Mercury concentrations and pools across 14 U.S. Forest Sites

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DRI Desert Research Institute

University of Nevada, Reno

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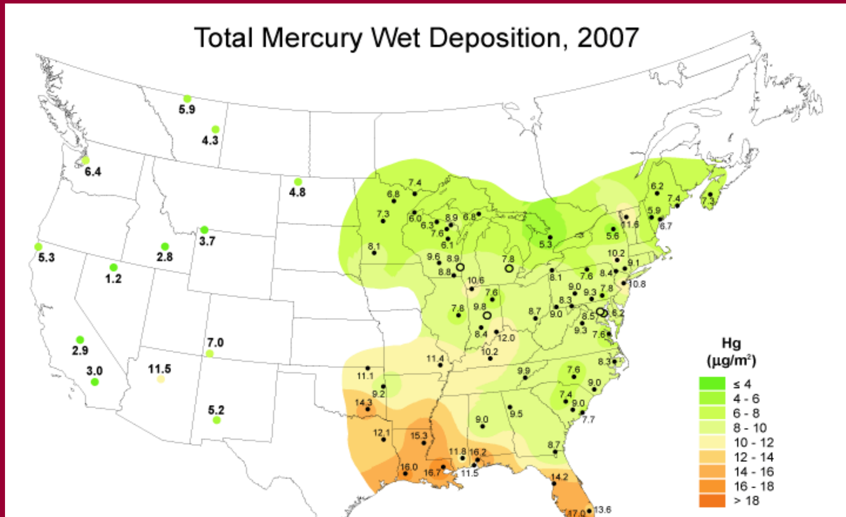
Effects of vegetation and organic carbon (C) on Hg cycling

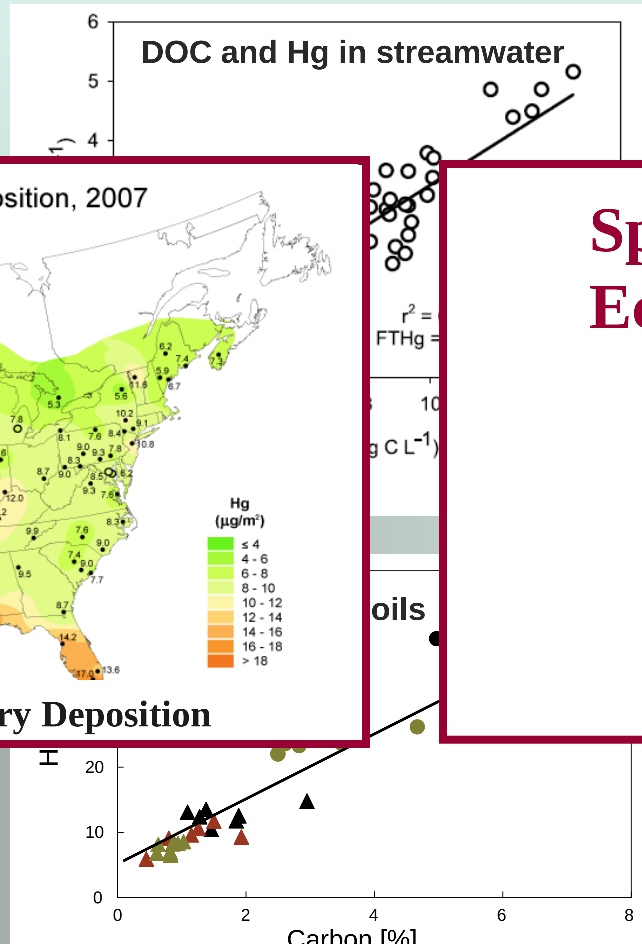
Deposition:

Retention/Mobilization:

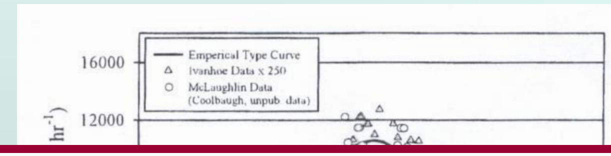
Emissions:

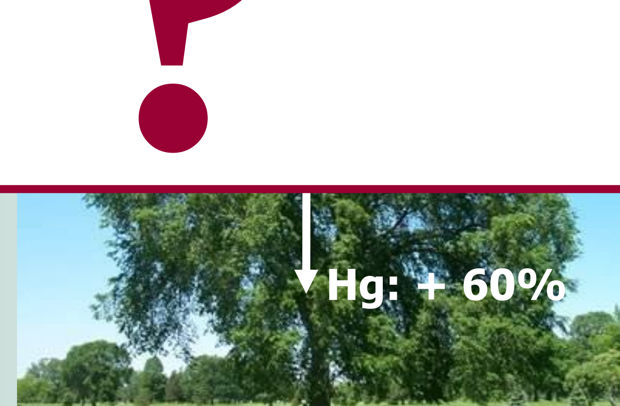


National Atmospheric Mercury Deposition Network



Obrist et al., 2009





Siwik et al. 2009

Spatial Distribution
Ecosystem control

?

Project Goal and Steps

To assess factors that drive Hg distribution in terrestrial ecosystems and fate processes of mercury in terrestrial pools

Project steps:

i. Systematically quantify Hg conc./pools sequestered in vegetation, litter, and soils
ii. Assess spatial distribution of Hg in respect to C, climate, meteorology
iii. Quantify fate of Hg during C mineralization in litter and soils
iv. Scaling up Hg concentrations/pools to contiguous US

Systematic sampling campaign: (no NADP sites!)


11. Bartlett, NH

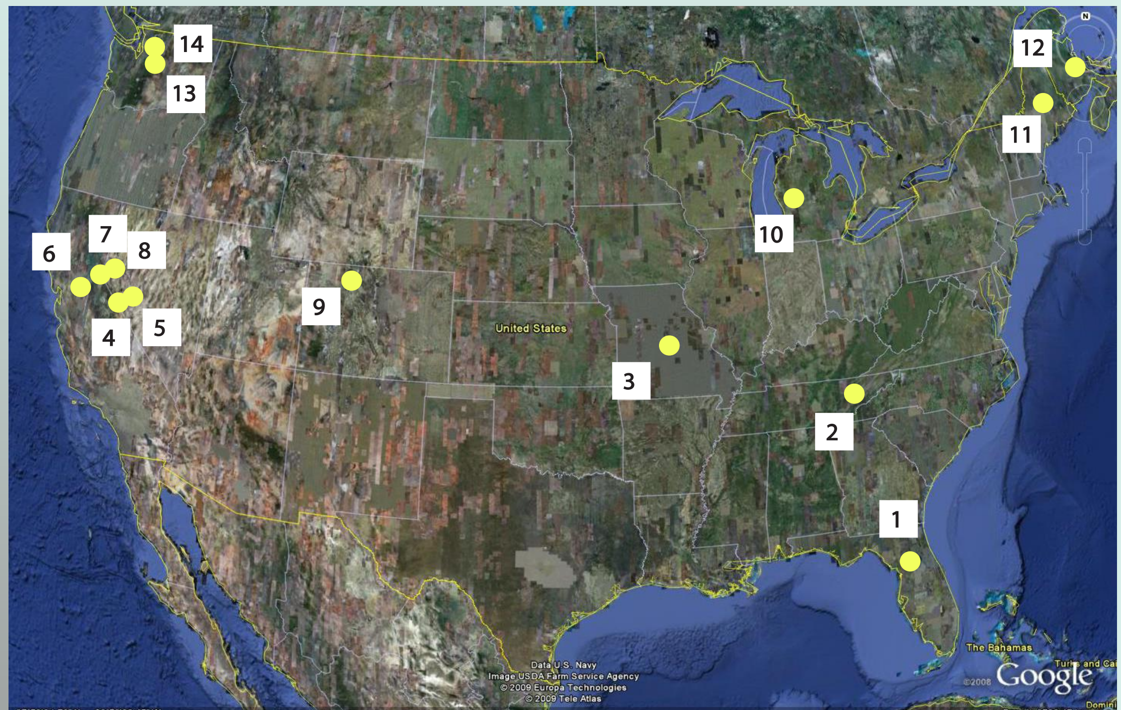

10. Hart, MI


9. Niwot Ridge, CO

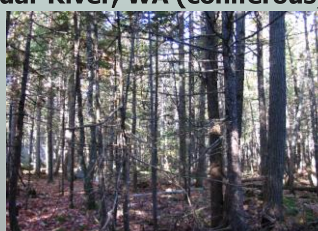

8. Truckee, CA


7. Truckee (post-fire)


12. Howland, ME




6. Marysville, CA


13. Cedar River, WA (coniferous)


5. Little Valley, NV


14. Cedar River, WA (Deciduous)


1. Gainesville, FL


2. Oak Ridge, TN

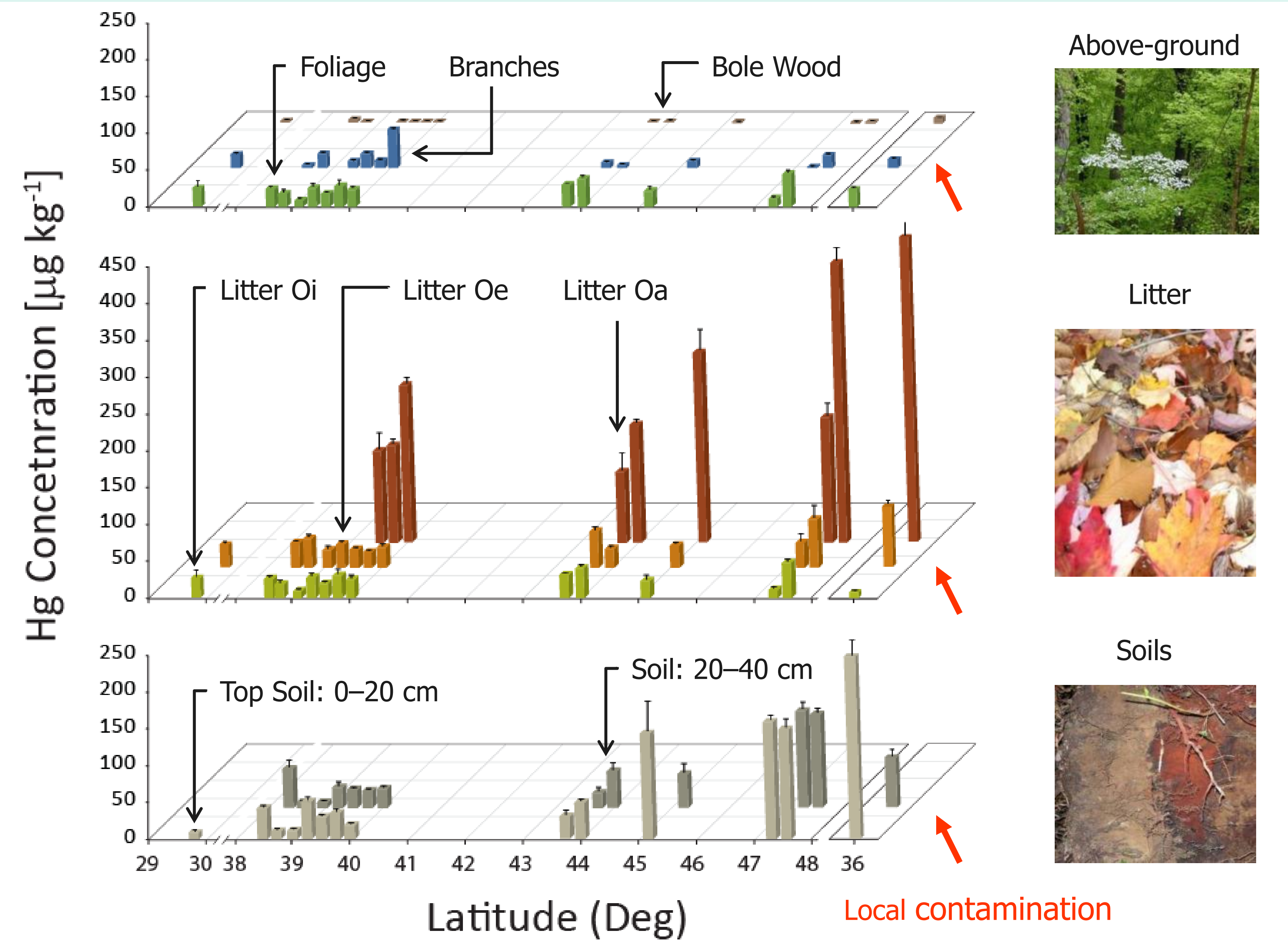

3. Ashland, MO


4. Little Valley, NV, postfire

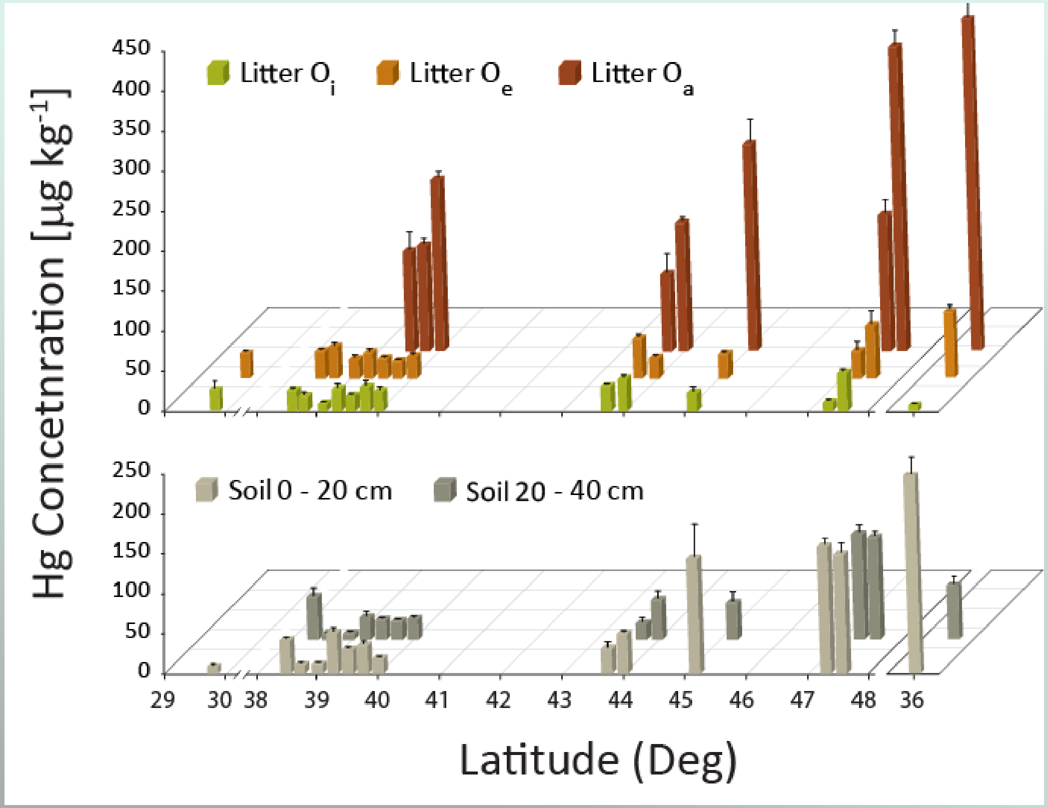
Systematic Sampling Campaign

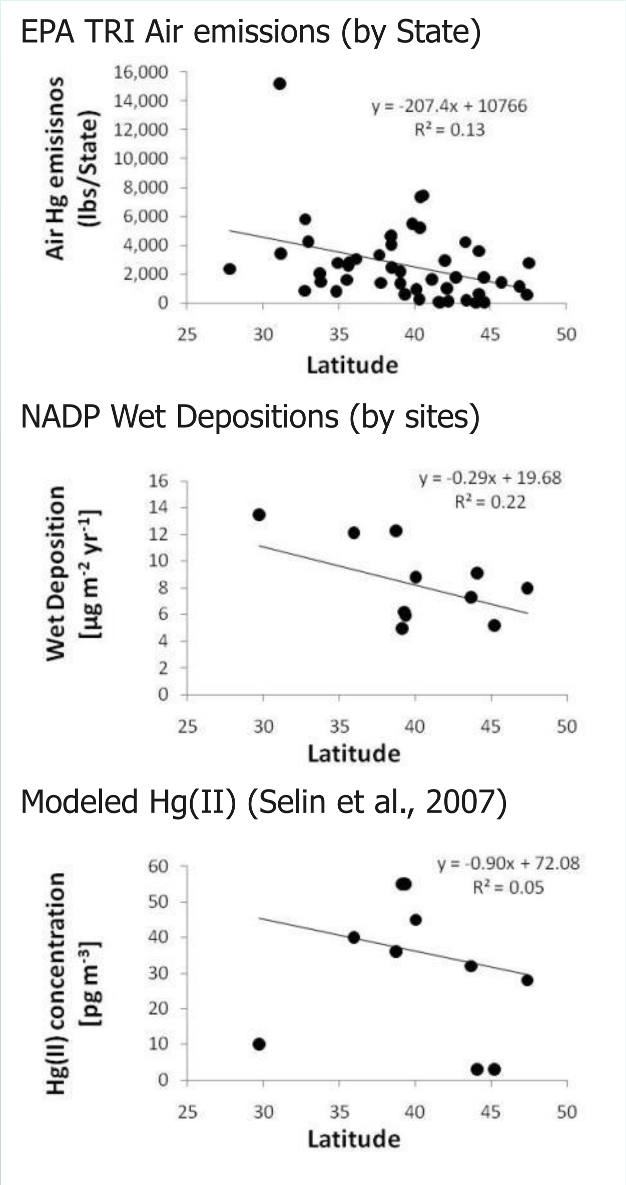
- Sampled all major ecosystem compartments, including major species (12 locations, n = 4 pooled samples/site/component)
- Analyzed for total Hg, Carbon, and Nitrogen concentrations
- Analyzed for methylated Hg (selected components)
- Developed full biomass, litter, soil C inventories on all sites
- Collected auxiliary site information

Results: Total Hg concentration



Total Hg: Spatial Patterns





- **No relationships to atmospheric pollution "measures"**
  - **EPA TRI Air Emissions**
  - **Wet deposition (MDN of NADP)**
  - **Modelled GEM and RGM concentrations or fluxes**

Total Hg: Spatial Patterns

Ecosystem Component	Latitude		Annual Precipitation		Soil Carbon (log)		Clay content		Multiple Regression (Latitude, Precipitation, Clay, Log(C)	
	P	r^2	*P*	r^2	*P*	r^2	*P*	r^2	*P*	r^2
Foliage	n.s.	-	<0.01	0.10					<0.01	0.10
Litter Oi	0.04	0.08	0.03	0.09					0.03	0.14
Litter Oe	<0.01	0.40	<0.01	0.21					<0.01	0.51
Litter Oa	<0.01	0.21	<0.01	0.23					0.02	0.24
Soil 0-10	<0.01	0.57	0.02	0.09	*<0.01*	0.39	<0.01	0.23	<0.01	0.85
Soil 10-20	<0.01	0.72	n.s.	-	*<0.01*	0.46	0.02	0.15	<0.01	0.94
Soil 20-40	<0.01	0.60	<0.01	0.65	*<0.01*	0.33	n.s.		<0.01	0.86

Strong Correlations observed with:

- **Latitude**
- **Annual Precipitation (but not Hg wet deposition)**
- **Soil Carbon**
- **Soil Clay**

No (consistent) relationships to:

- **Longitude, Temperature, Elevation, Litter-flux, Wet deposition conc., Wet deposition flux, EPA air emissions)**

Total Hg: Spatial Patterns

Link to Soil Carbon (as hypothesized)

- **Strong OM sorption capacity**
- **Consistent with depth**

Link to Clay c

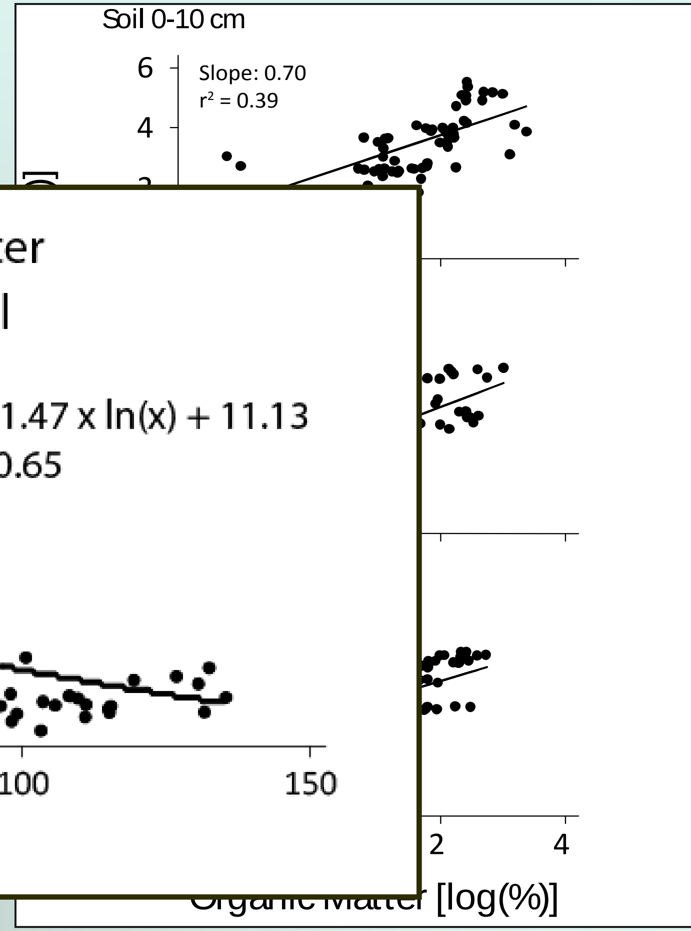
- **Stron**

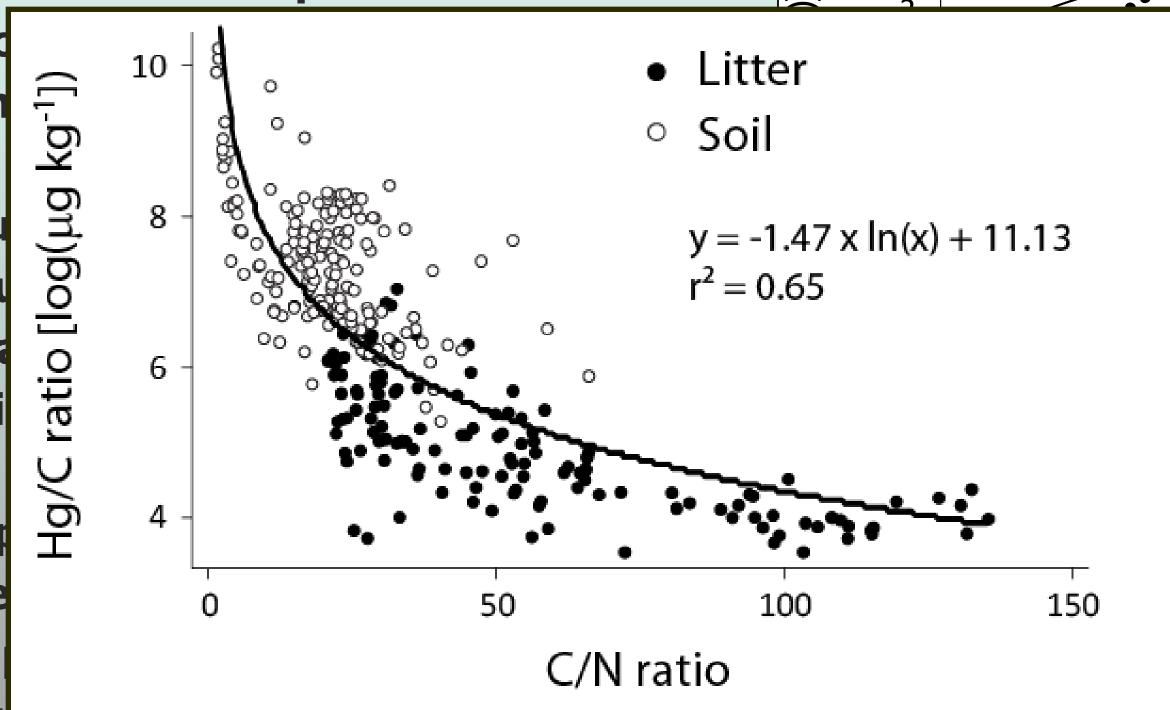
Link to Latitu

- **Latitu**
- **But: a**
- **Possi**

Link to Precip

- **No re**
- **Preci**
- **Through-fall deposition**





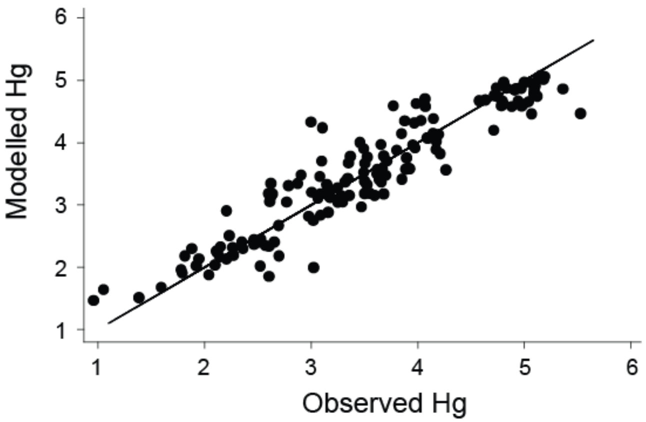
⇒ **Hg distribution in U.S. forests largely independent on regional deposition strength**

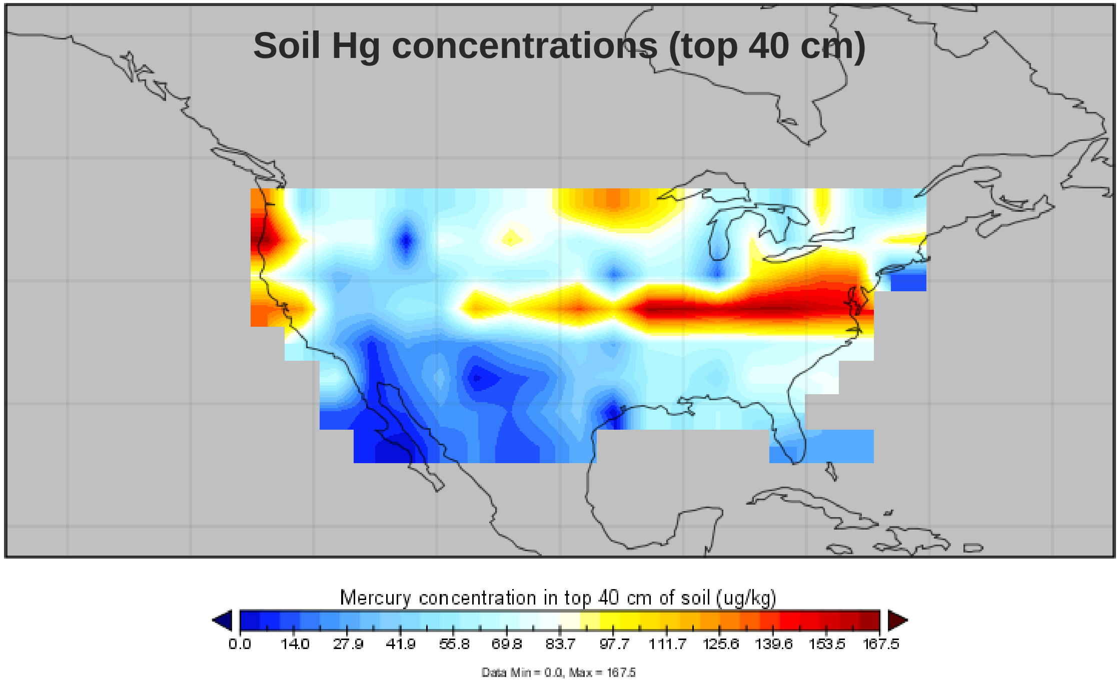
⇒ **Hg distribution consistently linked to presence of organic C (across climatic zones)**

⇒ **Hg loads also dependent on precipitation and latitude**

Total Hg: Scaling up to contiguous U.S. (Soil 0 to 40 cm)

Ecosystem Component	Multiple Regression (Latitude, Precipitation, Clay, Log(C)	
	P	r^2
Foliage	<0.01	0.10
Litter Oi	0.03	0.14
Litter Oe	<0.01	0.51
Litter Oa	0.02	0.24
Soil 0-10	<0.01	0.85
Soil 10-20	<0.01	0.94
Soil 20-40	<0.01	0.86
Soil 0-40	**<0.01**	**0.88**

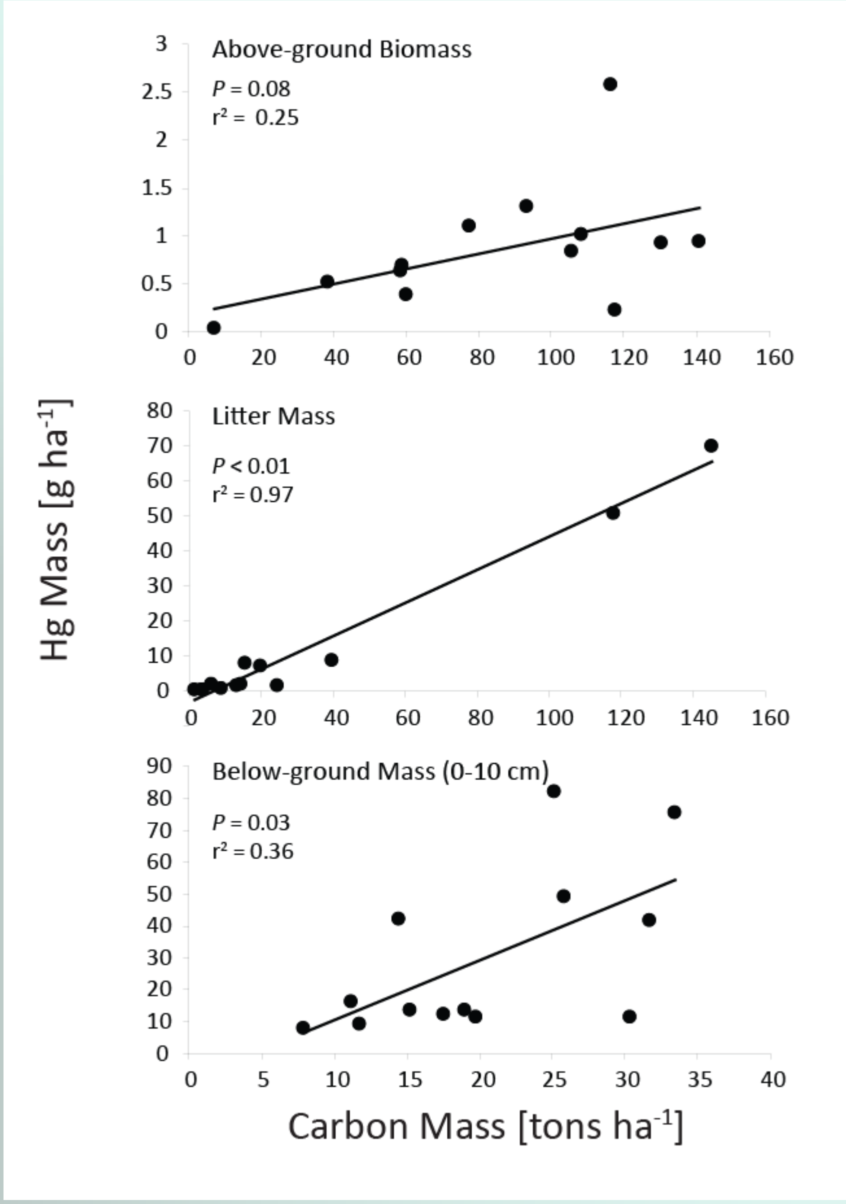




Total Ecosystem-Level Pools of Hg

- **Lowest: 14 g ha^{-1} in Sierra Nevada Pine forest**
- **Highest: 113 g ha^{-1} in Maine Coniferous forest**
- **Belowground Hg (upper 10 cm) account for 77% of total ecosystem stocks**

- **Strong links to respective C pools**
- **Total Hg pools related to latitude (r^2 = 0.30; α=0.10)**

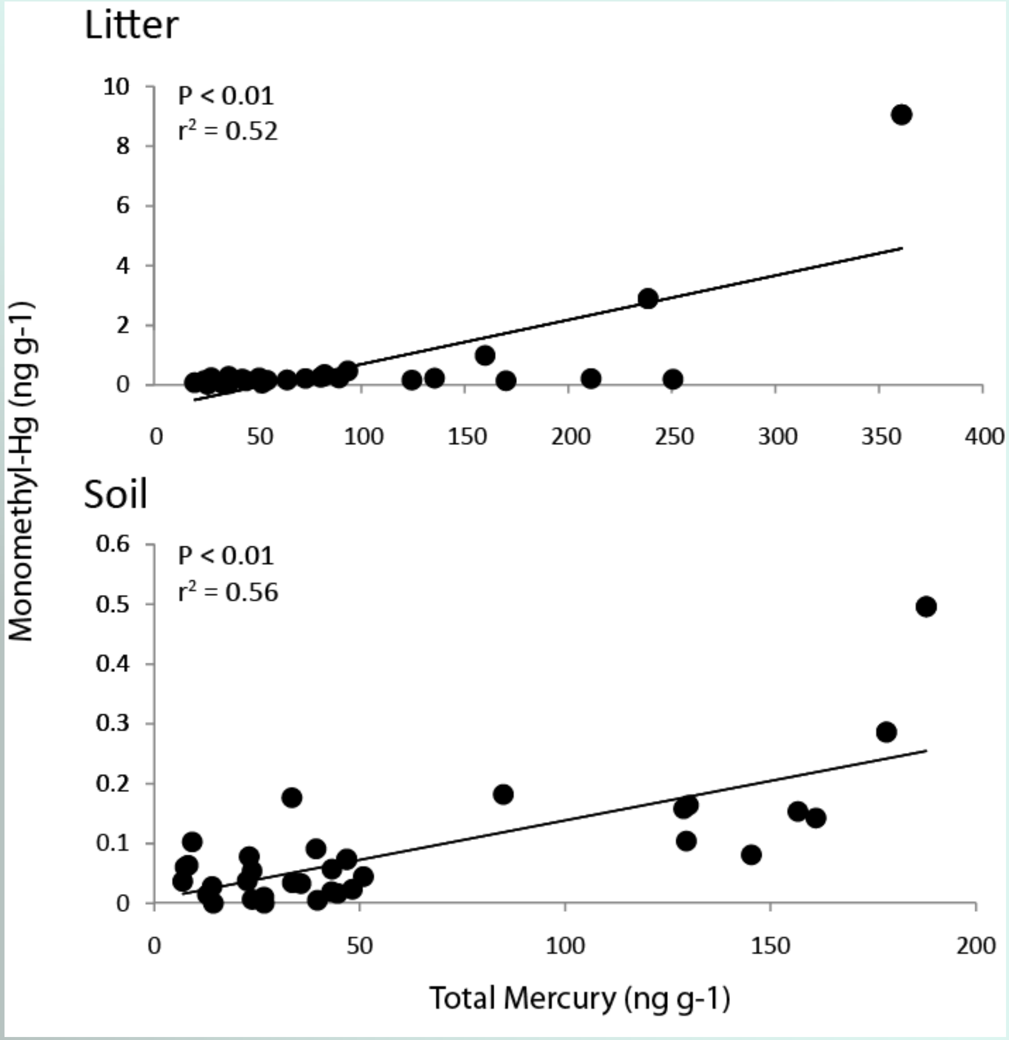


Methyl-Mercury

- Highest MeHg levels in Litter
- (Oi: 0.13 ng g^{-1} < Oe: 0.49 ng g^{-1} : Oa: 1.57 ng g^{-1})
- Soils: 0.09 ng g^{-1}

- % MeHg of total Hg
  - Litter: 0.4%
    (Oi: 0.4%; Oe: 0.4%; Oa: 0.5%)
  - Soils: 0.2%

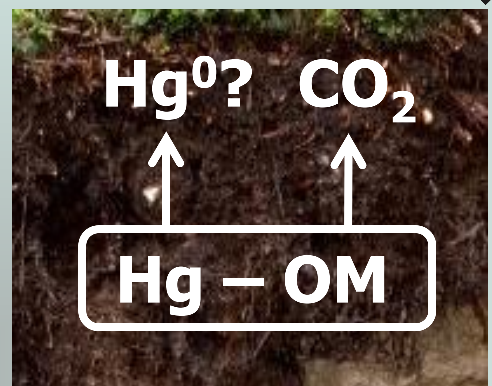
- ⇒ Total Hg to a large degree also determine levels of MeHg



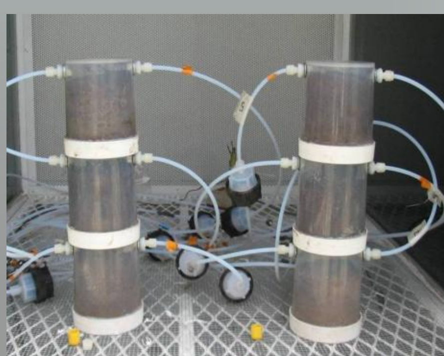
Fate processes of Hg during C decomposition

1. Field Stoichiometry

2. Controlled litter decomposition



3. Laboratory CO_2/Hg^0 flux studies



4. Soil gas CO_2/Hg^0 measurements

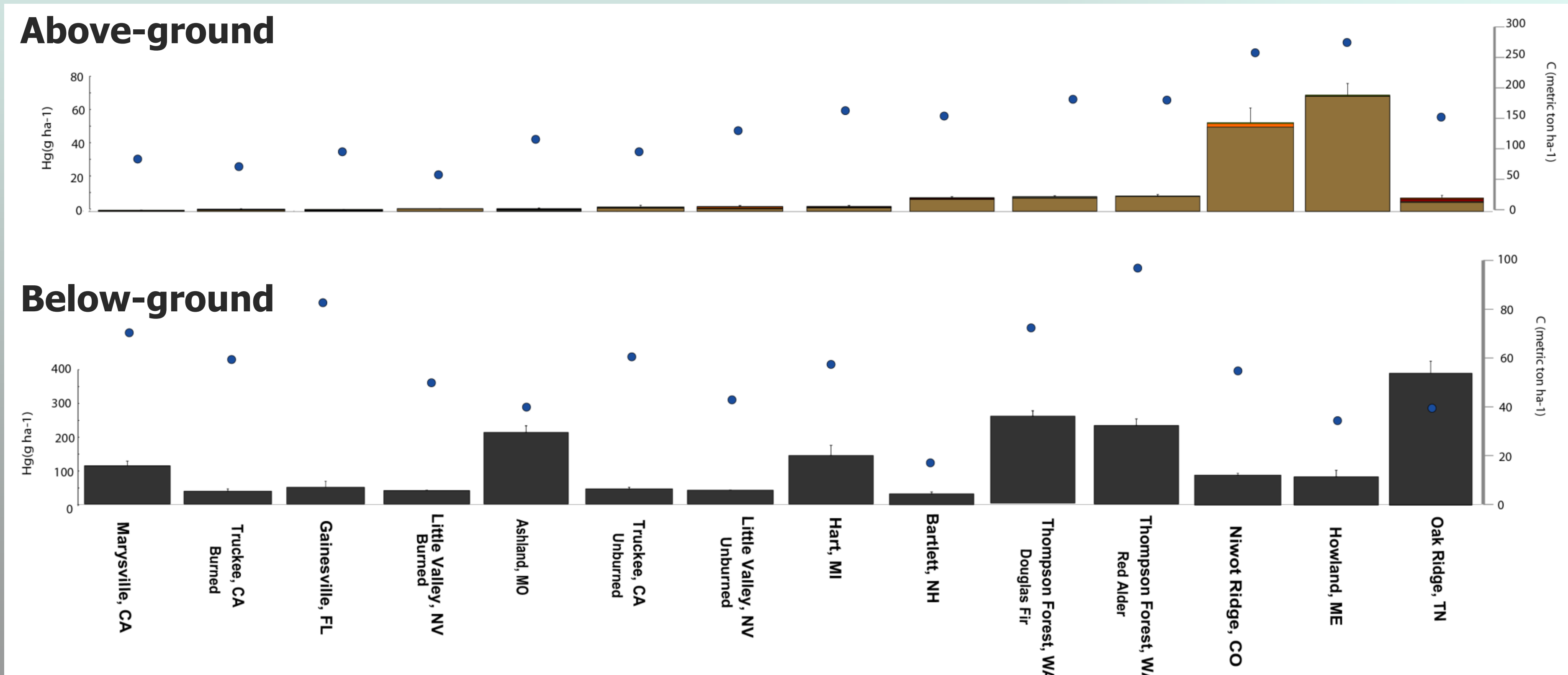
Acknowledgments:

- **PostDoc: X. Faïn**
- **Graduate Students: A. Pokharel, A. Pierce, Oleksandra (Sasha) Hararuk**
- **Undergraduate/High-School students: C. Berger, J. Dagget, R. Higgins, G. Marty, S. Vadwalas, So Lee**

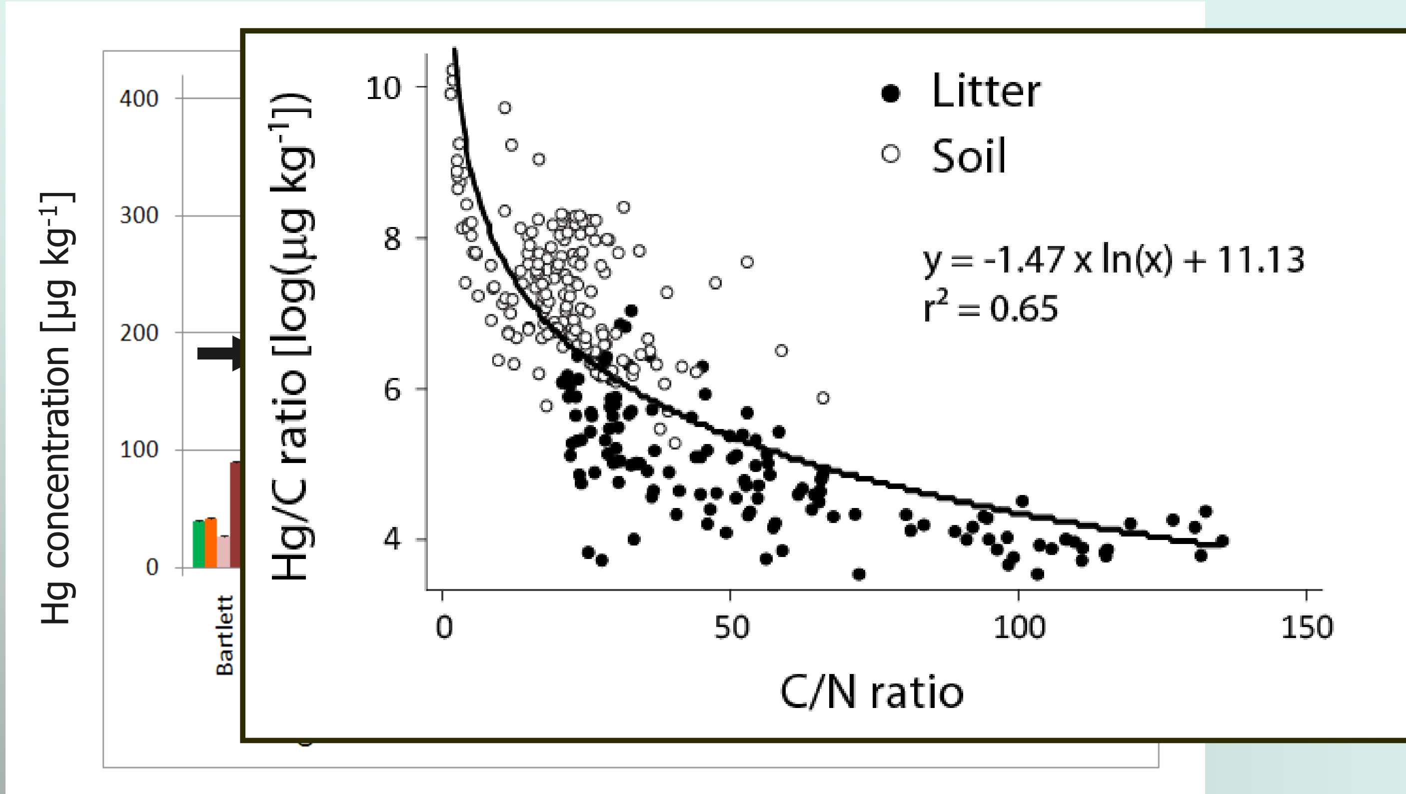
- **Site collaborators:**
  - **Nevada/California: Sierra Nevada (Pine): D. Johnson, W. Miller, R. Walker**
  - **California: Sierra Foothills (Blue Oak): J. Battles, R. Wenk**
  - **Washington State (Red Alder/Douglas Fir) : Bob Edmonds, Bob Gonyea**
  - **Colorado: : Niwot Ridge (Fir/Spruce): Maggie Prater, Russ Monson**
  - **Maine: Howland (Spruce/Hemlock): Bryan Dail, Andrew Richardson, Scott Ollinger**
  - **New Hampshire: Bartlett, (Maple/Beech): Andrew Richardson, Scott Ollinger, Bob Evans**
  - **Tennessee: Oak Ridge (Oak/Maple/Hickory): Dale Johnson, Paul Hanson, Patrick Mulholland, Don Todd**
  - **Florida: Gainesville (Slash/Longleaf Pine): Tim Martin, Rovel Bracho-Garrillo**
  - **Michigan (Sugar Maple): K. Pregitzer, Zak Donald, Patricia Micks**
  - **Missouri: Ashland (Oak/Hickory): Stephen Pallardy, Kevin Hosman, Paul Hanson**
  - **Blodgett Forest Research Station-Quintette, CA: Rob York, Yennifer York**

Total Ecosystem-Level Pools of Hg

- **Above-ground and below-ground pools +/- uncoupled:**



1. Stoichiometry



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Degree of Decomposition




2. Controlled litter decomposition study

Incubation Chamber

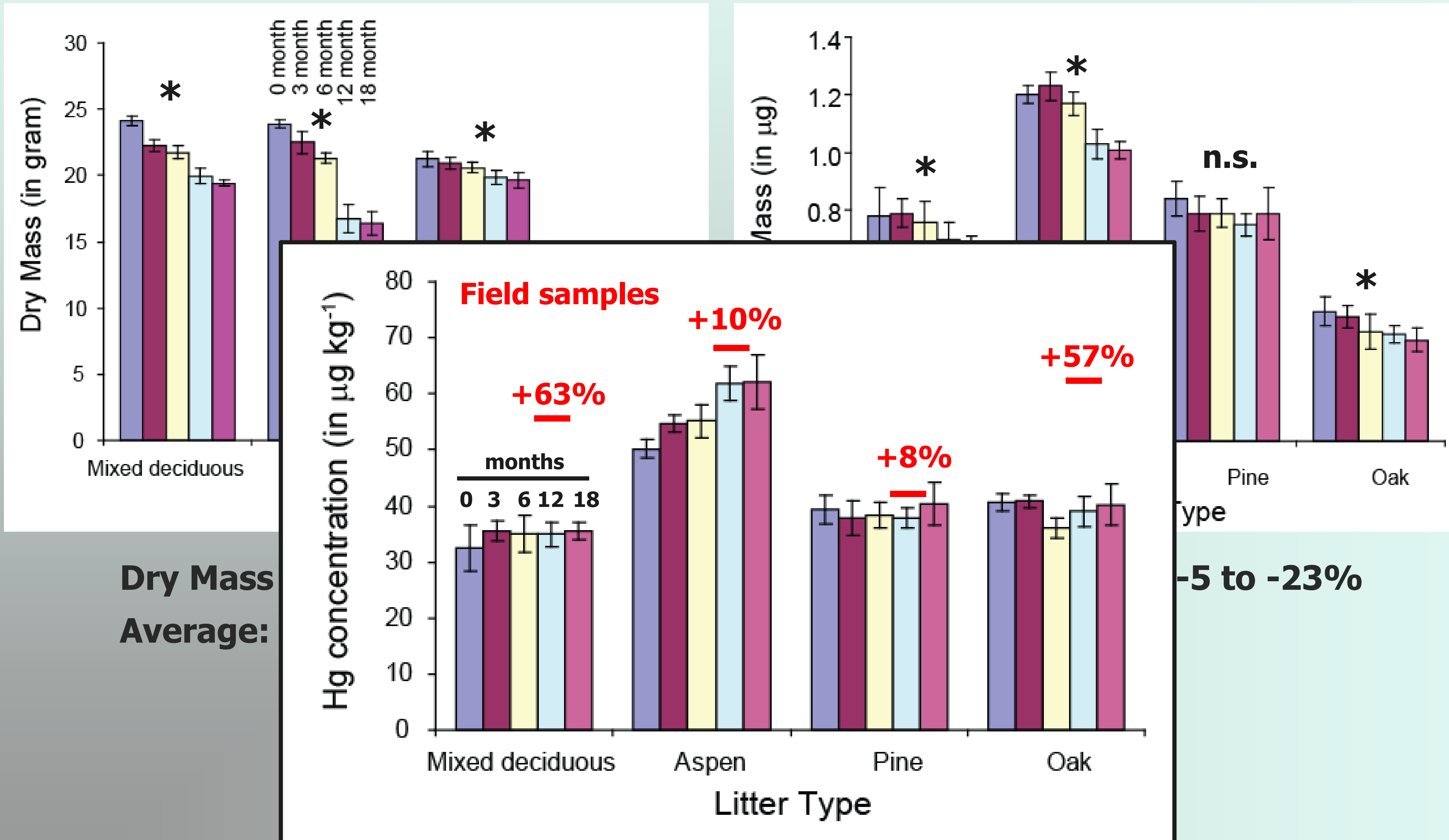
Glass jars

0.2 µm Teflon filter

Field control

- **Laboratory incubation: controlled conditions (temp, moisture, darkness), minimizing Hg deposition**
- **4 forest litter types (deciduous and coniferous)**
- **Sequential harvested of litter samples after 0, 3, 12, and 18 months**
- **Mass balance of Hg, Carbon, Nitrogen, and dry mass**
- **Field control: 12 months of field decomposition**

2. Controlled litter decomposition study

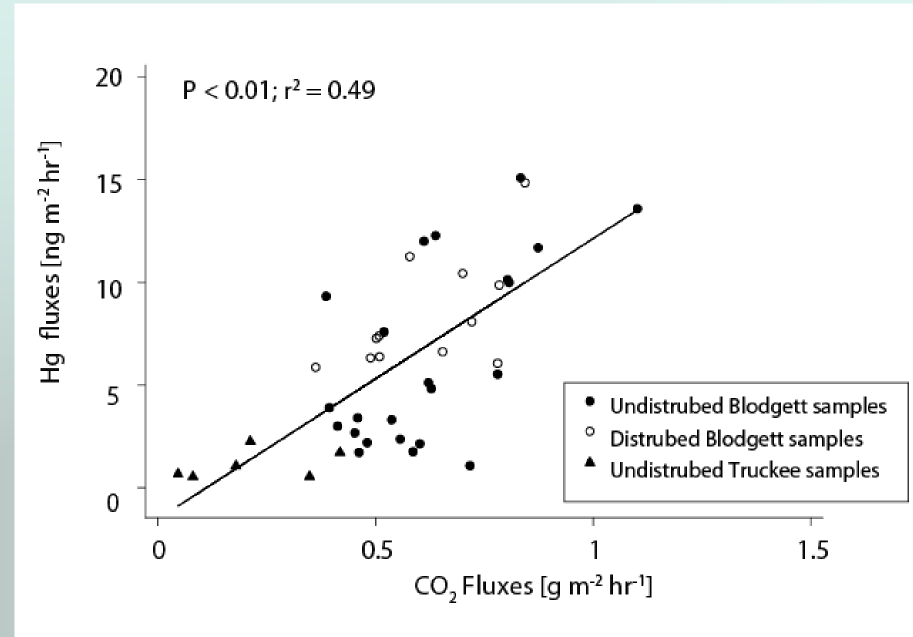


Dry Mass -5 to -23%

Average:

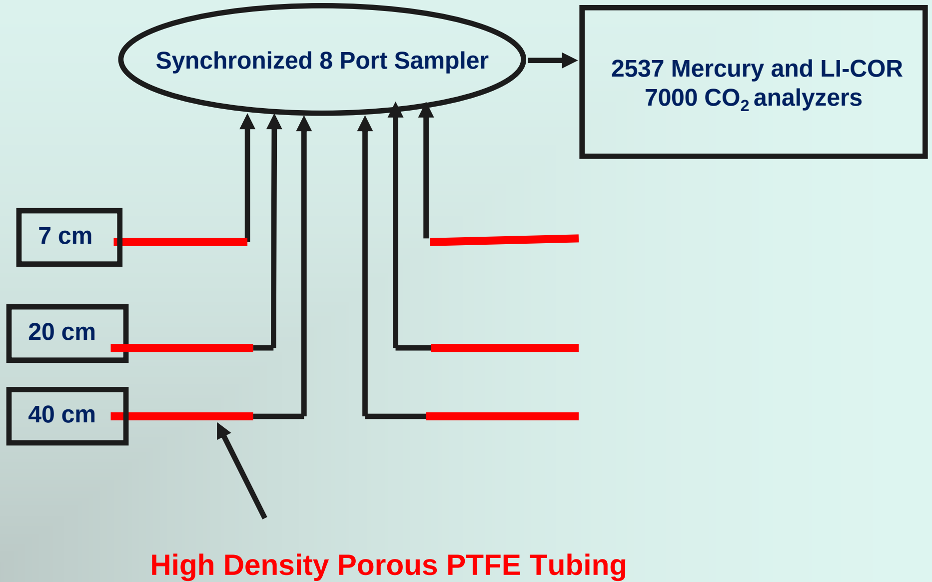
3. Laboratory soil flux

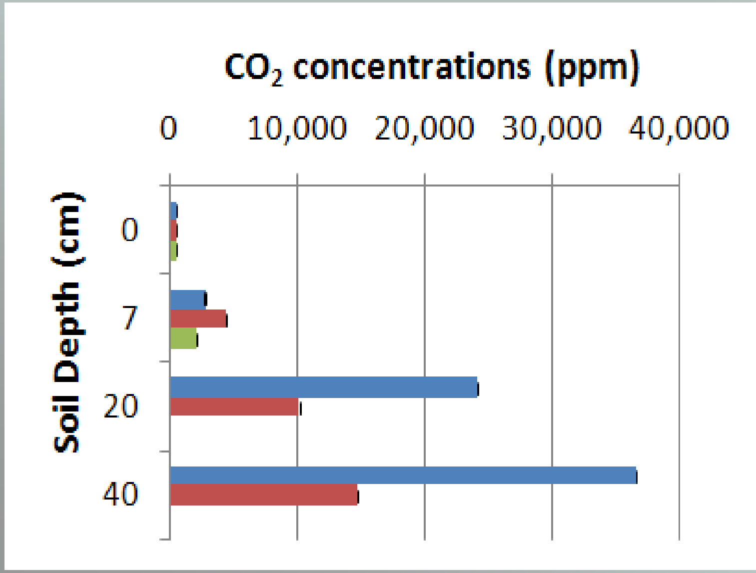
Corresponding measurement of soil CO_2 and Hg^0 efflux under controlled laboratory conditions

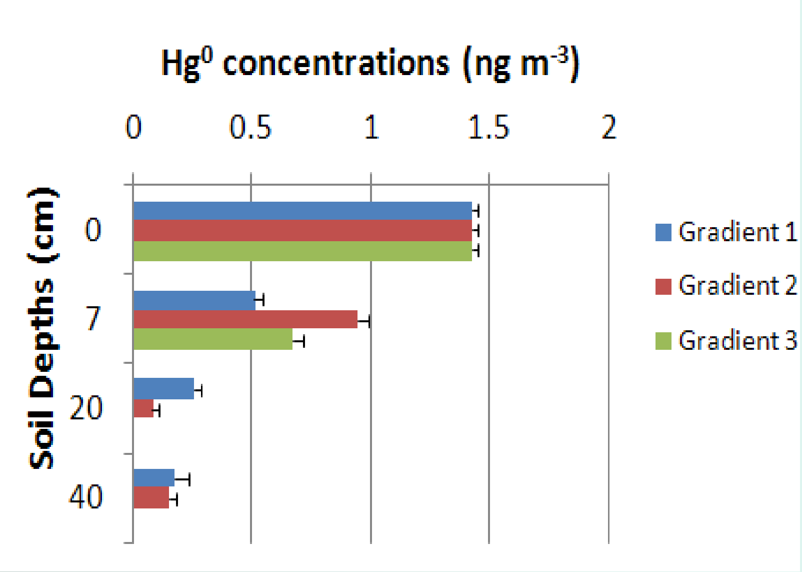


- **Correlation btw. soil Hg^0 and CO_2 evasion under controlled laboratory conditions**
- **Based on Hg/C ratios of emissions and soils: ~ 3% emitted**

4. Continuous soil gas CO_2 and Hg^0 monitoring







Fate processes of Hg during C decomposition

In soil:

- Hg^0 losses during decomposition are small
- Hg^0 movement through soils not diffusion driven, strong sorption of Hg^0 in soil matrix
- Potential Hg^0 losses from soils predominantly driven by surface processes

In Litter:

- Significant losses of Hg^0 during decomposition
- Only small Hg concentration increases during decomposition when additional sources are eliminated
- In field, strong sorption of atmospheric deposition as main source of Hg accumulation in old, decomposing litter
- Sorption and Hg^0 losses are tissue specific