

# Global Atmospheric Transport and Source-Receptor Relationships for Arsenic

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# Why do we care?

5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.998
13 <b>Al</b> Aluminum 26.982	14 <b>Si</b> Silicon 28.086	15 <b>P</b> Phosphorus 30.974	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.453
31 <b>Ga</b> Gallium 69.732	32 <b>Ge</b> Germanium 72.61	33 <b>As</b> Arsenic 74.922	34 <b>Se</b> Selenium 78.09	35 <b>Br</b> Bromine 79.904
49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.904

- Very toxic – historically called the "king of poisons" and also "poison of kings"
- **Group 1 carcinogens** listed by IARC - cause cancer in the skin, lungs, bladder and kidney...
- Can also cause a variety other diseases, such as high blood pressure, heart attacks, blackfoot disease ...

➤ EU set standard for atmospheric arsenic concentration in 2013: annual mean =  $6 \text{ ng m}^{-3}$

➤ U.S. EPA has not set standards for atmospheric As (only for drinking water = 10 ppb), but might be possible in the future ...

# Worrisome levels of arsenic in (U.S.) food



Product	Origin	Total arsenic (ppb) <sup>1</sup>	Inorganic arsenic (micrograms/serving) <sup>2</sup>
<b>RICE (45 g, about ¼ cup uncooked)</b>			
<b>365 Everyday Value Long Grain Brown (Whole Foods)</b>	3	210 to 282	<b>7.4 to 8.4</b>
<b>365 Everyday Value Organic Indian Basmati White (Whole Foods)</b>	India	82.2 to 99.9	2.9 to 3.5
<b>365 Everyday Value Organic Thai Jasmine White (Whole Foods)</b>	Thailand	104 to 150	2.7 to 3.0
<b>Archer Farms Organic Basmati (Target)</b>	India	54.7 to 81.7	1.3 to 2.2
<b>Archer Farms Organic Jasmine (Target)</b>	Thailand	112 to 121	2.7 to 3.9
<b>Cajun Country Enriched Long Grain</b>	LA	328 to 348	4.8 to <b>5.2</b>
<b>Cajun Country Popcorn Long Grain</b>	LA	350 to 436	3.9 to <b>5.3</b>
<b>Canilla Extra Long Grain Enriched</b>	U.S.	198 to 431	3.2 to <b>7.2</b>
<b>Carolina Enriched Extra Long Grain Long Grain</b>	AR,LA,TX	144 to 236	3.4 to 4.8
<b>Carolina Jasmine Enriched Thai Fragrant Long Grain</b>	Thailand	119 to 159	3.0 to 3.2
<b>Carolina Whole Grain Brown</b>	AR,LA,TX	277 to 318	<b>6.4 to 8.7</b>
<b>Della Basmati Brown</b>	AR	308 to 568	<b>5.9 to 9.4</b>
<b>Della Basmati White</b>	AR	191 to 227	3.5 to 4.5
<b>Doguet's Brown</b>	U.S.	283 to 342	<b>5.6 to 6.4</b>
<b>Doguet's Enriched Long Grain</b>	U.S.	124 to 219	3.3 to 4.4
<b>Goya Enriched Medium Grain</b>	3	196 to 297	3.8 to <b>5.1</b>
<b>Great Value Brown (Walmart)</b>	U.S.	212 to 344	<b>5.2 to 6.8</b>
<b>Great Value Parboiled (Walmart)</b>	U.S.	138 to 239	4.1 to 4.4
<b>Jazzmen Louisiana Aromatic Brown</b>	LA	237 to 295	4.7 to <b>8.6</b>
<b>Jazzmen Louisiana Aromatic White</b>	LA	168 to 209	3.2 to 4.1
<b>Lundberg California White Basmati</b>	CA	64.3 to 75.5	1.3 to 1.6
<b>Lundberg Short Grain Brown</b>	CA	169 to 204	3.8 to <b>5.4</b>
<b>Mahatma Extra Long Grain Enriched</b>	U.S.	129 to 284	3.4 to 4.9
<b>Market Pantry Enriched Long Grain White (Target)</b>	AR,LA,TX	184 to 254	4.0 to 4.6
<b>Martin Long Grain Brown</b>	MO	113 to 455	3.7 to <b>9.6</b>
<b>Martin Long Grain Enriched</b>	MO	133 to 193	2.3 to 3.4
<b>Rice-Select Organic Texmati White</b>	TX	330 to 917	3.8 to 4.8
<b>Texas Best Organics Long Grain Brown</b>	TX	252 to 287	4.2 to <b>7.6</b>
<b>Texas Best Organics Long Grain White</b>	TX	138 to 226	3.2 to 4.3
<b>Trader Joe's White Basmati From India</b>	India	75.9 to 86.0	2.5 to 2.9
<b>Uncle Ben's Original Enriched Parboiled Long Grain</b>	U.S.	220 to 246	<b>5.9 to 6.3</b>
<b>Uncle Ben's Whole Grain Brown</b>	U.S.	209 to 285	<b>5.7 to 6.7</b>

“Organic rice baby cereal, rice breakfast cereals, brown rice, white rice—new tests by Consumer Reports have found that those and other types of rice products on grocery shelves contain arsenic, many at worrisome levels.”

<http://consumerreports.org/cro/arsenicinfood.htm>

# Major sources of arsenic emissions into the atmosphere

## ➤ Anthropogenic sources

- metal (copper, zinc and lead) smelting
- coal combustion
- herbicide application
- wood preservation
- waste incineration

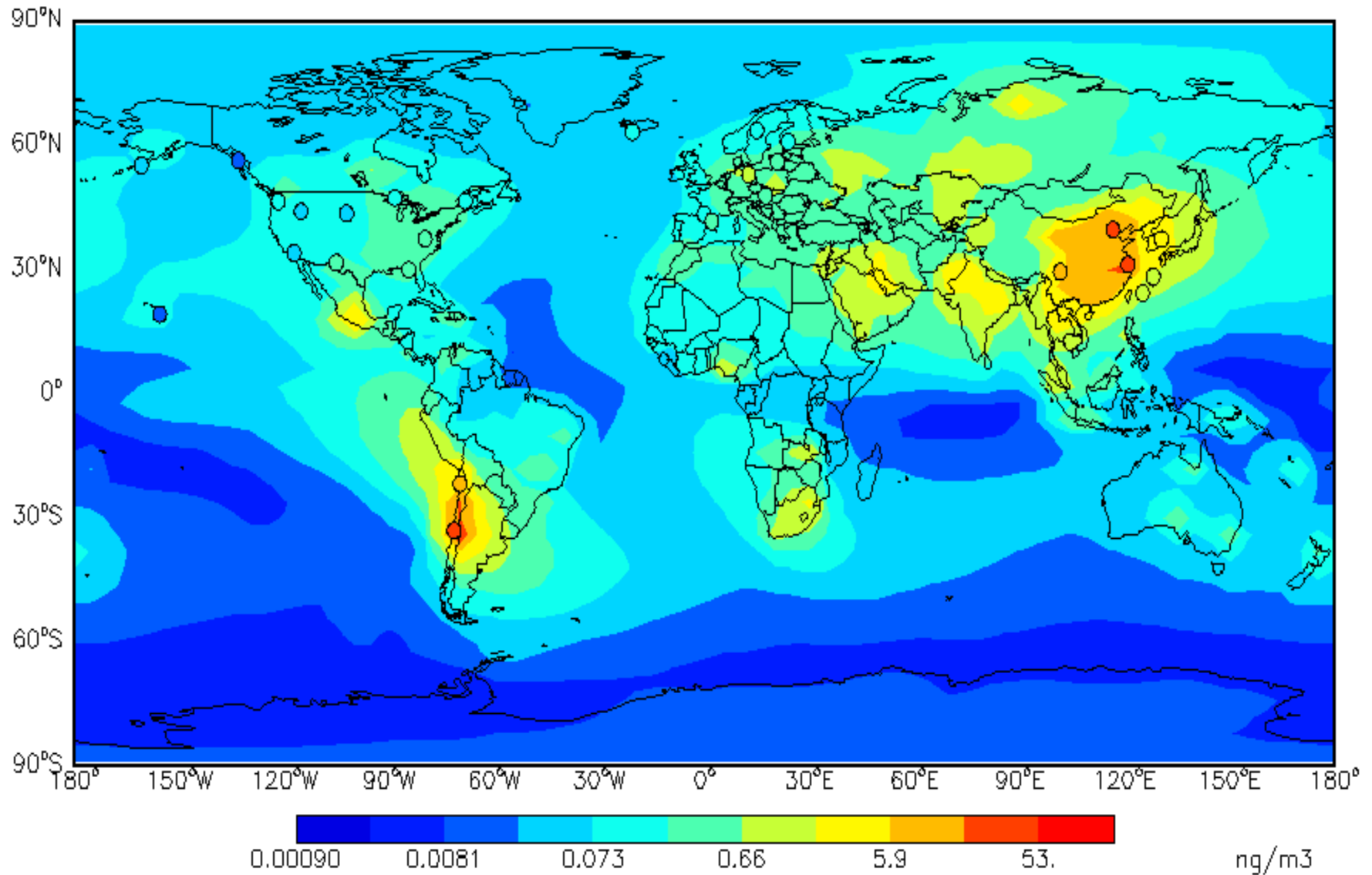
## ➤ Natural sources

- volcano emissions
- wind erosion
- biological activities

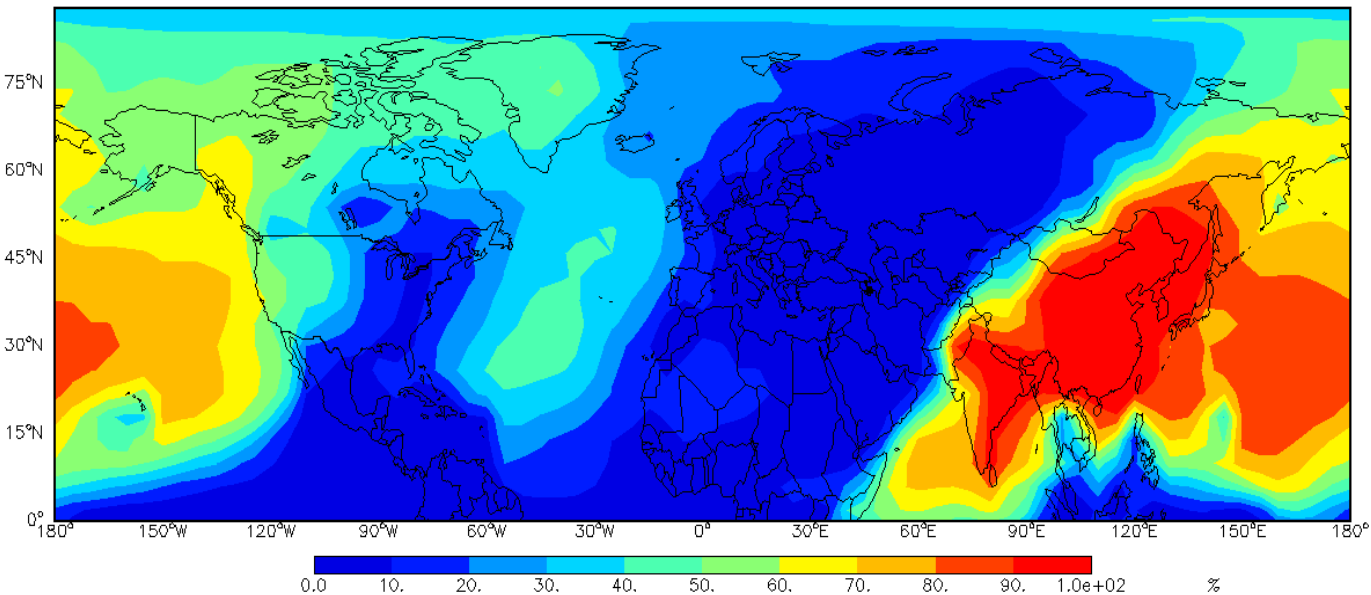
# Developing the global arsenic emission inventory

- **United States – EPA 1999 inventory**
- **EU – ESPREME 2000**
- **Canada - Environment Canada's National Pollutant Release Inventory**
- **Australia - National Pollutant Inventory**
- **Chile - Gidhagen et al, AE 36, 3803-3817, 2002.**
- **China**
  - calculated arsenic emissions by applying emission factors to metal production (Cu, Pb and Zn smelting) and coal consumption.**
- **Other parts of the world**
  - take advantage of the available SO<sub>2</sub> inventory & apply the corresponding As/S ratios.**

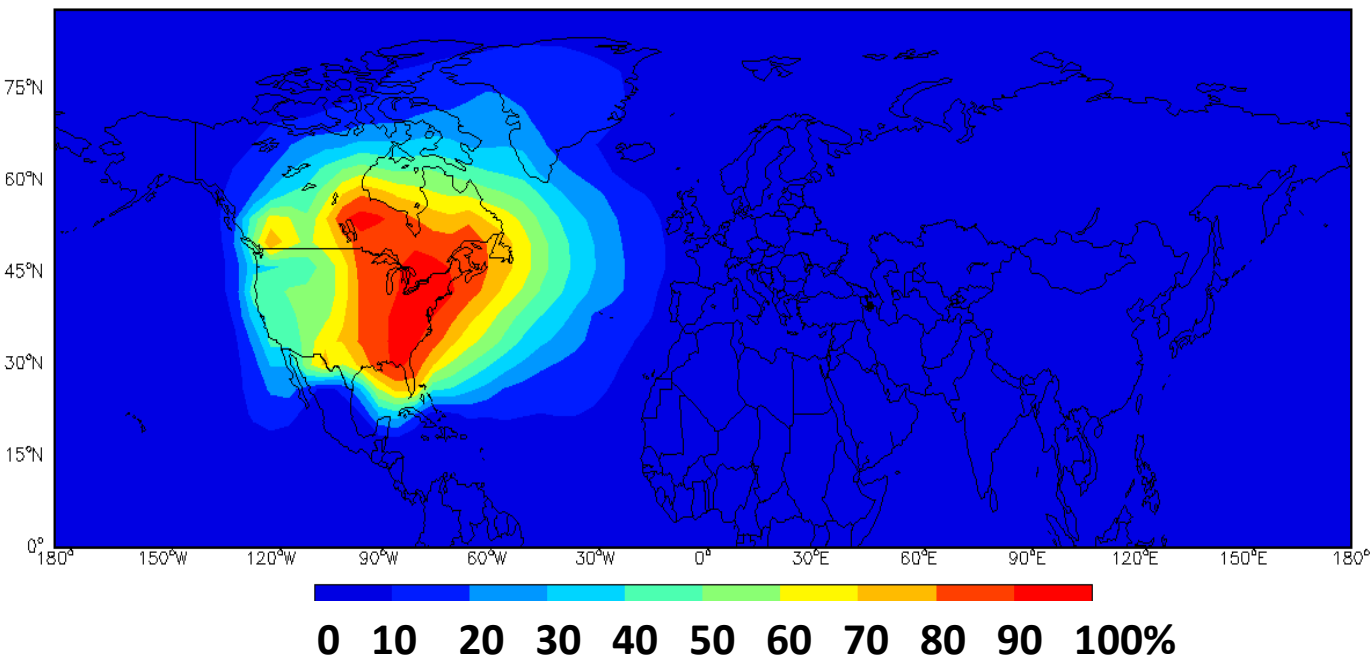
# Model evaluation - annual mean As concentrations in surface air compared with observations



# Source attribution of atmospheric arsenic deposition



**% contribution  
from Asia**



**% contribution from  
North America**

# Global source-receptor relationships for atmospheric As concentration (deposition) shown as % contribution

## Source regions

	Source regions		
	Asia	Europe	North America
Asia (10 – 70°N, 60 – 145°E)	54.4 (56)	4.4 (5.1)	0.1 (0.2)
Europe (35 – 70°N, 5°W – 60°E)	5.3 (8.4)	69.2 (61)	1.4 (2.1)
North America (30 – 70°N, 125 – 65°W)	22.4 (34.1)	2.2 (1.2)	57.2 (43.8)
Western US (30 – 48°N, 125 – 100°W)	31.7 (42.3)	0.4 (0.5)	48.9 (32.7)
Eastern US (30 – 48°N, 100 – 70°W)	7.4 (13.8)	0.2 (0.2)	86.3 (69.6)

Receptor regions



# Conclusions

- We have expanded the GEOS-Chem CTM for As simulation – we developed a global As inventory and performed the first study on the global atmospheric transport of arsenic;
- The model reproduces the observed arsenic concentrations in surface air for various sites around the world reasonably well;
- About 1/3 of the total arsenic deposition over North America is attributed to Asian emissions;
- Reduction of arsenic emissions over source regions (such as Asia and South America) could have significant environmental benefits globally.