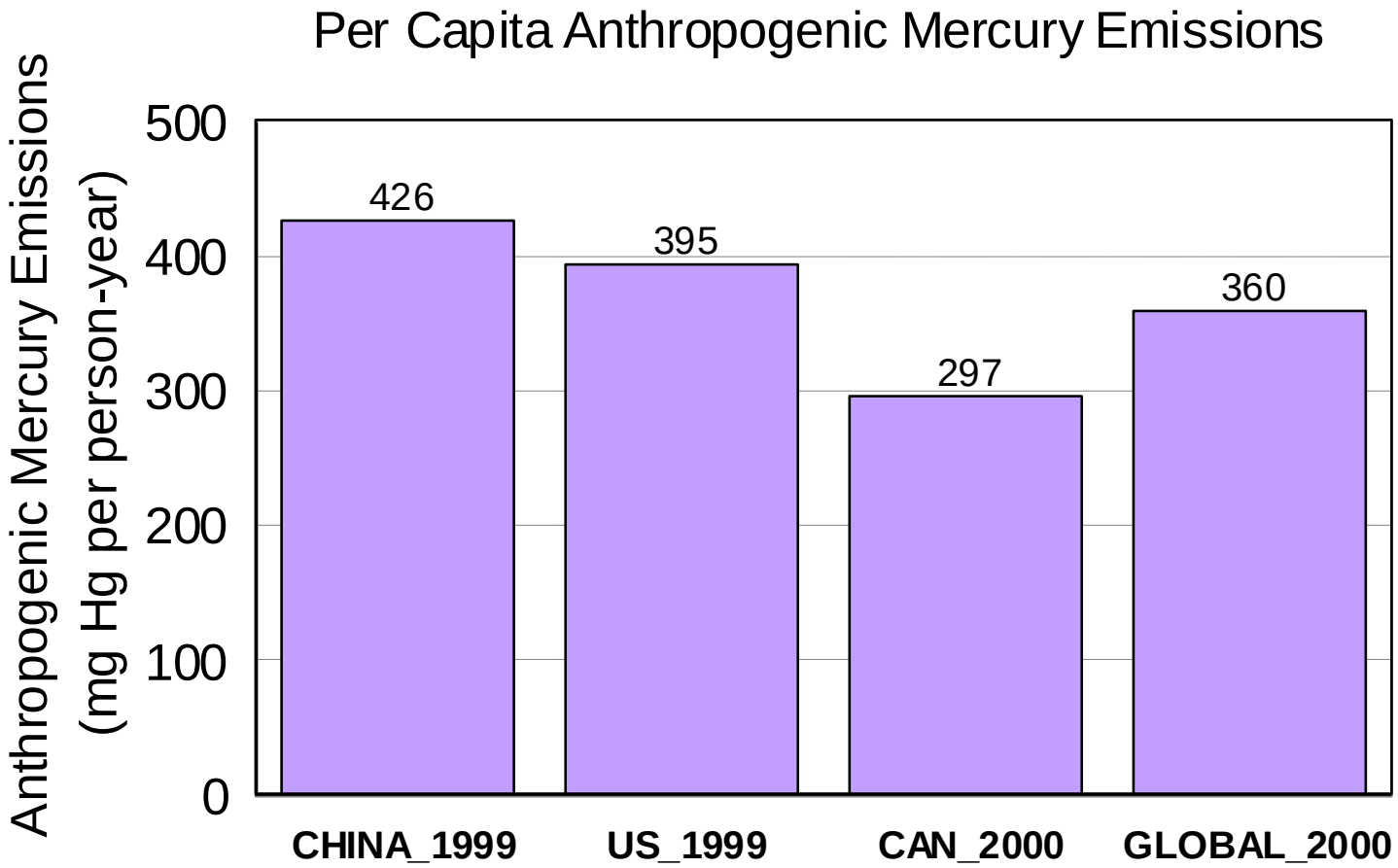
Total Hg, point sources + distributed sources, 0.5° grid



unprojected (geographic)

citation:
Pacyna, J., S. Wilson and F. Steenhuisen. 2005.
Spatially Distributed Inventories of Global Anthropogenic Emissions of Mercury to the Atmosphere.
(www.amap.no/Resources/HgEmissions/HgInventoryMain.html)

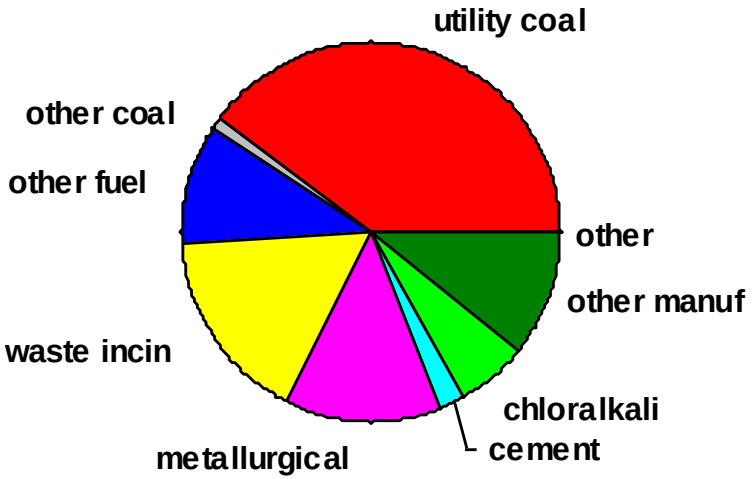
S. Wilson (AMAP), F. Steenhuisen (Arctic Centre, RuG), J. Pacyna (NILU)



Source of global data: Global Anthropogenic Mercury Emission Inventories for 2000 and 1995: Pacyna, J. and E. Pacyna. Journal of Air and Waste Management Association (in prep. 2005); *http://www.amap.no/Resources/HgEmissions/HgInventoryDocs.html*

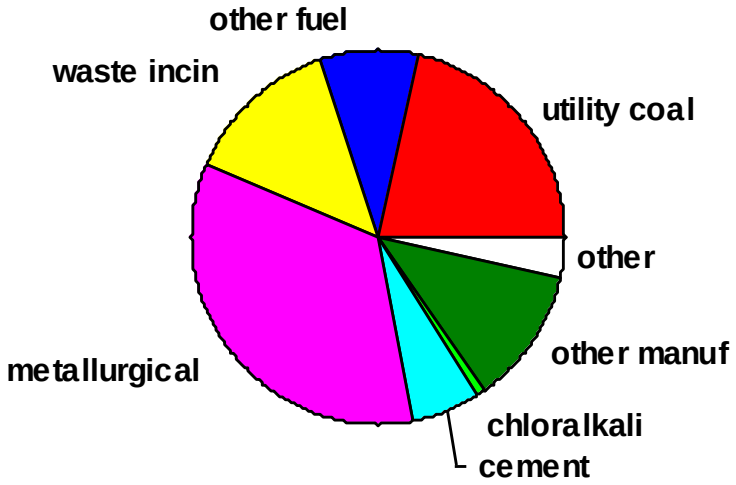
Different patterns of anthropogenic mercury emissions

U.S. Anthopogenic Mercury Emissions, 1999



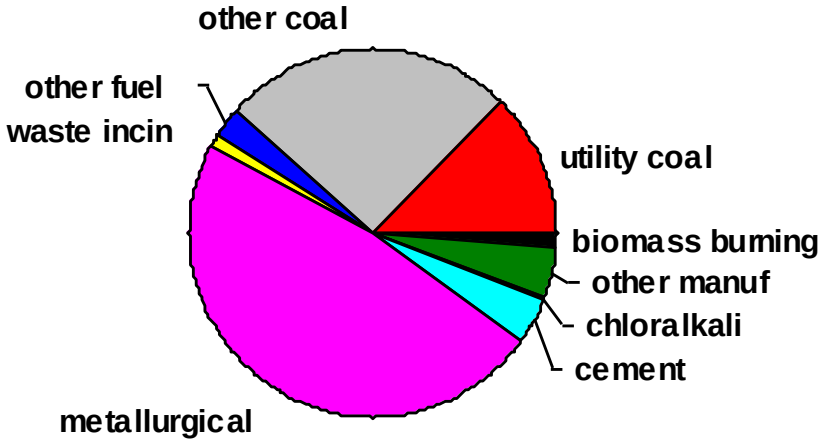
Source: U.S. EPA

Canada Anthopogenic Mercury Emissions, 2000



Source: Environment Canada

China Anthopogenic Mercury Emissions, 1999



Source: Streets et al., 2005, "Anthropogenic mercury emissions in China", Atmospheric Environment 39, 7789-7806

Some Current Emissions Inventory Challenges

- Re-emissions of previously deposited anthropogenic Hg
- Emissions speciation [at least among Hg(0), Hg(II), Hg(p); more specific species if possible]
- Reporting and harmonization of source categories
- Mobile source emissions?
- Enough temporal resolution to know when emissions for individual point sources change significantly

  Note: Hg continuous emissions monitors now commercially available

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*

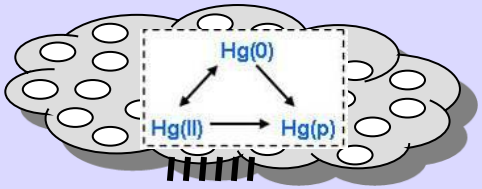
We don't have information about major events

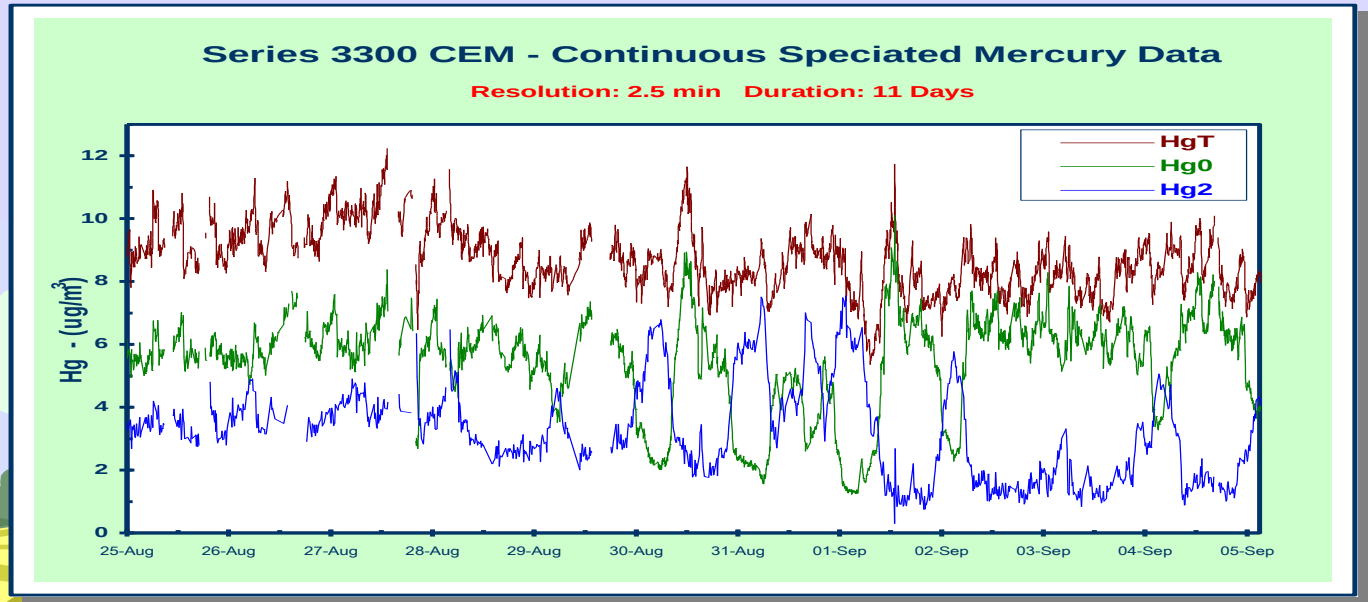
- *e.g., maintenance or permanent closures, installation of new pollution control devices, process changes*
- *Therefore, difficult to interpret trends in ambient data*

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?*

Hg from other sources: local, regional & more distant

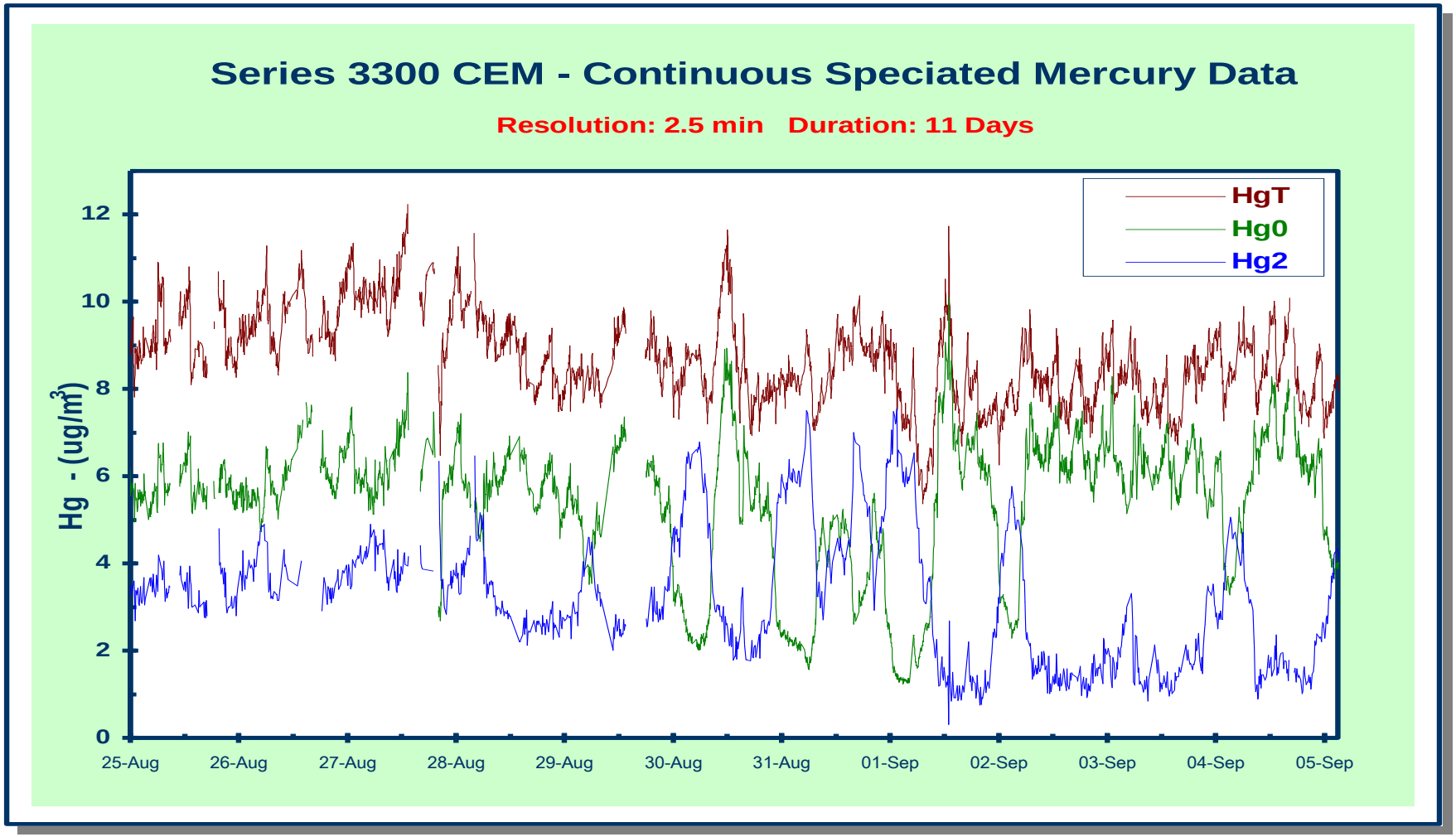




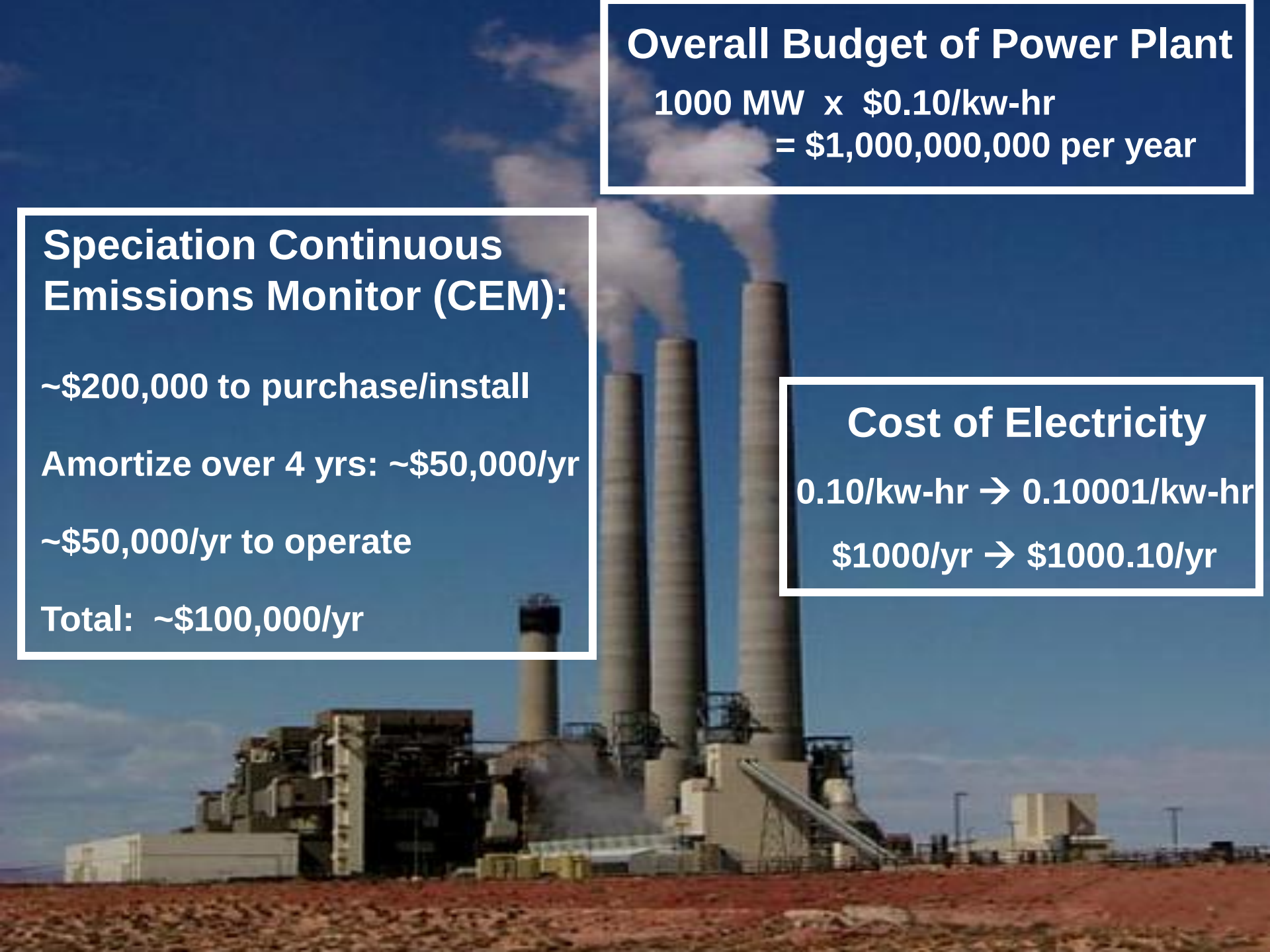
atmospheric deposition to the water surface

Measurement of wet deposition

Measurement of ambient air concentrations



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



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

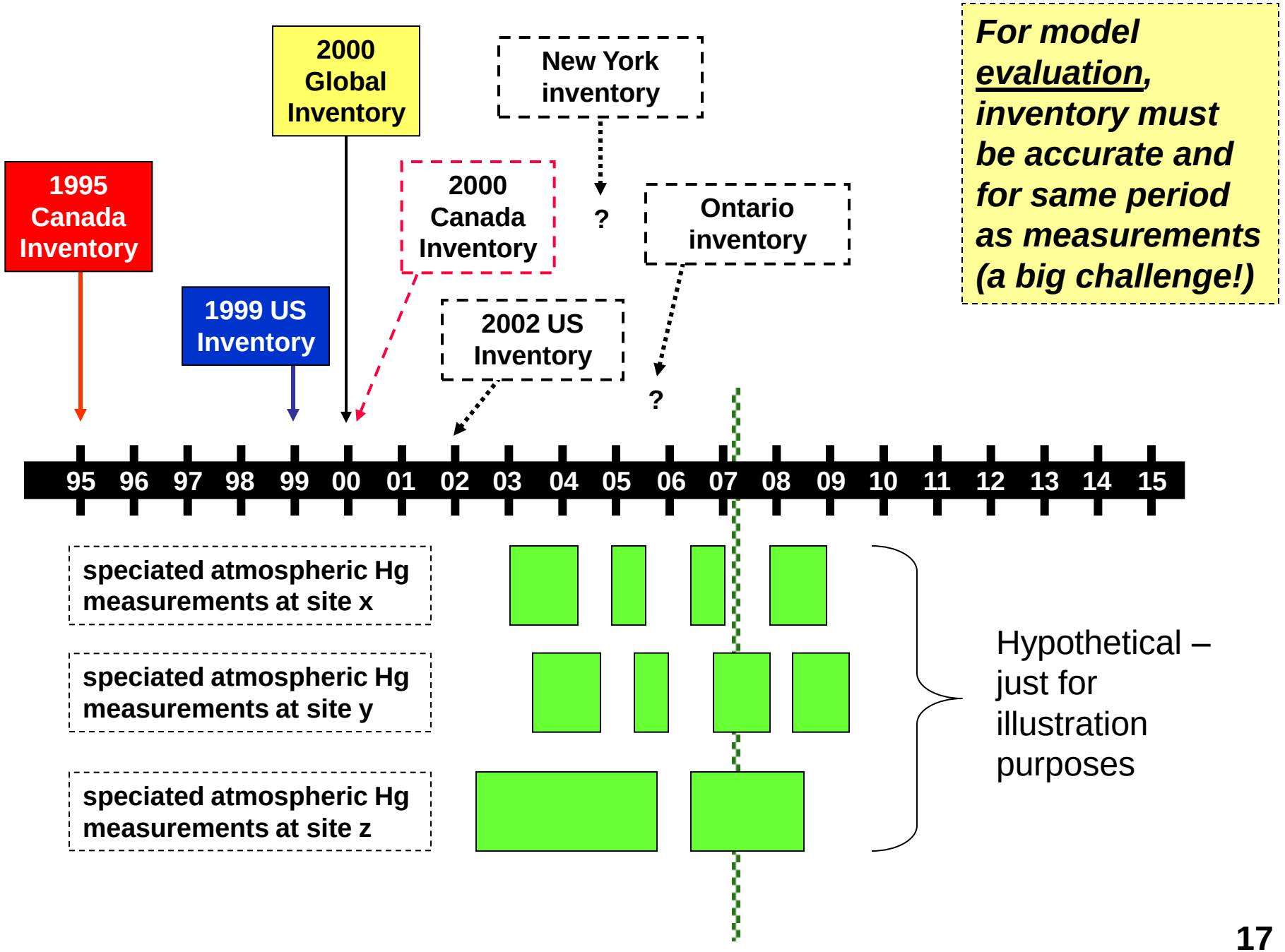
~$50,000/yr to operate

Total: ~$100,000/yr

Cost of Electricity

0.10/kw-hr → 0.10001/kw-hr

$1000/yr → $1000.10/yr



For model <u>evaluation</u>, inventory must be accurate and for same period as measurements (a big challenge!)