Effects of global change on the atmospheric mercury burden and mercury sequestration through changes in ecosystem carbon pools

Daniel Obrist (PI) – Desert Research Institute, Reno NV

Yiqi Luo (Co-PI) – University of Oklahoma, Norman

Dale Johnson (Co-PI) – University of Nevada, Reno

Steve Lindberg (Co-PI) - consultant

This research is funded by

U.S. EPA - Science To Achieve Results (STAR) Program

Grant # RD833378010

EPA STAR 'kick-off' meeting
February 2006

Summary

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Terrestrial carbon (C) pools an play important role in uptake, deposition, sequestration, and (re-)emission of atmospheric mercury (Hg)**
- **Biomass and soil C pools are highly sensitive to climate / land use changes**

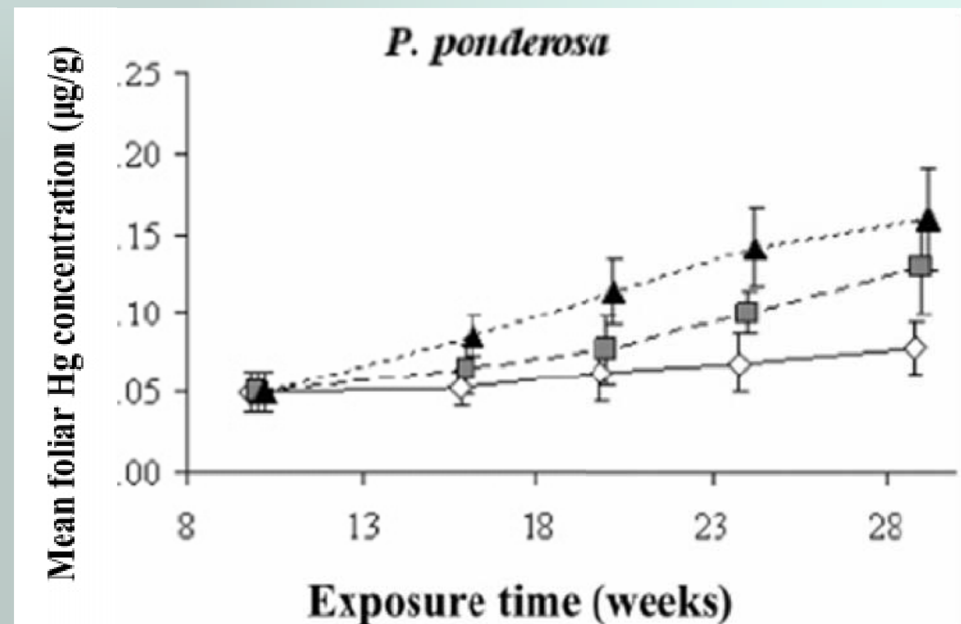
Project goal:

To assess how global change is likely to affect Hg uptake, sequestration, and emissions associated with vegetation and soil C pools during the next 100 years

Role of carbon pools: Plant Hg uptake

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Biomass contains significant amount of Hg (leaves ~24 μg kg^{-1})**
- **Above-ground biomass Hg mainly originates from atmosphere**
  - ⇒ **Litterfall and plant senescence represent important pathways for atmospheric Hg deposition**



Millhollen et al (EST 2006)

Role of carbon pools: Plant Hg uptake

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

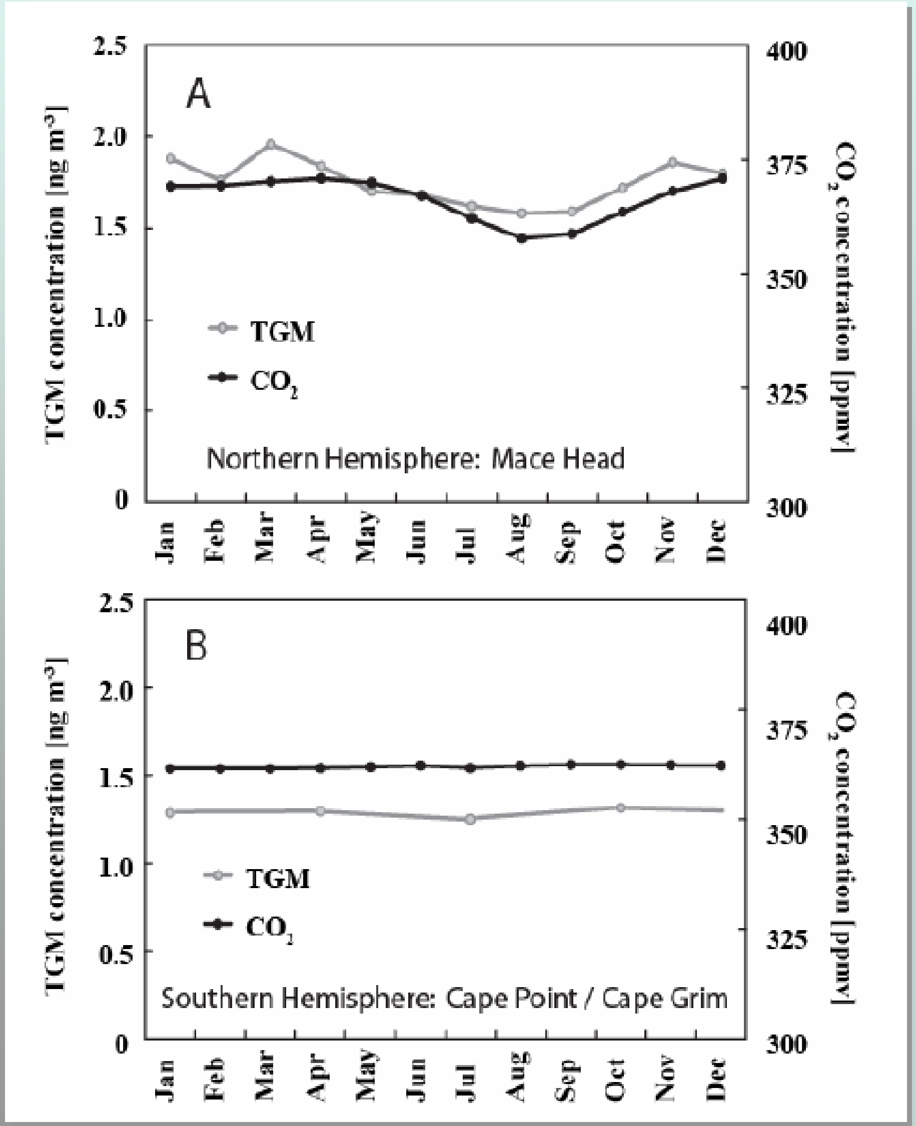
Annual Global NPP (Pg C/yr)	60			
Annual Biomass Production (=NPP*2; Pg/yr)	120 50% Forests/shrublands 60		50% Grasslands/others 60	
Annual Above-ground Biomass Production (Pg/yr)	55% of 60: 33 30% Leaves 9.9	70% Wood 23.1	45% of 60: 27 100% leaves 27	0% Wood --
Tissue Hg Concentration (ppb)	24	6	24	--
Annual Atmospheric Hg Uptake (Mg Hg/yr)	237.6	138.6	648.0	--
Sum	1024.2			

Obrist (Biogeochem in press)

- **Total atmospheric Hg Pool: ~ 2,500 to 5,000 Mg**
  (Mason et al. 1994; Banic et al. 2003)

Role of carbon pools: Plant Hg uptake

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010



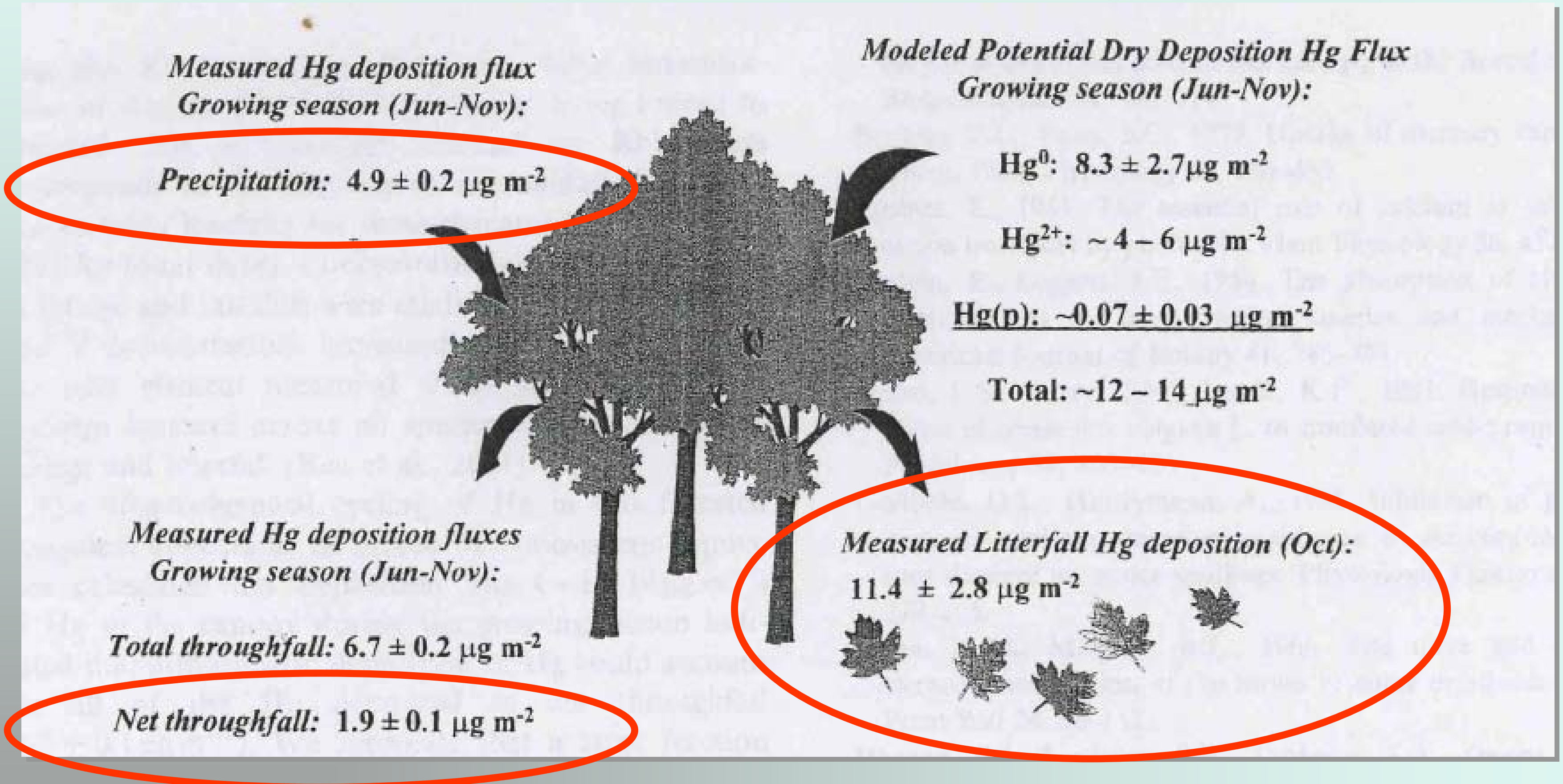
"Plant Hg Pump" strong enough to affect atmospheric Hg levels?

Obrist (Biogeochem in press)

Data from Ebinghaus et al. (Atmos Environ 2002) and Baker et al. (Atmos Environ 2003)

This research is funded by
U.S. EPA-Science To Achieve Results (STAR) Program
Grant # RD833378010

Role of carbon pools: Plant Hg uptake

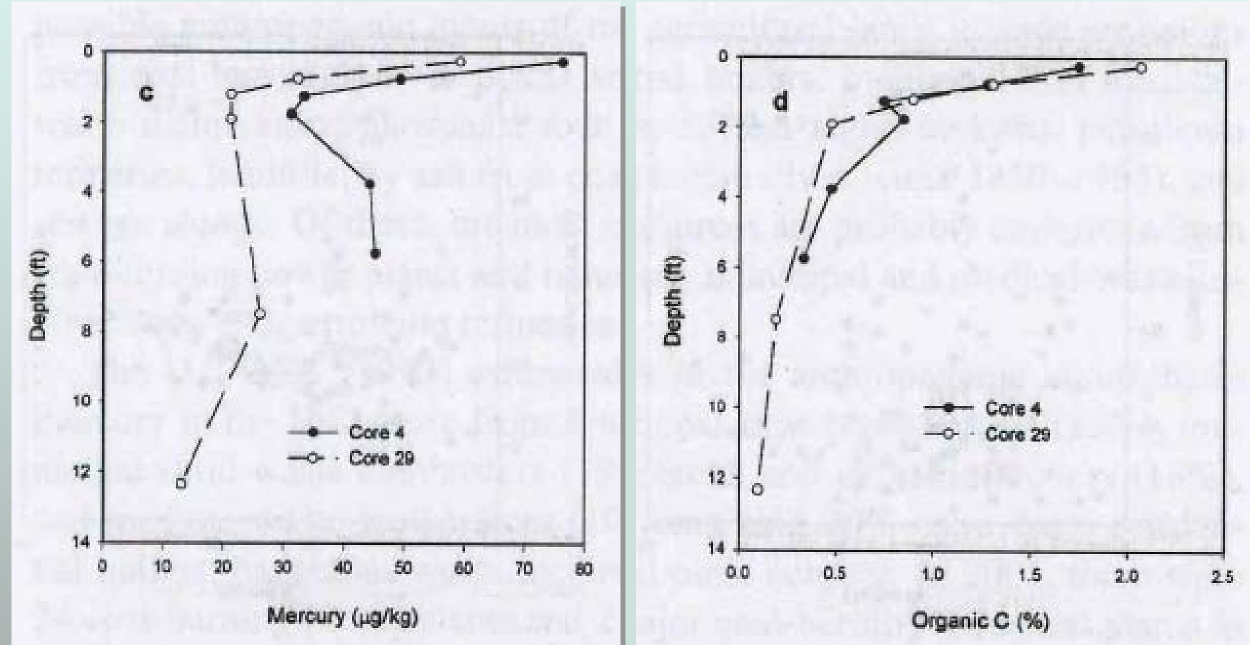


Rea et al (Atmos Environ 2001)

- **Ecosystem level: Hg deposition ~3-4 x higher in vegetated ecosystems than in the open field**

Role of carbon pools: Hg sequestration

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program Grant # RD833378010



Dreher & Follmer (Water Air Soil Poll 2004)

- **30,000 Mg Hg sequestered in US forest soils?**
  - **115-210 Mg/yr anthropogenic/industrial US Hg emissions (EPA 1999, UNEP 2002)**
- **How stable are these Hg pools?**

Goals and proposed work

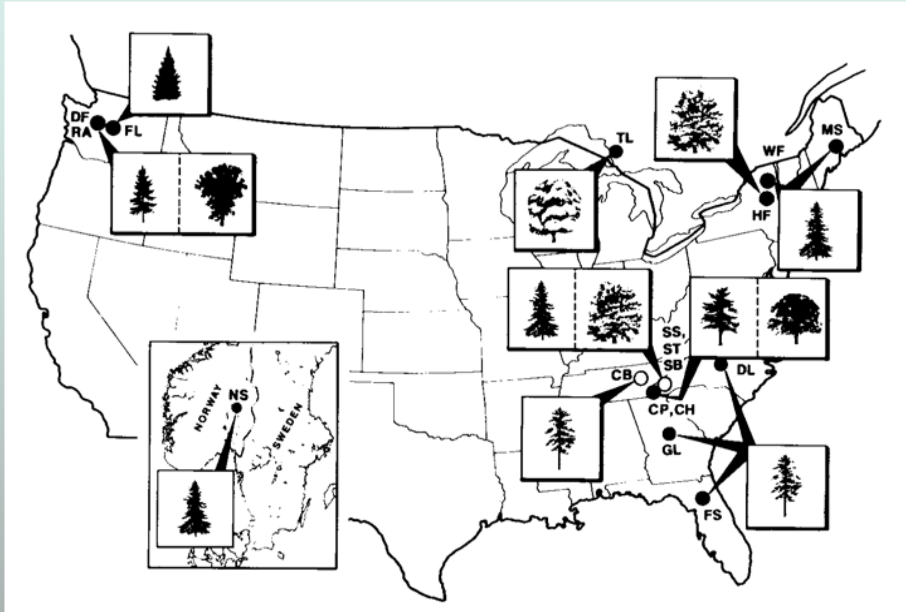
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Goal 1**
  - Systematically quantify Hg concentrations associated with vegetation, litter, and soil C pools
- **Approach**
  - Use of IFS (Integrated Forest Study) site network with available data on C pools, fluxes, and turnover rates in all major ecosystem compartments
  - Determination of Hg contents in respective C pools
- **Expected Results**
  - Systematic inventory of Hg pools associated with C stocks across forest sites in the US
  - Estimation of atmospheric Hg inputs and sequestration through litterfall and plant senescence
  - Determination of resilience and sequestration potential of Hg in various ecosystem compartments

Goals and proposed work

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

IFS Forest sites



- 17 forested sites (9 sites proposed in our study)
- Detailed budgets for OC in 11 major ecosystem compartments available

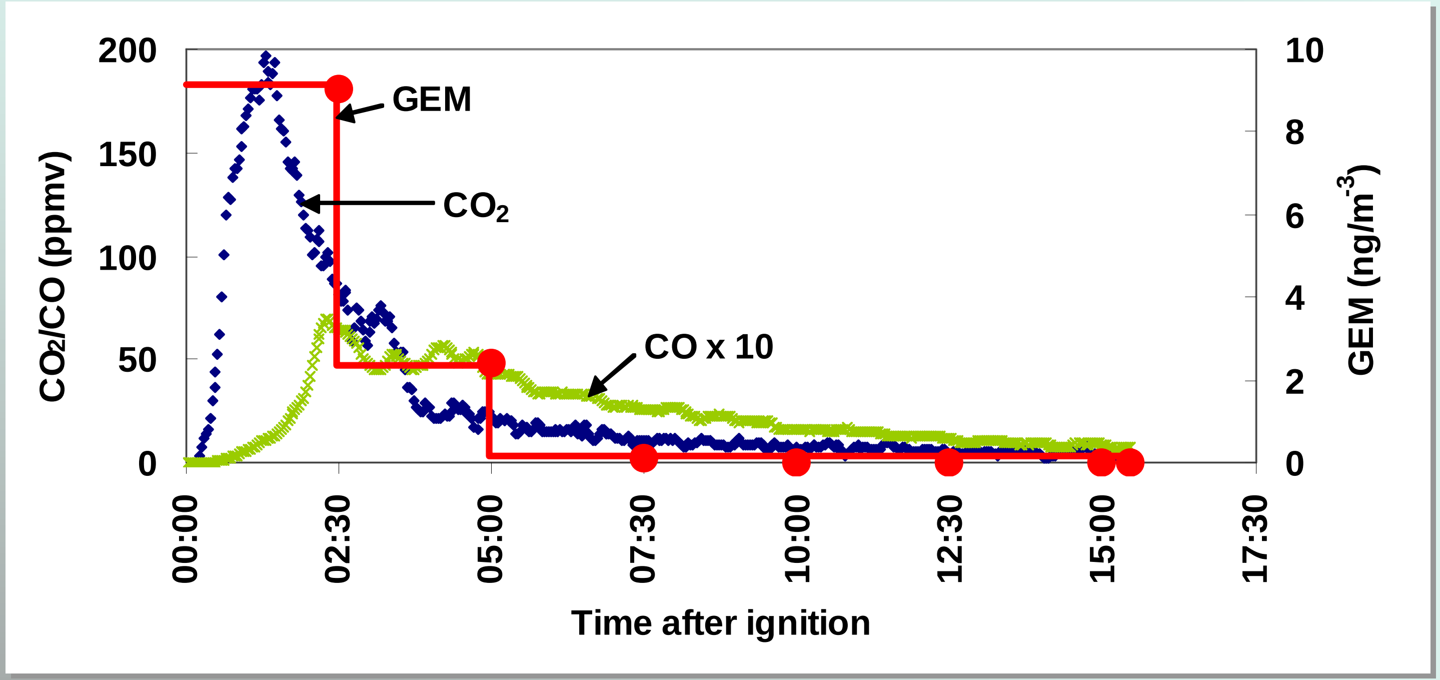
Component	Organic Matter
OVERSTORY	
FOLIAGE	6,180
BRANCH	22,900
BOLE	242,200
STUMP	
ROOTS	44,500
TOTAL	315,780
UNDERSTORY	3,050
FOREST FLOOR	
O HORIZONS	23,500
WOOD[a]	13,200
TOTAL	36,700
SOIL, EXTRACTABLE	
A (0–7 cm)	—
A (7–15 cm)	—
B (15–30 cm)	—
BC (30–45 cm)	—
TOTAL	—
SOIL, TOTAL[b]	
A (0–7 cm)	61,800
A (7–15 cm)	40,400
B (15–30 cm)	55,800
BC (30–45 cm)	60,400
TOTAL	218,400

[a] Includes only wood <6 cm diameter.
[b] Soil organic matter, soil carbon × 2.

Johnson & Lindberg (Ecological Studies, 91, 1992)

Role of carbon pools: Hg emissions

- Hg emissions measured at the USFS Fires Science Lab



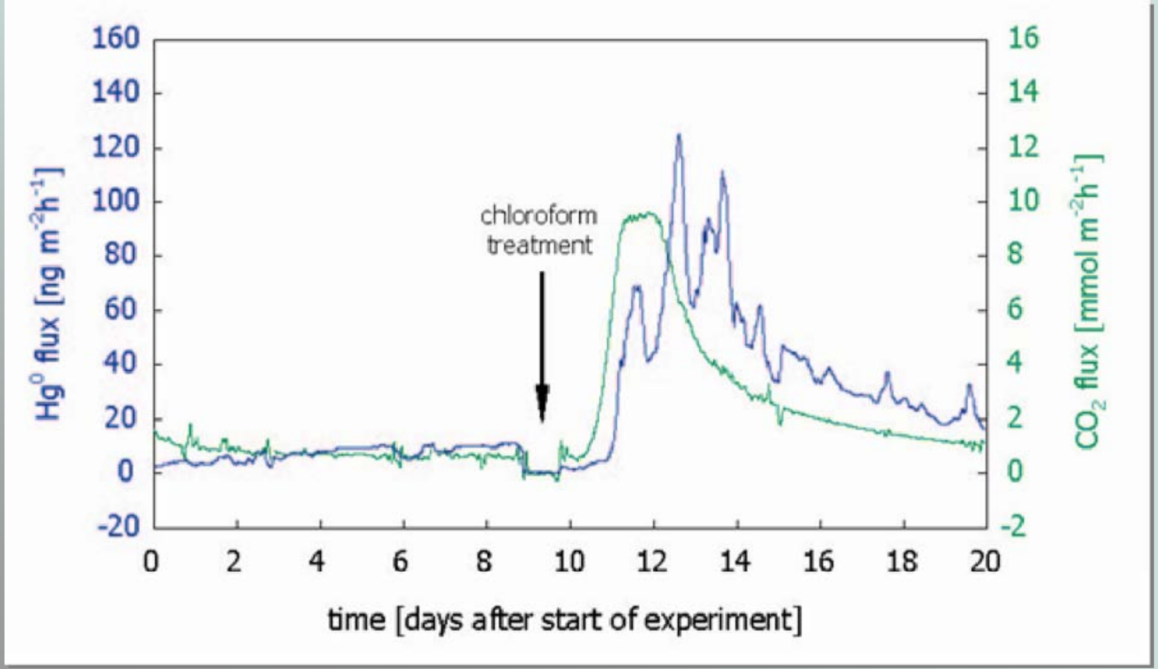
Obrist et al. (in prep)

- Natural Hg emissions through wildfires significant
  - 250-430 Mg yr^{-1} (Sigler et al, EST 2003)
  - Significantly higher (e.g., 15 x in circumboreal systems) when organic soil C pools burn (Turetsky et al; GRL 2006)

Role of carbon pools: Hg emissions

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Indication of Hg emissions during carbon mineralization**
- **Soil Hg degassing strongly correlated to CO_2 soil emission (i.e., carbon mineralization)**
- **Manipulations of microbial activity lead to parallel changes in Hg degassing rates**



Fritsche et al. (in press)

Goals and proposed work

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Goal 2**
  - Assess the fate of Hg during C mineralization
- **Approach**
  - Field studies and controlled laboratory studies
  - Quantify relationship btw. CO_2 efflux and Hg degassing
  - Use of automated field and lab flux chambers
- **Expected Results**
  - Understanding of fate processes of Hg during C mineralization
  - Quantification of de-gassing, mobilization, and long(er)-term sequestration of Hg during C losses

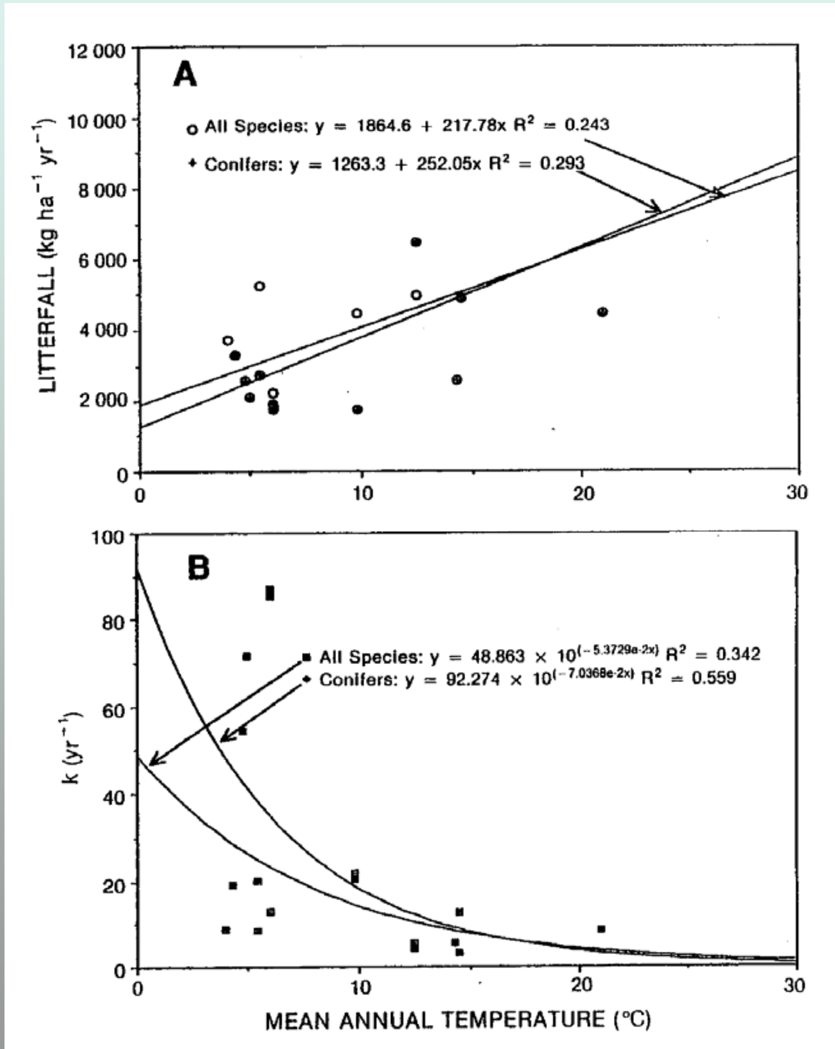
Goals and proposed work

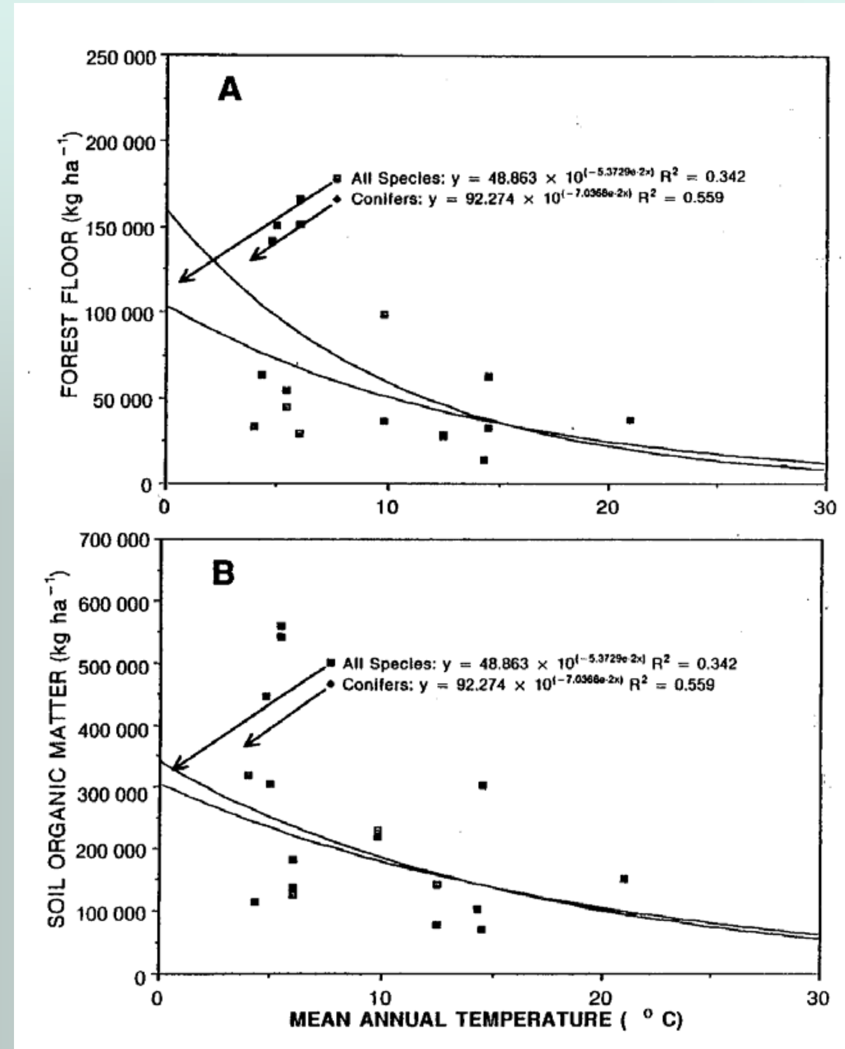
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Goal 3:**
  - Evaluate dependence of C-related Hg pools and fluxes to climate parameters
- **Approach**
  - Linear and non-linear regression analyses
  - Use of a variety of environmental parameters (e.g., air and soil temp., precip., solar radiation)
- **Expected Results**
  - Development of hierarchy of factors controlling Hg accumulation/turnover in C pools
  - Input parameters for global climate change model

Goals and proposed work

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010





Johnson (Soil Science Soc America 1995)

Goals and proposed work

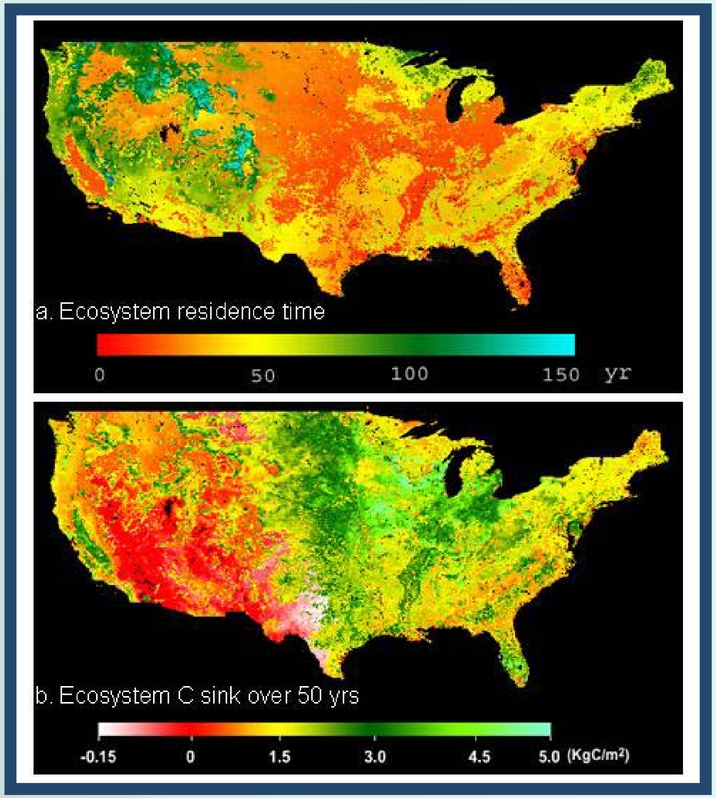
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Goal 4**
  - Integration of Hg data into TECO global change C model
- **Approach**
  - Development of a Hg module for TECO model
  - Use of field, lab, and literature data to parameterize TECO module for Hg
- **Expected results**
  - Scaling up Hg fluxes and sequestration to the coterminous US
  - Prediction of Hg pools/fluxes associated with C dynamics for IPCC global change scenarios
  - Development of mitigation measures to protect/stabilize atmospheric Hg sequestration in terrestrial C stocks

Goals and proposed work

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **TECO carbon model**
  - Simulates C and N dynamics in 10 plant and soil pools
  - Model outputs: C inputs (NPP, litterfall and senescence) C residence time, C sequestration capacity
  - Five global change factors: rising atmospheric CO_2, climate warming, changes in precipitation, N deposition, changes in species composition
  - Spatial modeling to coterminous US
- **New Hg module (to be developed)**
  - Identical structure to C flux module
  - Hg fluxes/pools will be stochiometrically coupled with C flows/pools
  - Input parameters gained from the field, lab, and literature



Luo et al (in press)

Summary

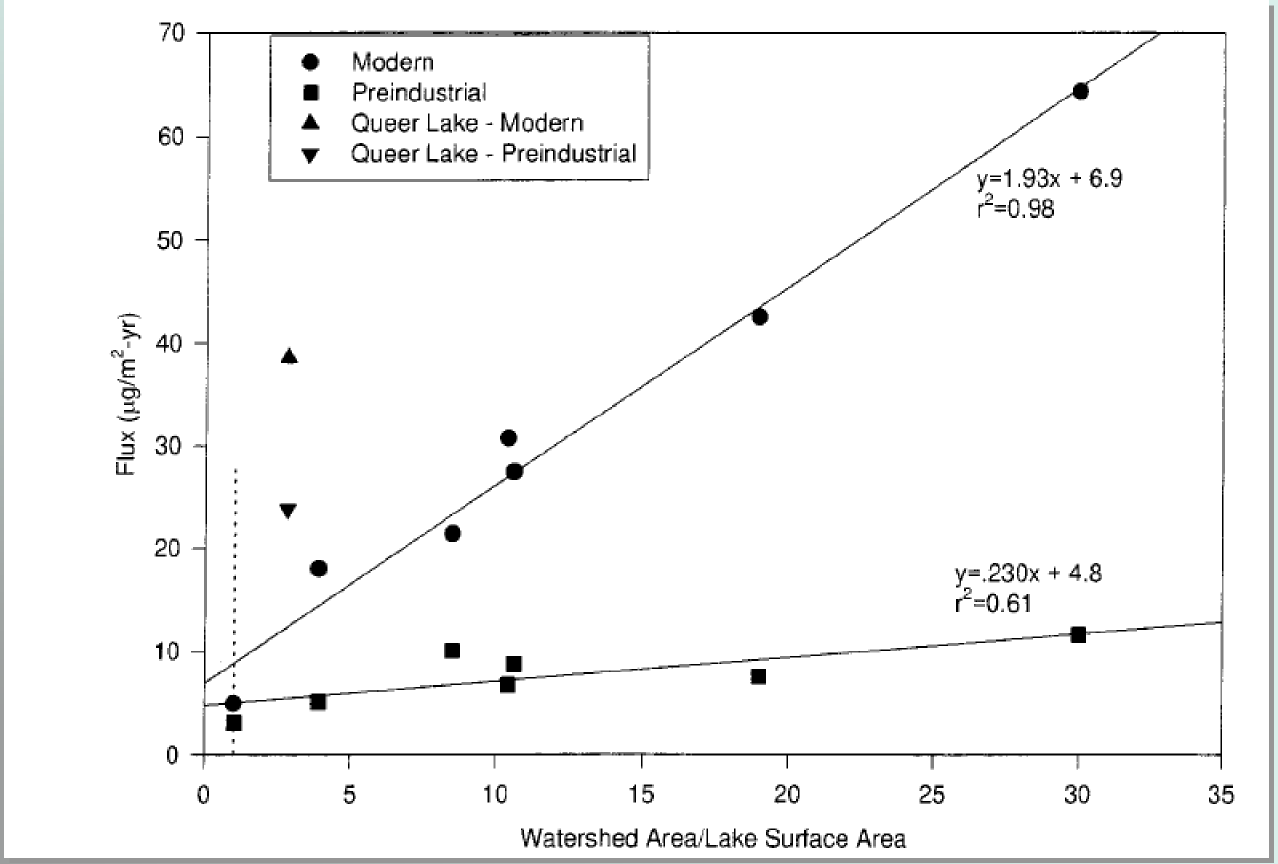
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Expected results**
  - Systematic database on Hg pools associated with current ecosystem C pools
  - Characterization of how climate factors control Hg fluxes (inputs, sequestration, and losses)
  - Fate determination of Hg during C mineralization
  - Predictions on how future pools and fluxes of Hg will affect atmospheric Hg burden (based on IPCC scenarios)
- **Benefits and Outputs**
  - Advanced knowledge of natural sinks, sources, and sequestration potential for atmospheric mercury
  - Understanding how global change may affect atmospheric mercury burden
  - Evaluation of cost-effective mitigation measures for atmospheric Hg integrated into land management practices

Introduction

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD833378010

- **Terrestrial systems are the main source of Hg in (most) aquatic systems**
- **Main input of Hg to terrestrial ecosystems occurs via atmospheric deposition**



Lorey & Driscoll (EST 1999)