What can year-long hourly measurements tell us about emissions?

EPA STAR-OTAQ Transportation Emissions Research Forum

Ann Arbor, MI, 4-5 March 2014

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Saint Louis University / University Wisconsin - Madison

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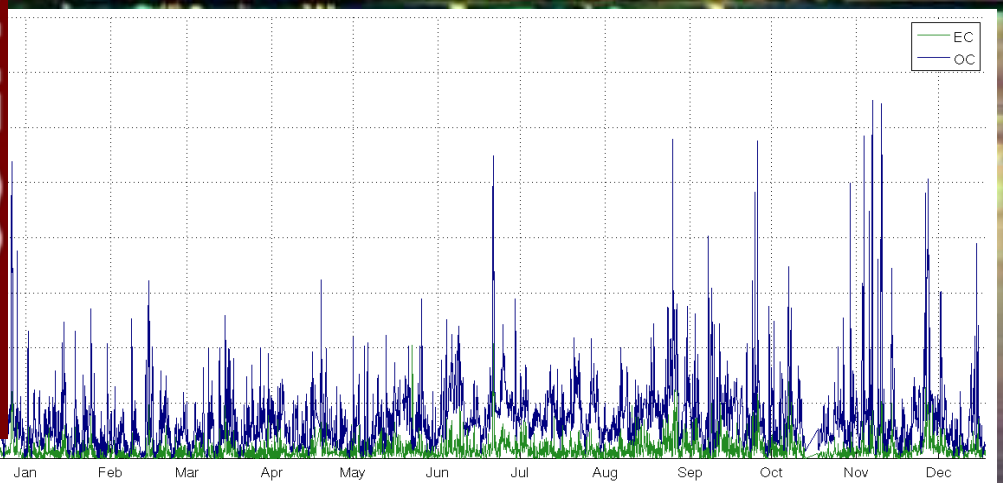

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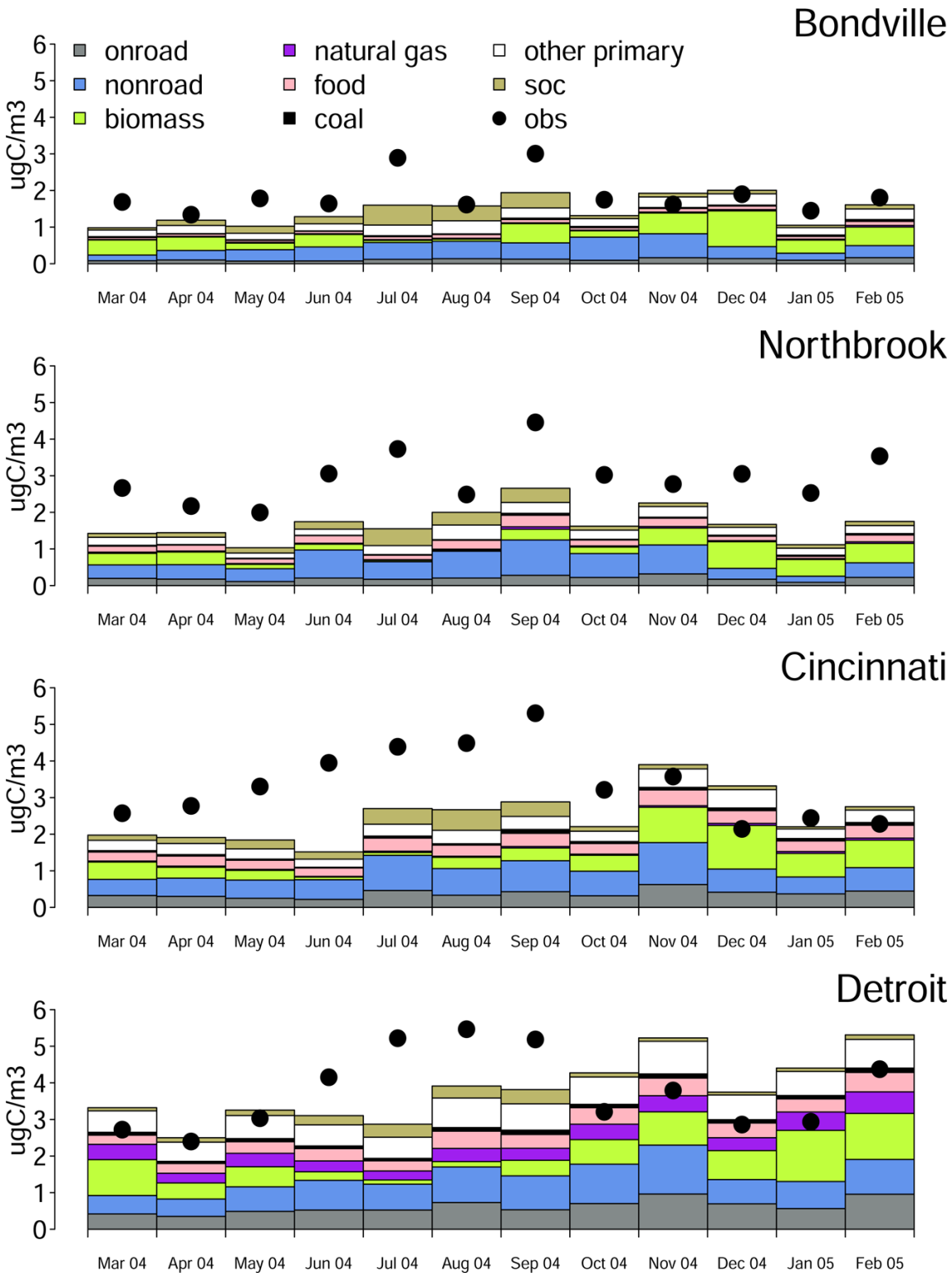
U.S. EPA - Science To Achieve Results (STAR) Program

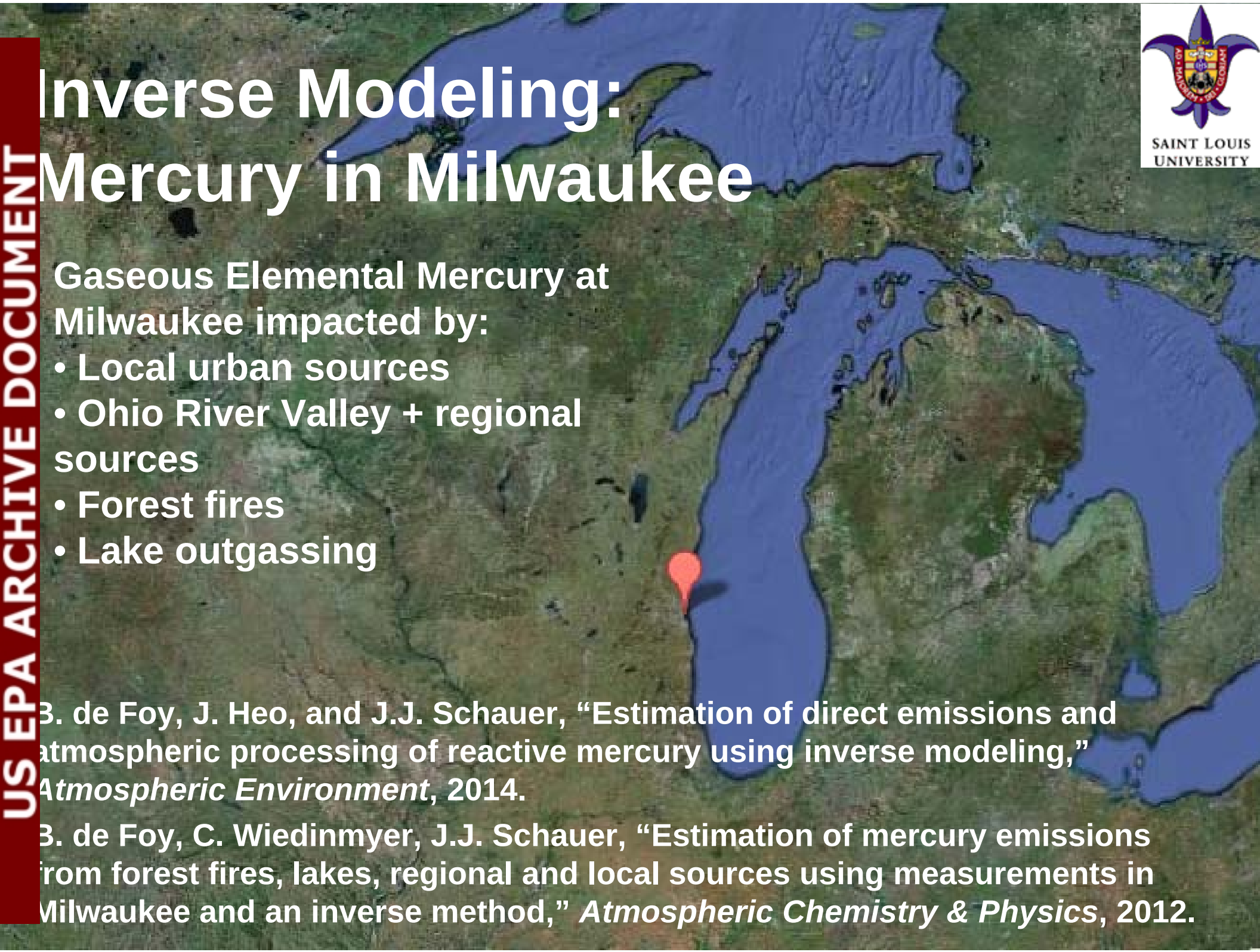
Grant # RD 83455701

CMAQ model contributions to total organic and elemental carbon by month and site with observations



iagnostic Air Quality Model Evaluation
f Source-Specific Primary and
econdary Fine Particulate Carbon
apelenok et al., ES&T 2013

Inverse Modeling: Mercury in Milwaukee



Gaseous Elemental Mercury at Milwaukee impacted by:

- Local urban sources
- Ohio River Valley + regional sources
- Forest fires
- Lake outgassing

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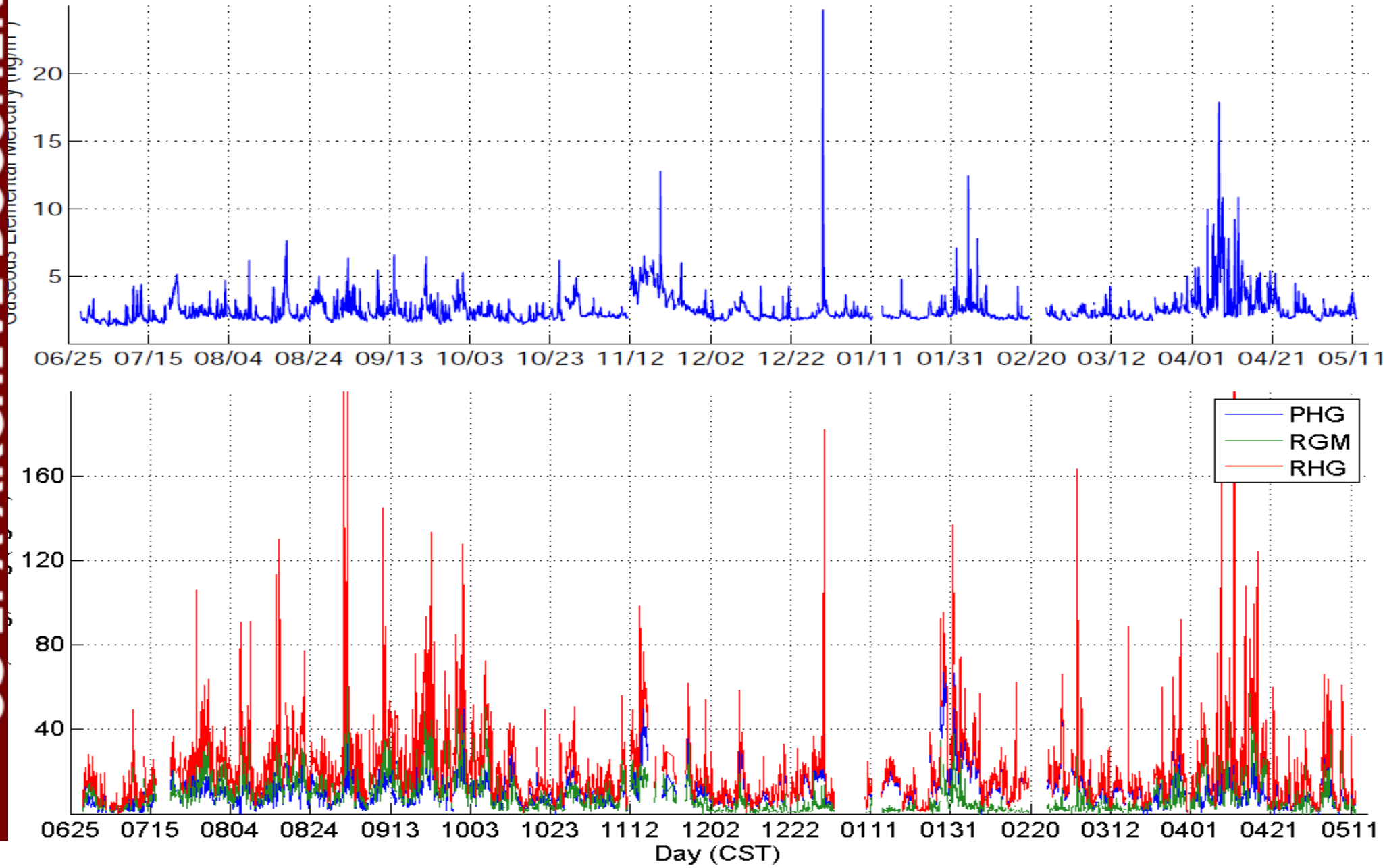
B. de Foy, J. Heo, and J.J. Schauer, "Estimation of direct emissions and atmospheric processing of reactive mercury using inverse modeling," *Atmospheric Environment*, 2014.

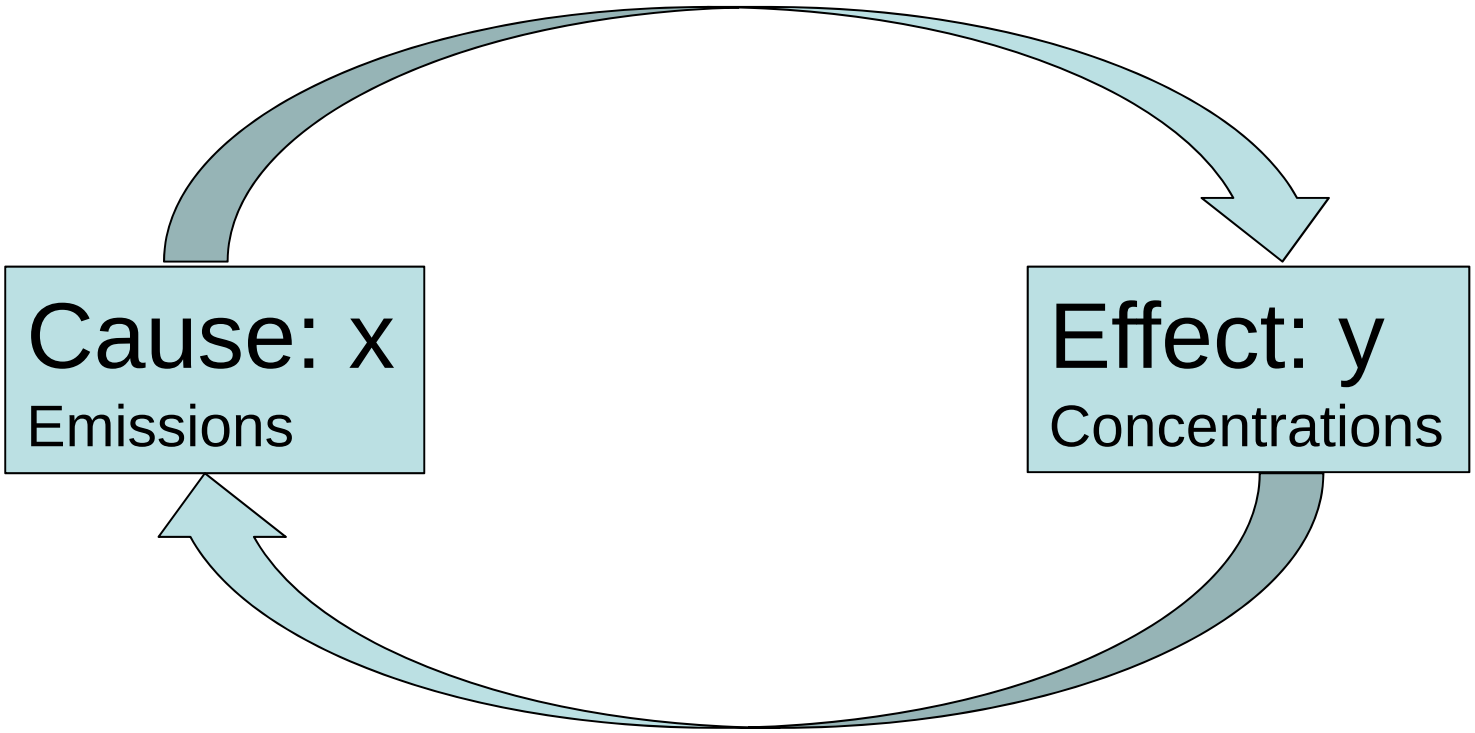
B. de Foy, C. Wiedinmyer, J.J. Schauer, "Estimation of mercury emissions from forest fires, lakes, regional and local sources using measurements in Milwaukee and an inverse method," *Atmospheric Chemistry & Physics*, 2012.

Speciated Mercury Measurements in Milwaukee



Inverse Modeling

Forward Simulation: $y = Hx$



Inverse Problem: $x = H^{-1}y$

xtbook Intro: “Parameter Estimation and Inverse Problems” by Aster, Borchers and Thurber
aphical Intro: “A Conceptual Introduction to Geophysical Inversion” by Andy Ganse, U. Washington

Inverse Modeling: Bayesian Formulation Simplifies to Least-Squares Inversion when Error Covariances are Diagonal

Bayesian Formulation:

$$J = (\mathbf{H}\boldsymbol{x} - \boldsymbol{y})^T \mathbf{R}_a^{-1} (\mathbf{H}\boldsymbol{x} - \boldsymbol{y}) + \boldsymbol{x}^T \mathbf{R}_b^{-1} \boldsymbol{x}$$

Simplifies to:

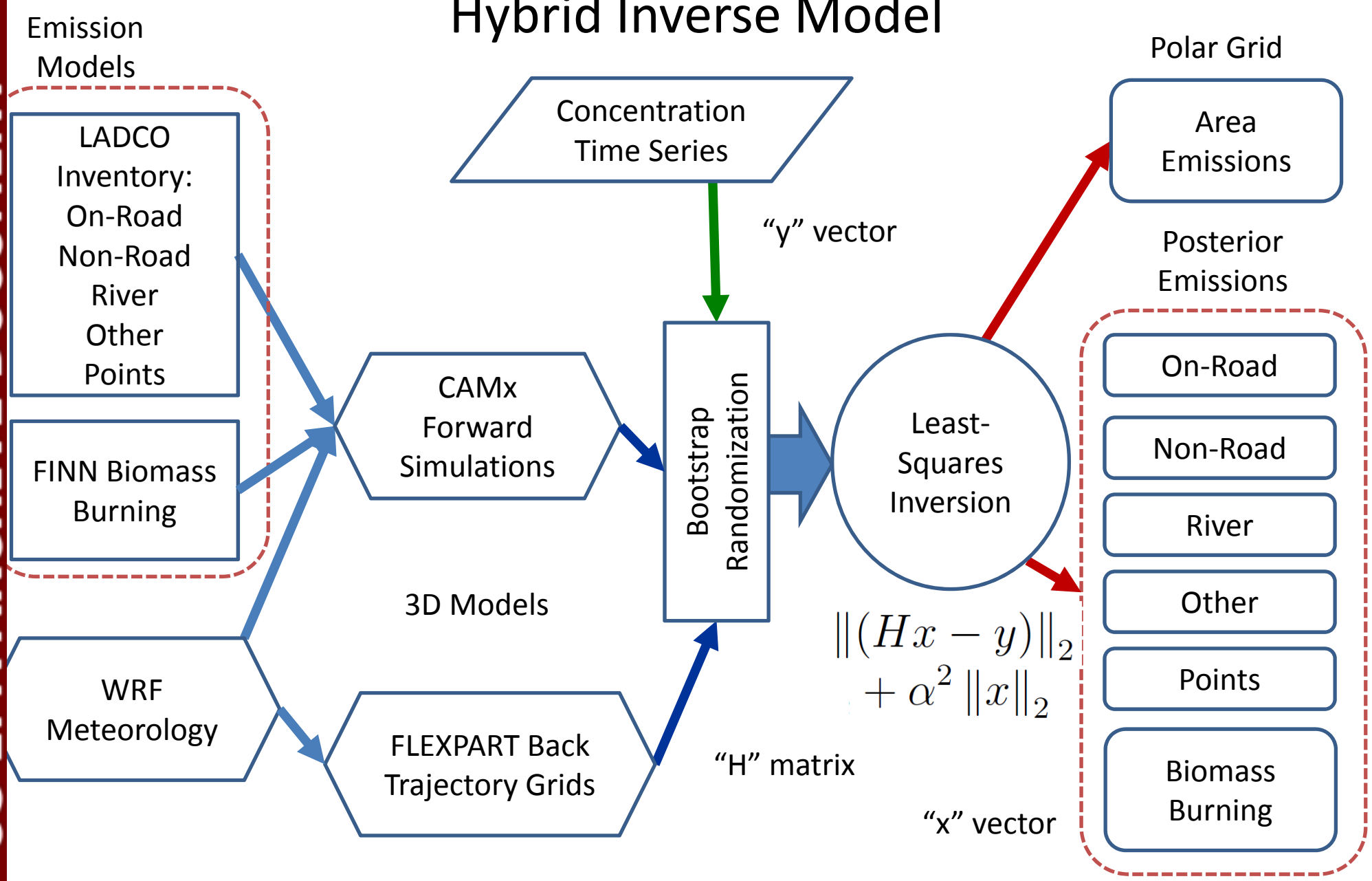
$$J = (\mathbf{H}\boldsymbol{x} - \boldsymbol{y})^T (\mathbf{H}\boldsymbol{x} - \boldsymbol{y}) + \alpha^2 \boldsymbol{x}^T \boldsymbol{x}$$

Solution in a single step of least-squares:

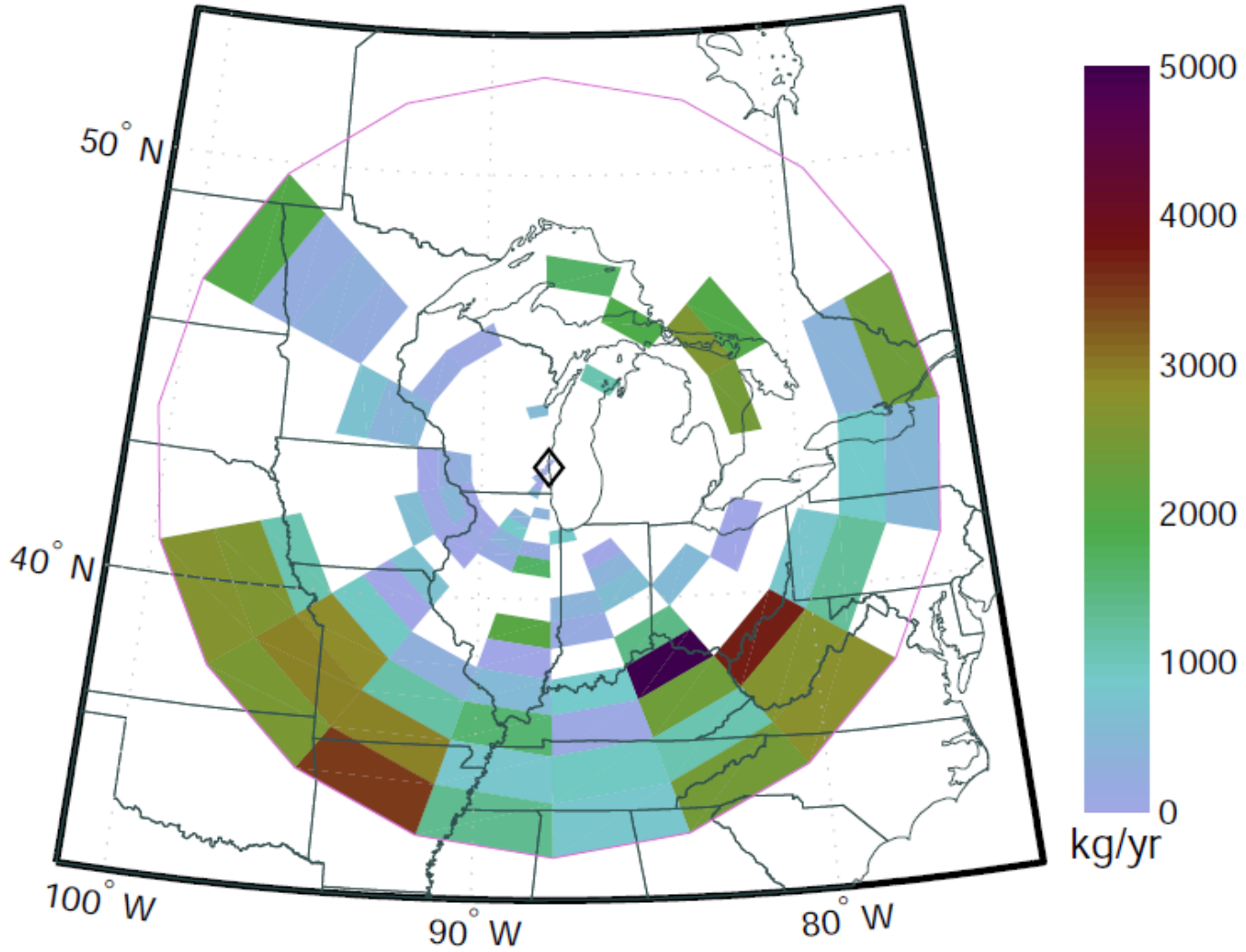
$$J = \left\| \boldsymbol{s} \cdot (\mathbf{H}'' \boldsymbol{x} - \boldsymbol{y}'') \right\|_2$$

B. de Foy, C. Wiedinmyer, J.J. Schauer, "Estimation of mercury emissions from forest fires, lakes, regional and local sources using measurements in Milwaukee and an inverse method," *Atmospheric Chemistry & Physics*, 2012.

Hybrid Inverse Model

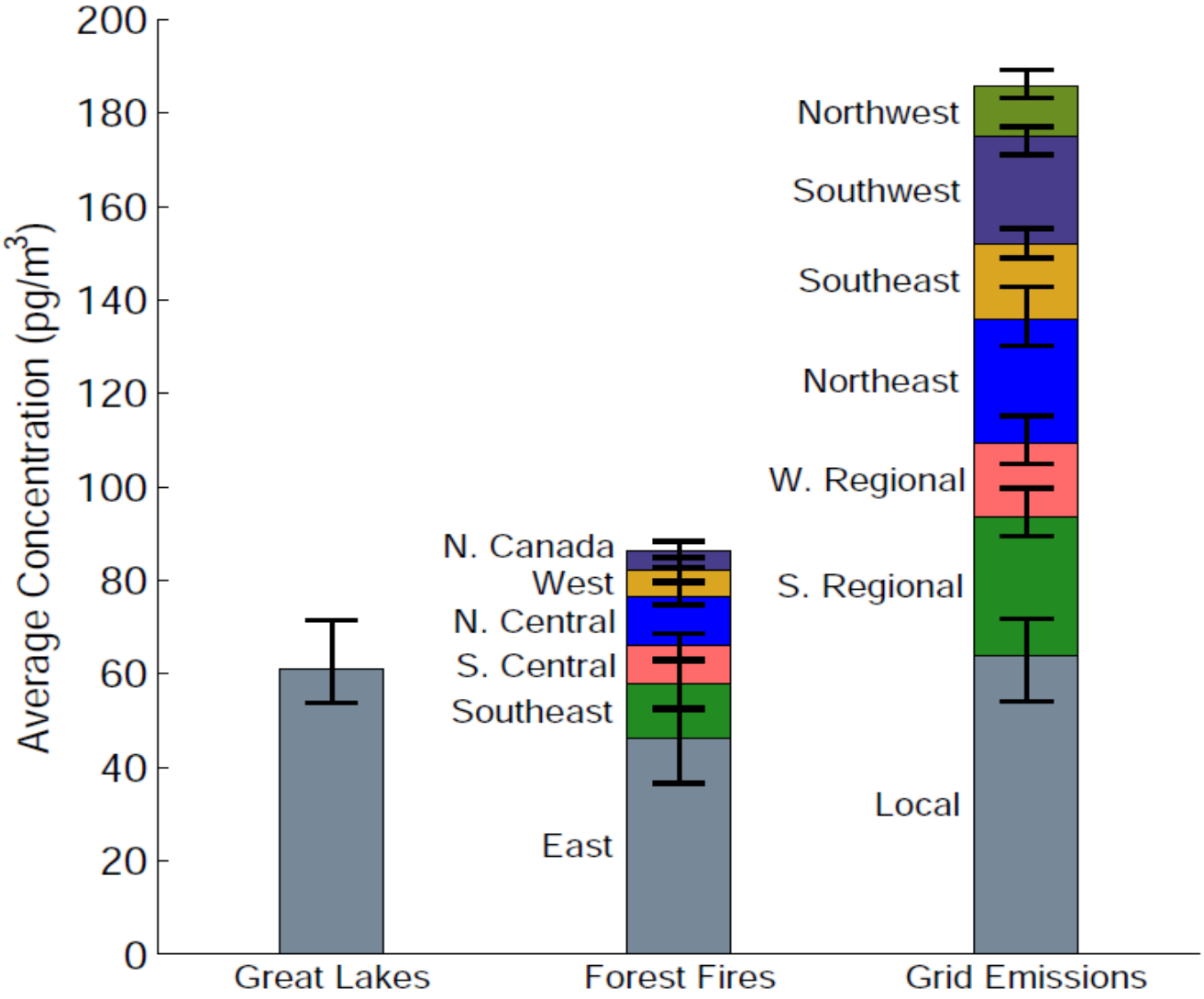


Gridded Emissions of Gaseous Elemental Mercury Estimated from Back-Trajectories



B. de Foy, C. Wiedinmyer, J.J. Schauer, "Estimation of mercury emissions from forest fires, akes, regional and local sources using measurements in Milwaukee and an inverse method," *Atmospheric Chemistry & Physics*, 2012.

Source Group Impacts on Gaseous Elemental Mercury in Milwaukee Based on CAMx Simulations and Back-Trajectories.



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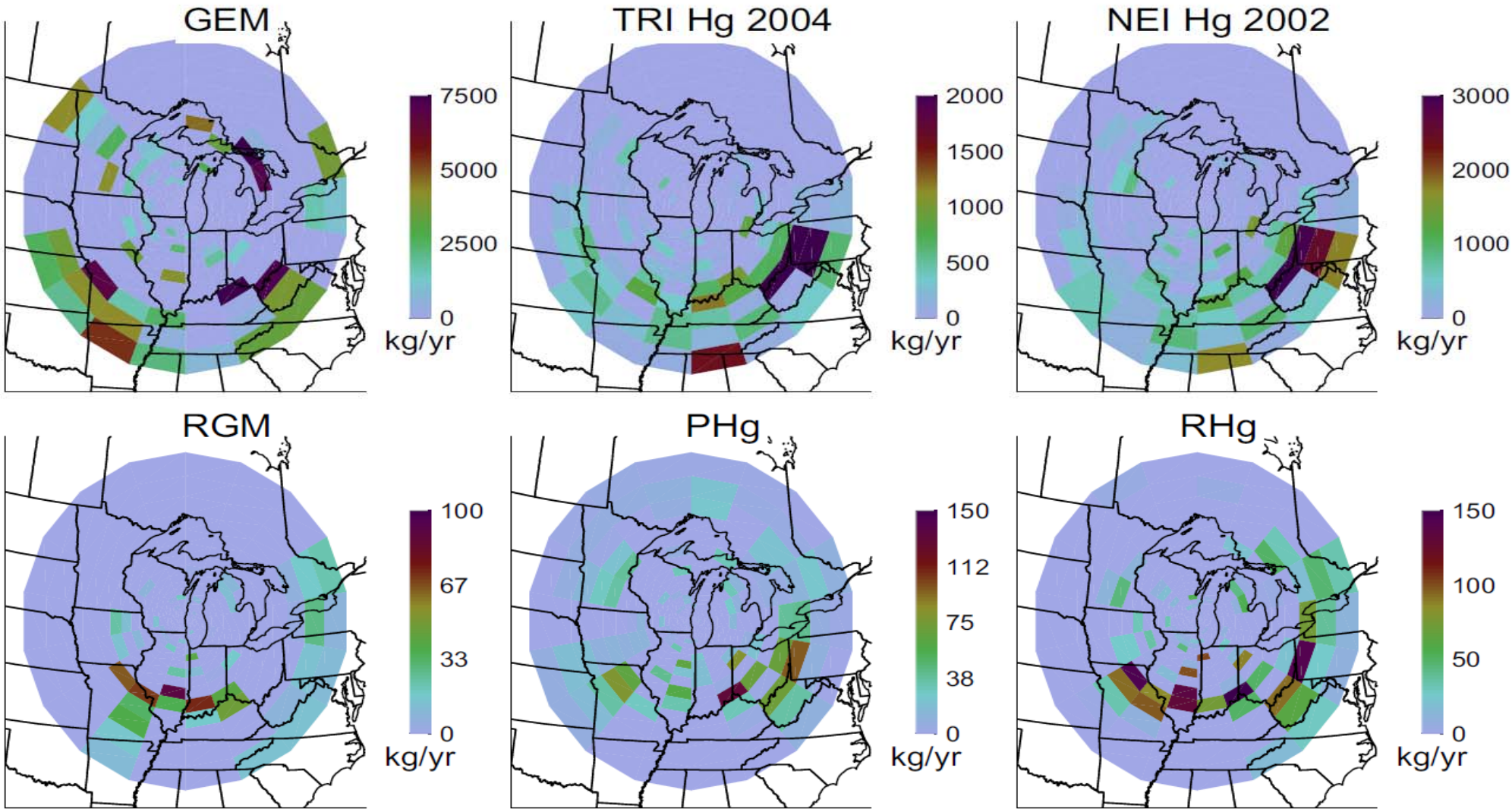
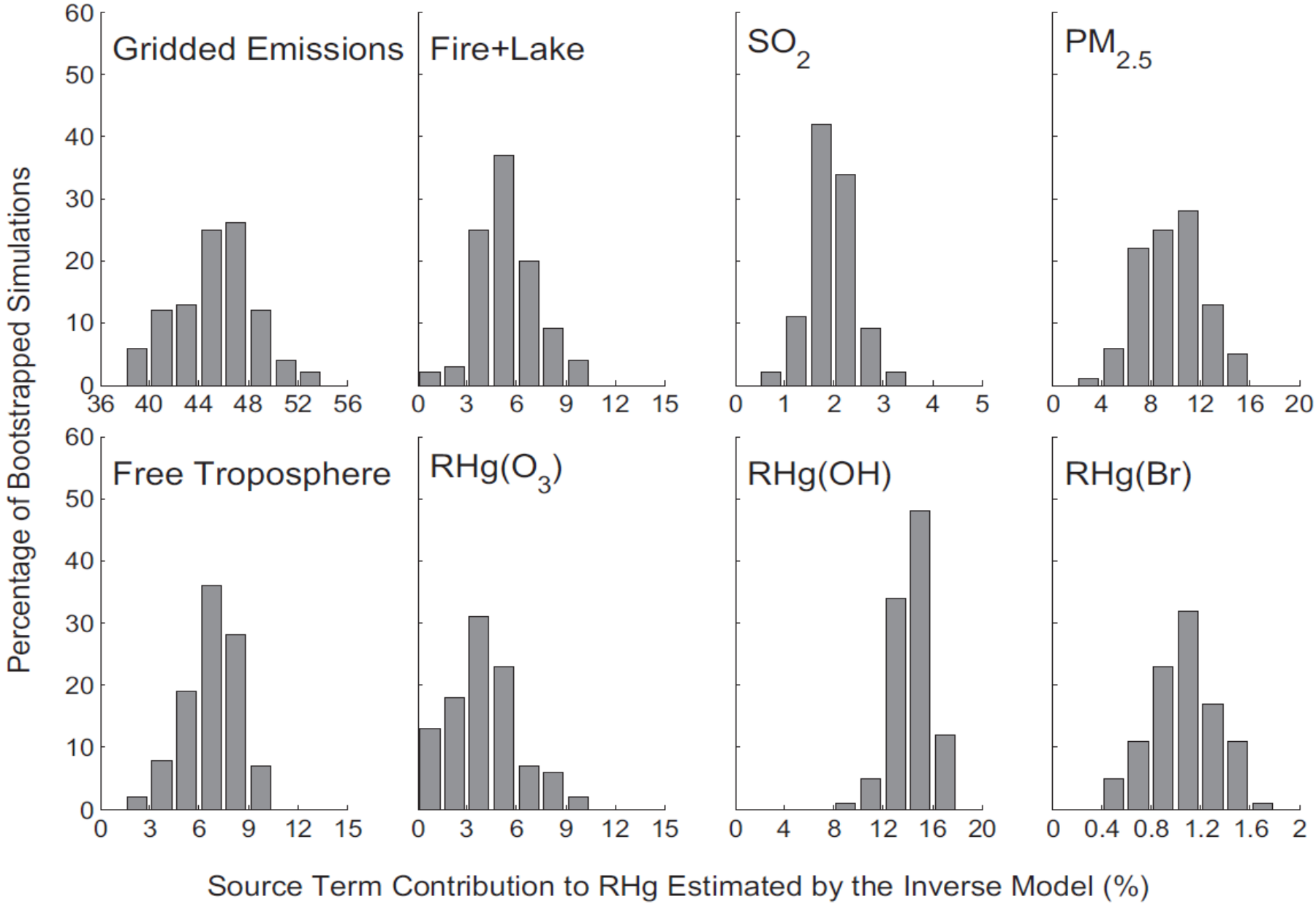
Gridded Emissions of Speciated Mercury Compared with TRI and NEI

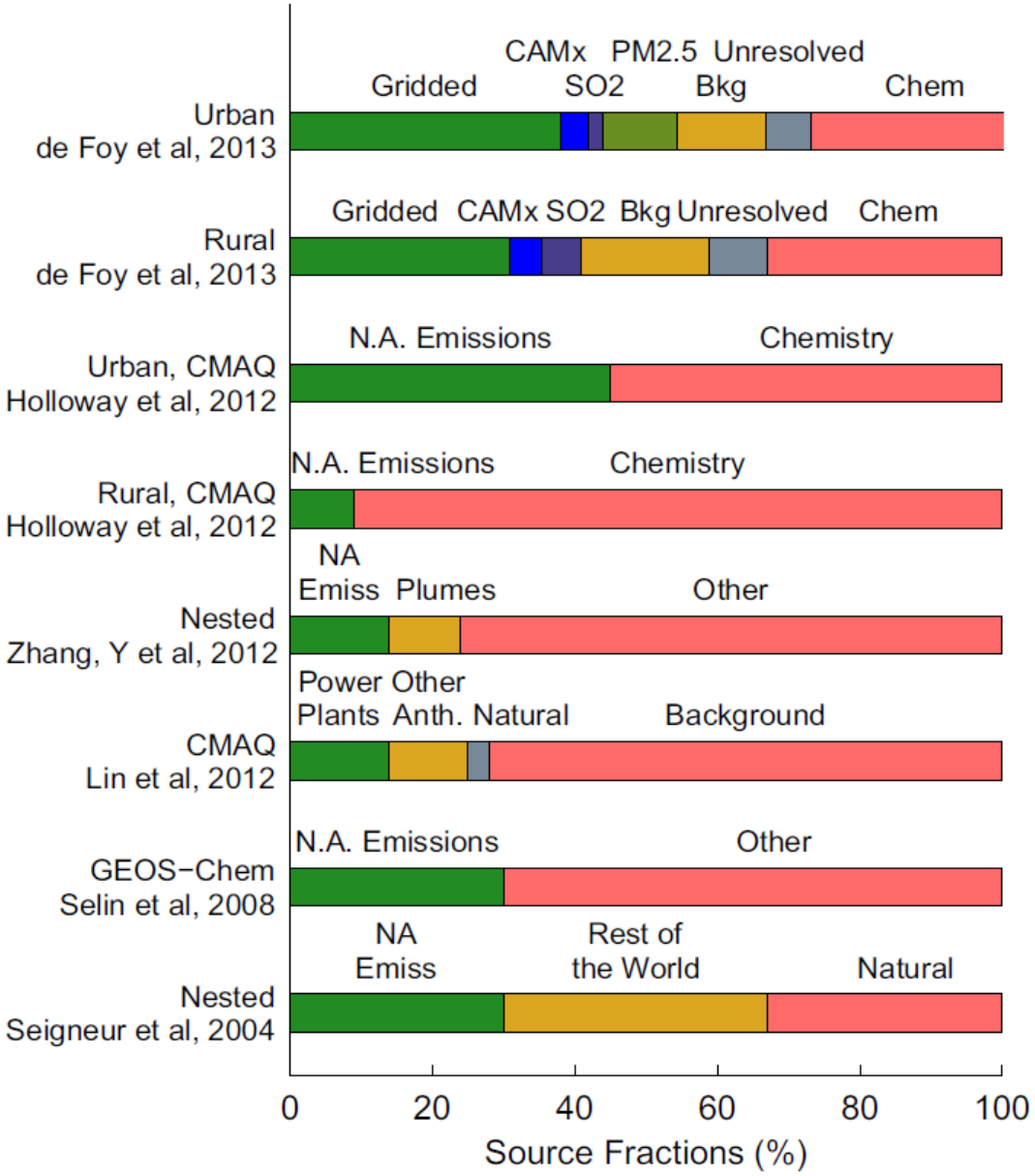


B. de Foy, J. Heo, and J.J. Schauer, "Estimation of direct emissions and atmospheric processing of reactive mercury using inverse modeling," *Atmospheric Environment*, 2014.

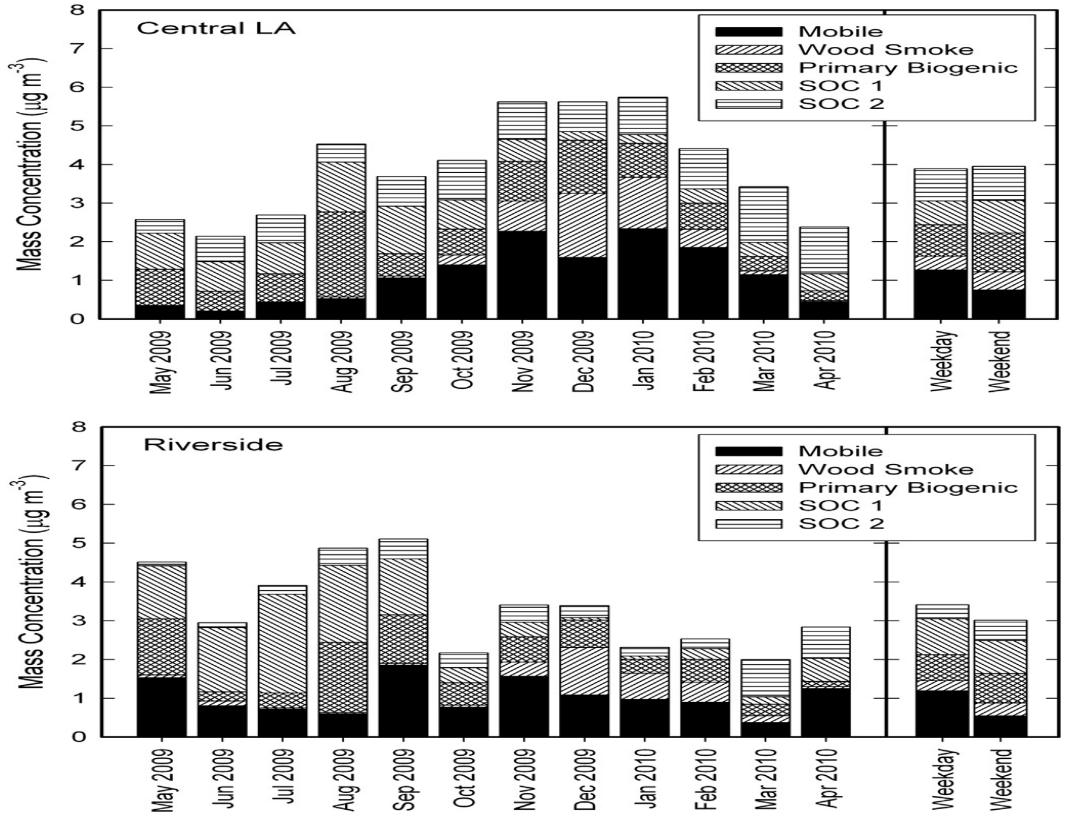
Contributions to Reactive Mercury in Milwaukee Uncertainty Analysis using Bootstrapping



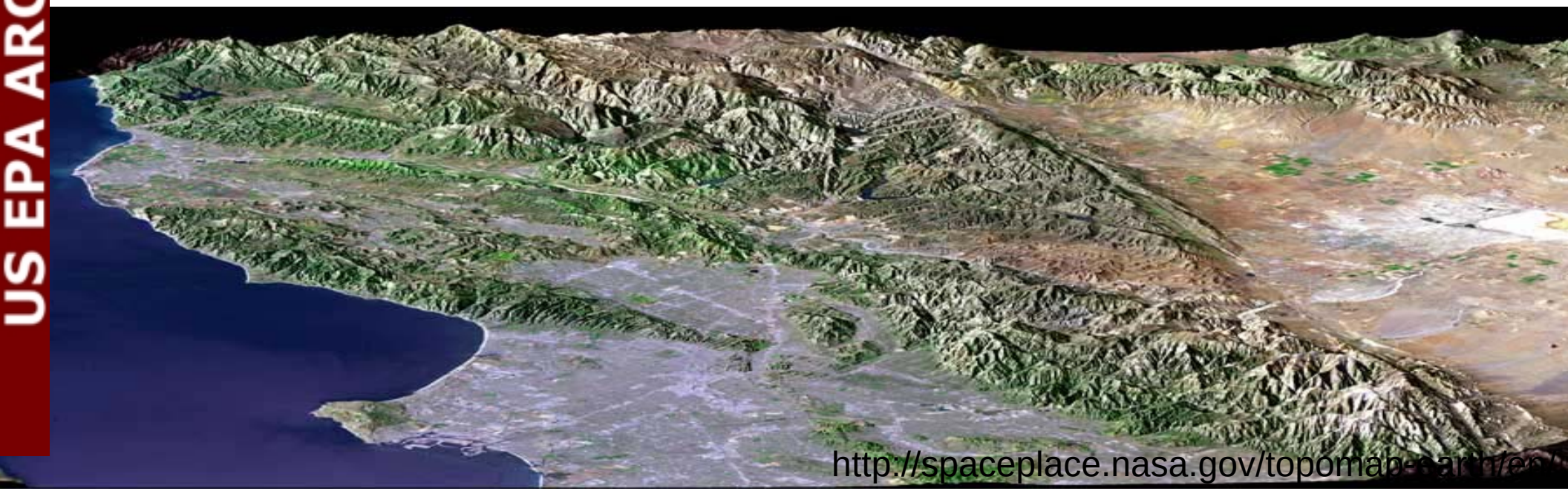
Source Attribution of Reactive Mercury: Current inverse model suggests that a greater fraction is directly emitted compared to previous modeling studies



Los Angeles: PMF Source Apportionment of PM2.5 Organic Carbon

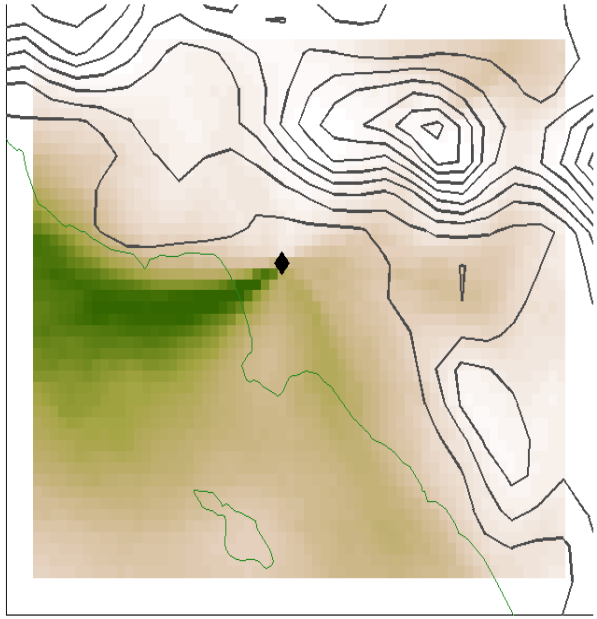


Heo et al., “Source apportionments of M2.5 organic carbon using molecular arker Positive Matrix Factorization and omparison of results from different eceptor models” *tmospheric Environment*, 2013.

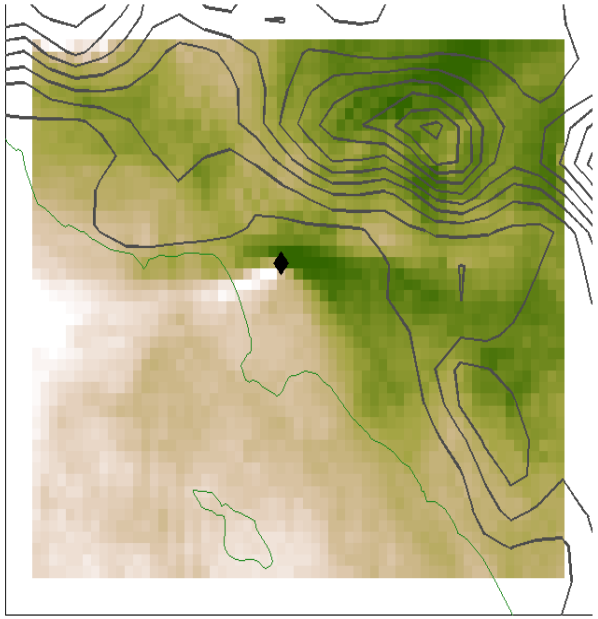


http://spaceplace.nasa.gov/topomap-earth/en/

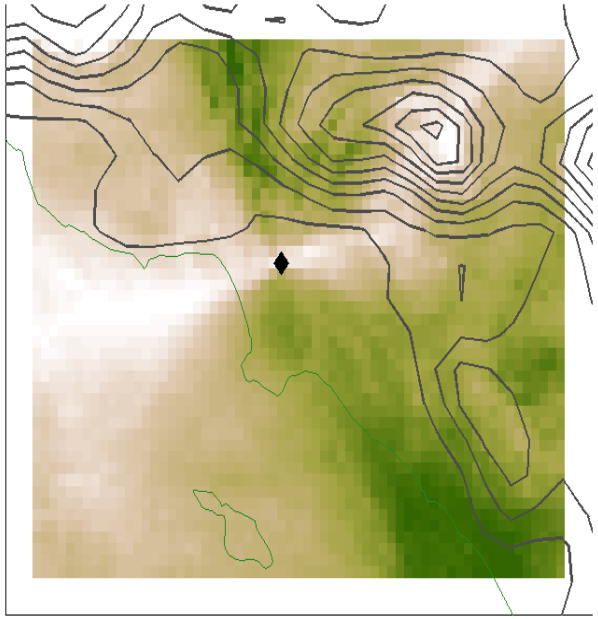
Back-Trajectory Analysis for Los Angeles: Carbon Monoxide, May 2009 – April 2010



Residence Time Analysis shows dominant flow pattern: westerly flow from the Pacific Ocean



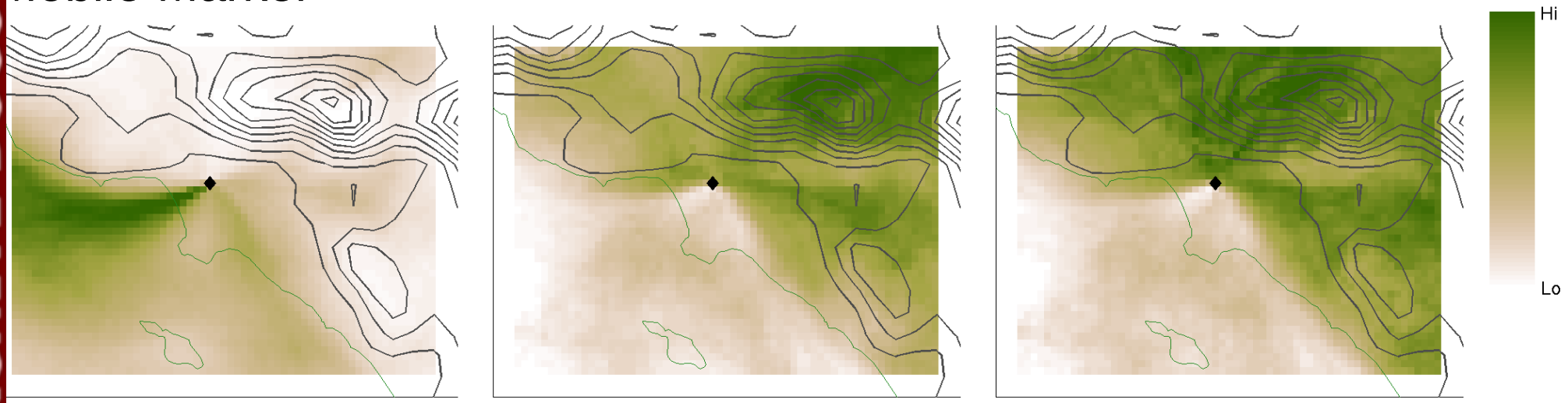
Concentration Field Analysis shows high CO concentrations are associated with downslope winds and night time drainage flows.



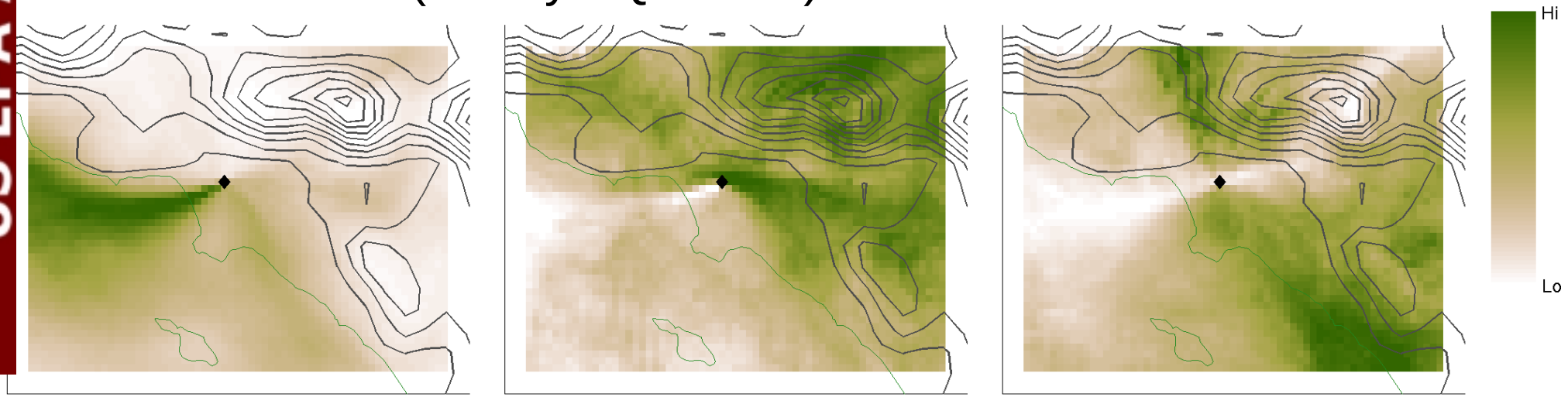
Column Concentration Field Analysis shows larger amounts of CO in the boundary layer are associated with flow from the South Coast and from the Central Valley.

Back-Trajectory Analysis for Los Angeles: PMF using 24hr samples, May 2009 – April 2010

Mobile Marker



Carbon Monoxide (Hourly AQS Data)



EC / OC Emissions using East – St. Louis Supersite Hourly Measurements

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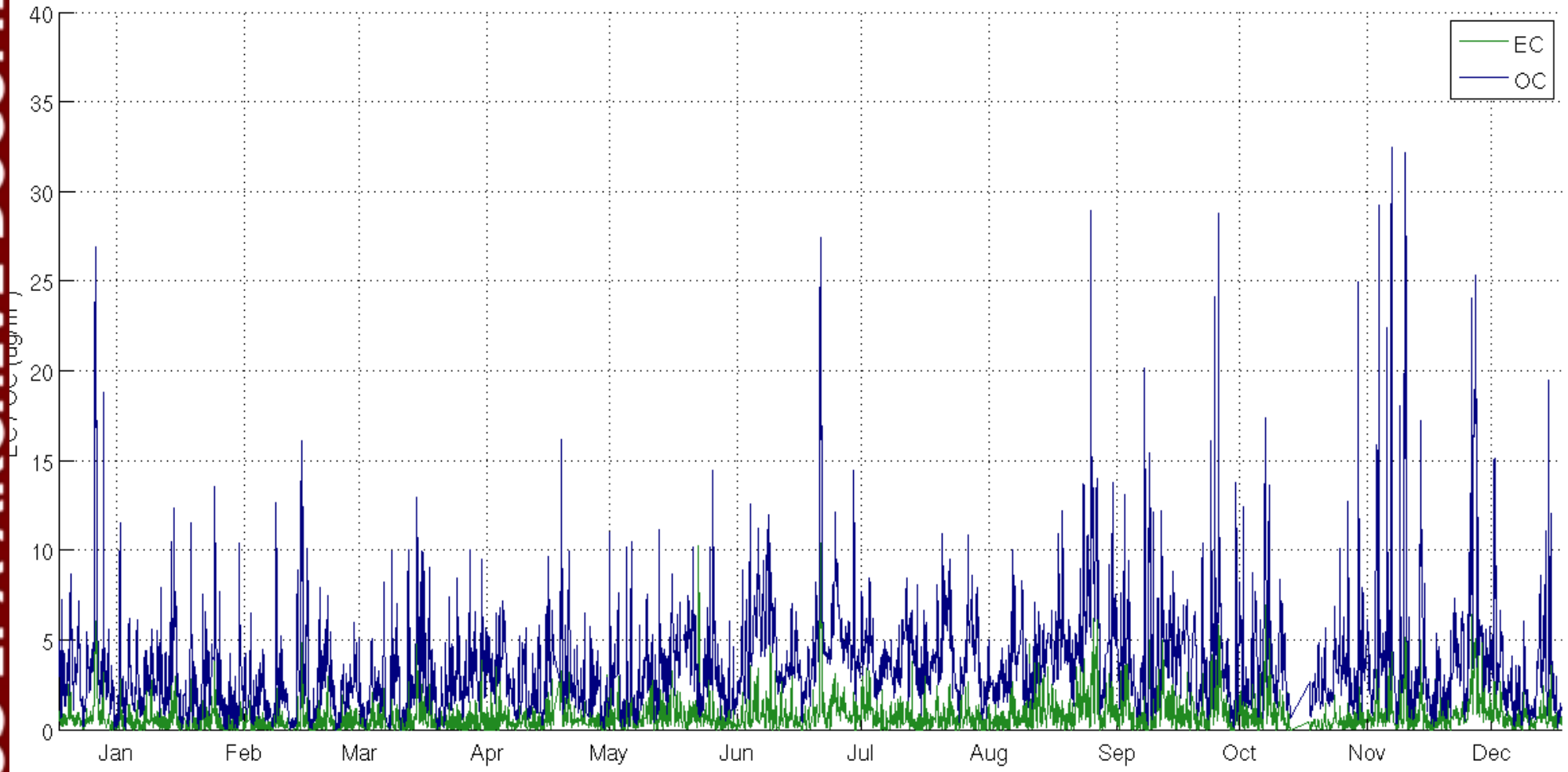
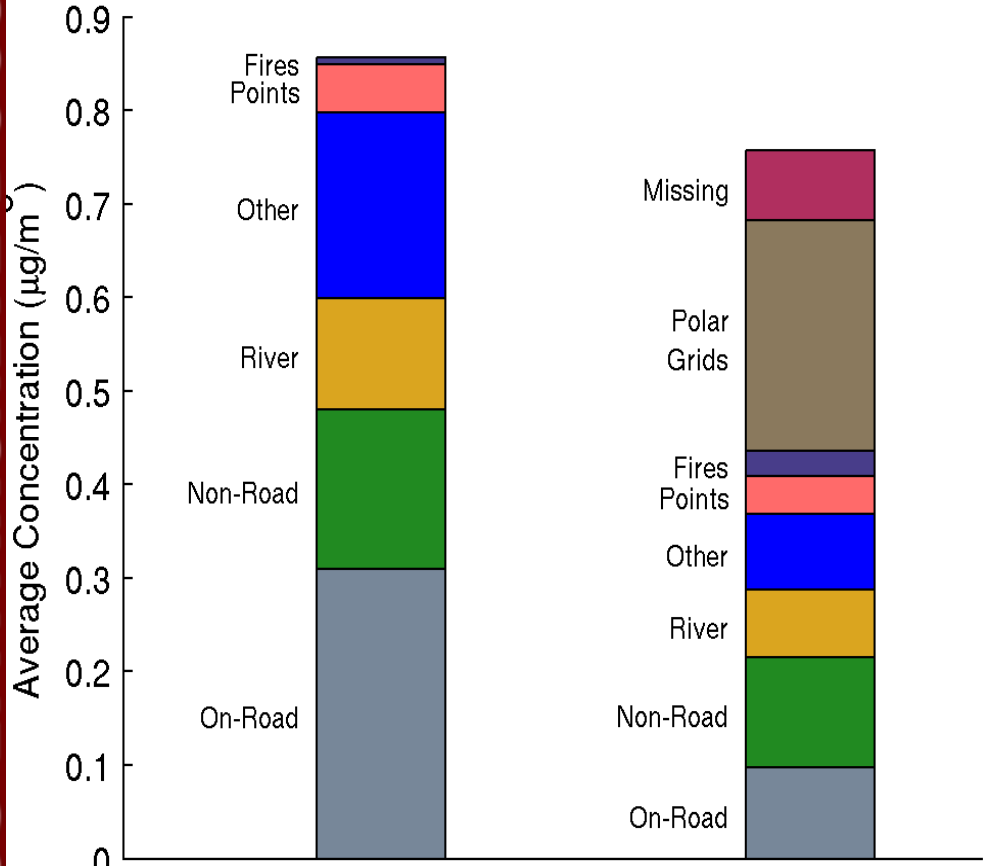
http://www.iasaglobal.org/images/iasa/Stlouis.jpg

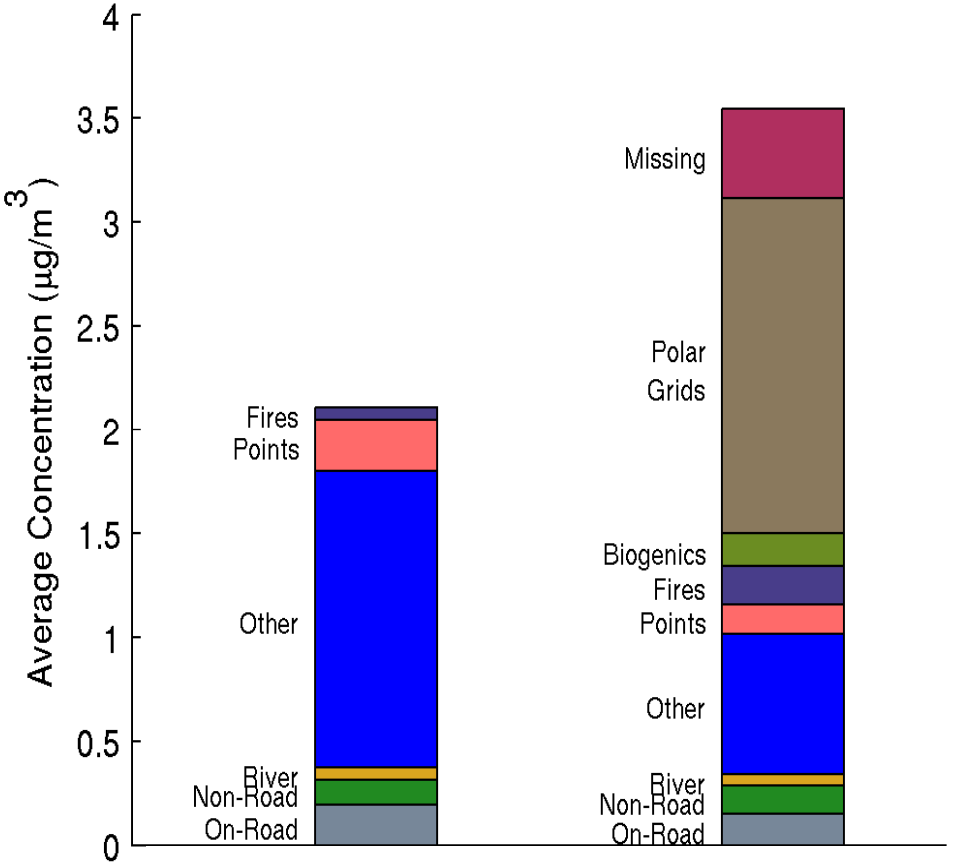
East – St. Louis Supersite: Continuous Hourly EC/OC Measurements for 2002



Contributions by Source Types using the LADCO Inventory and the Inverse Model Results

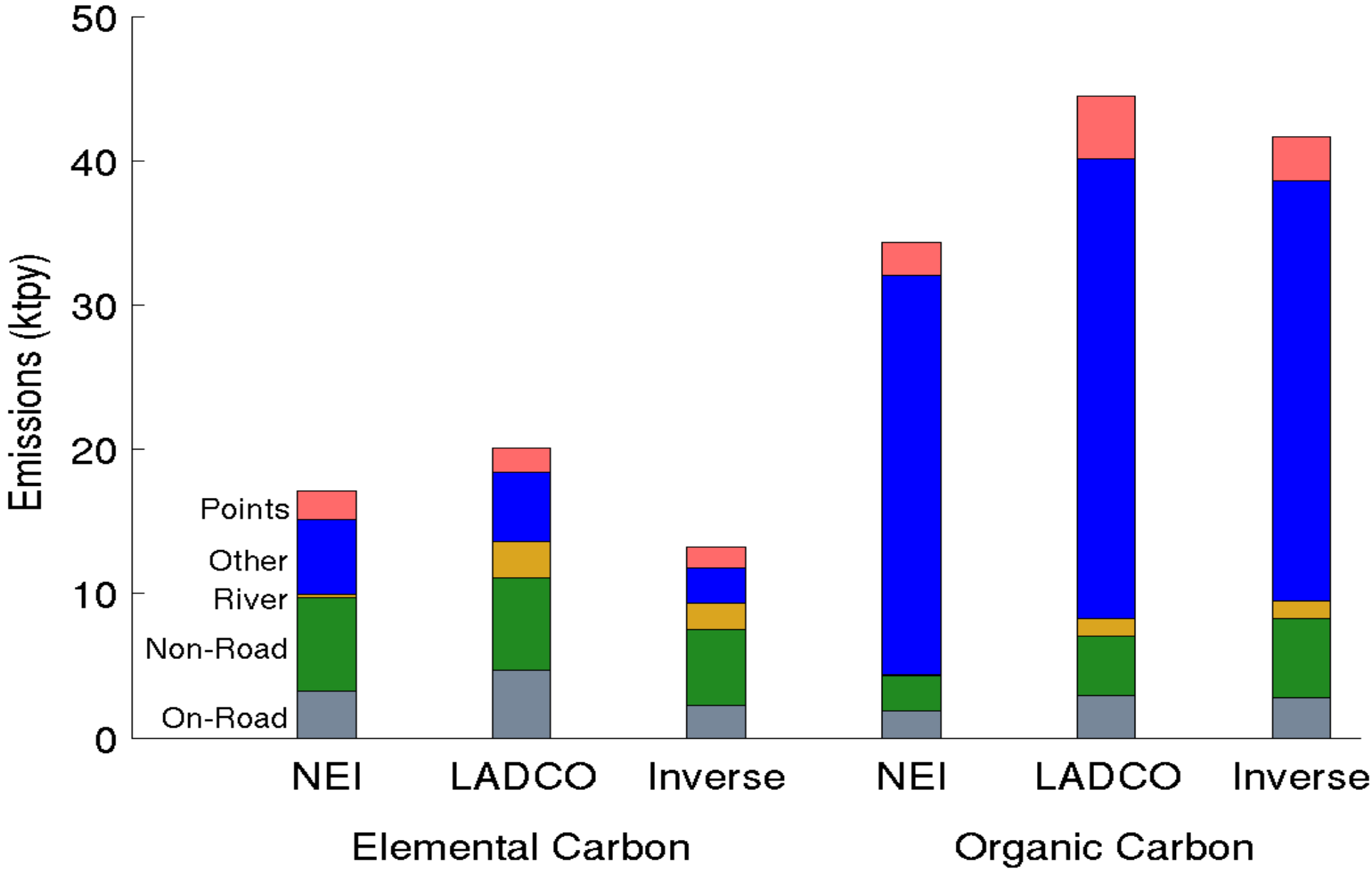


Elemental Carbon



Organic Carbon

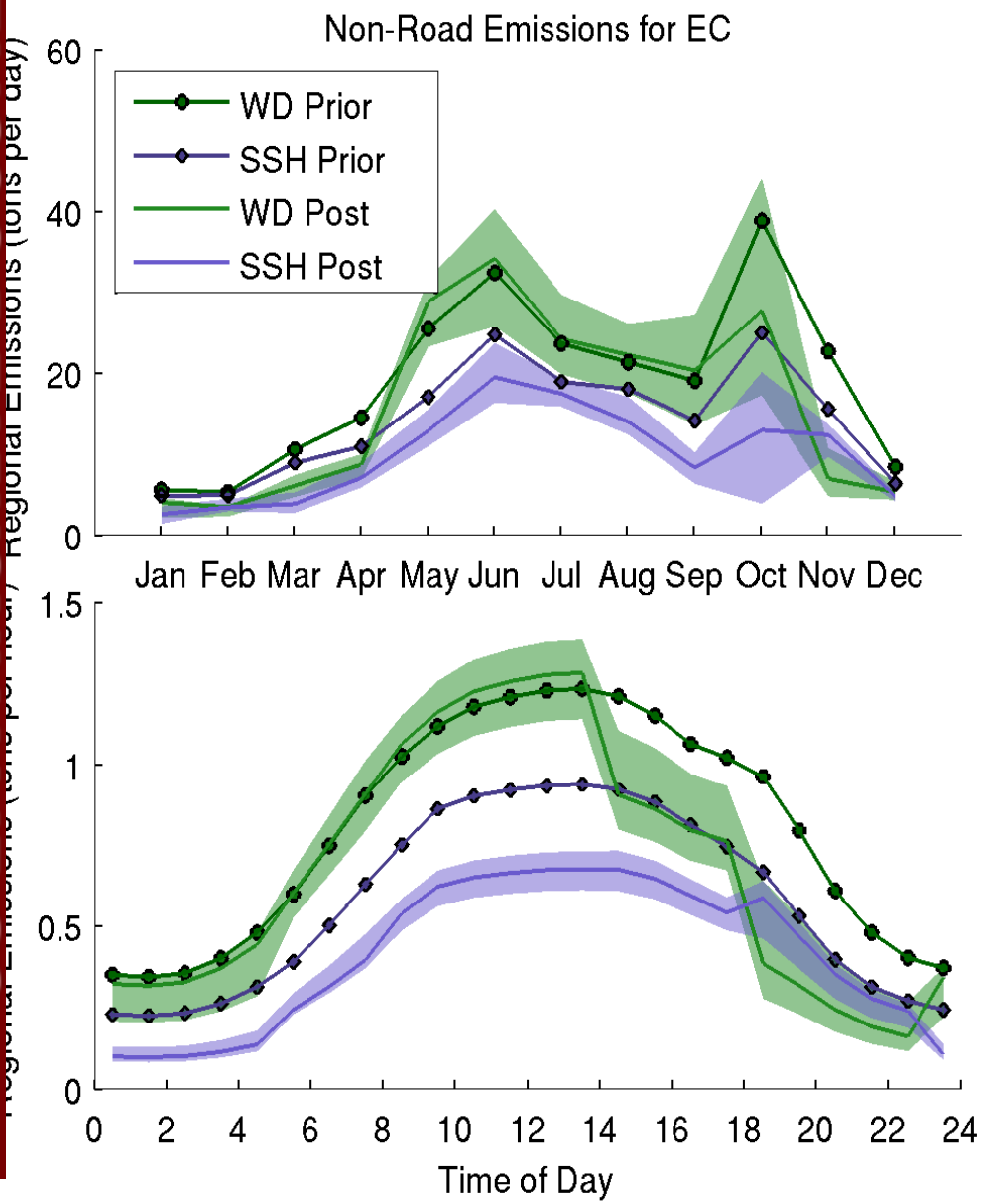
Emissions by Source Type
For St. Louis and the Surrounding Region

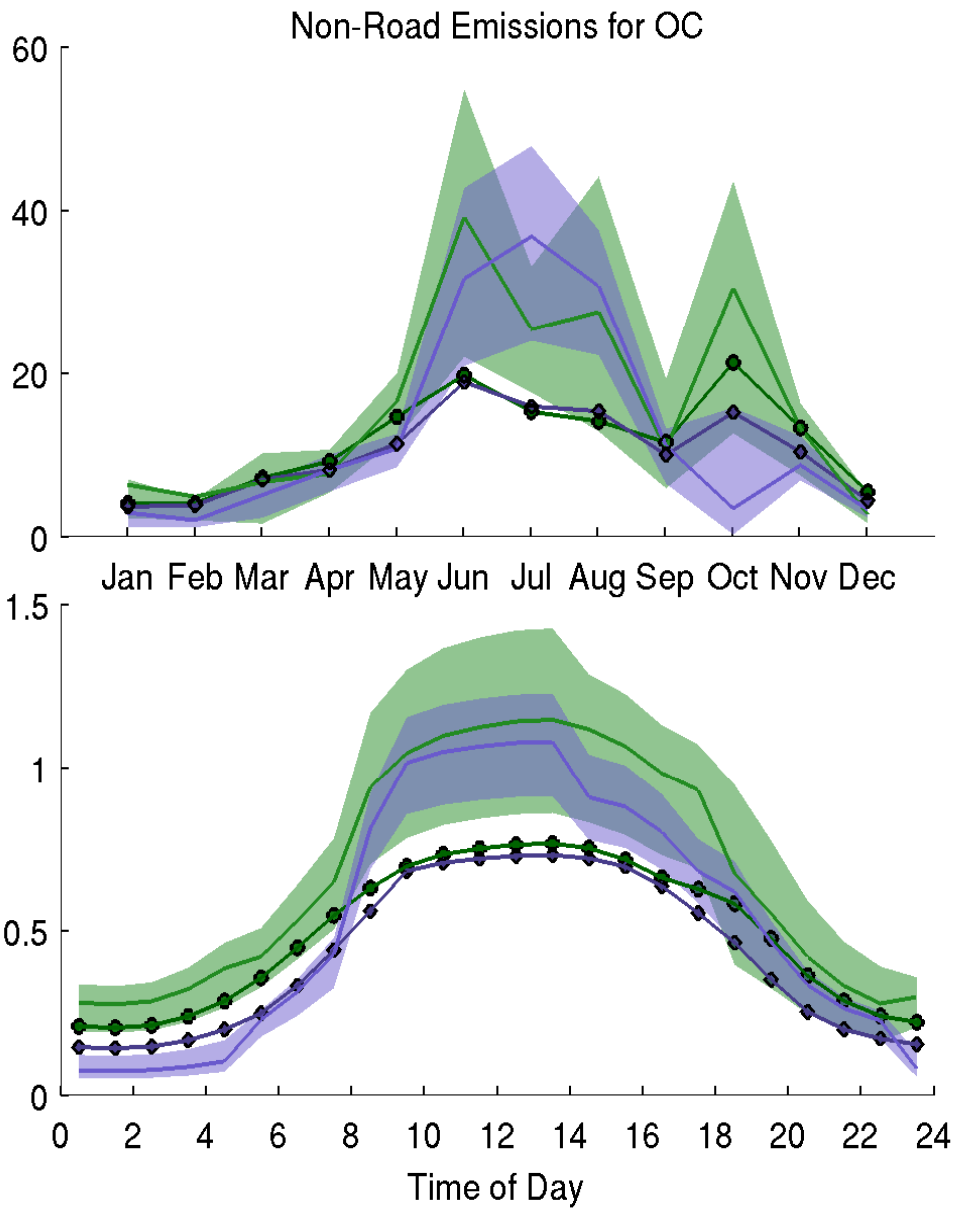


Diurnal and Monthly Emission Profiles for Non-Road Emissions

LADCO Prior Inventory shown with Solid Markers

Inverse Model Range based on Bootstrapping shown with Shading

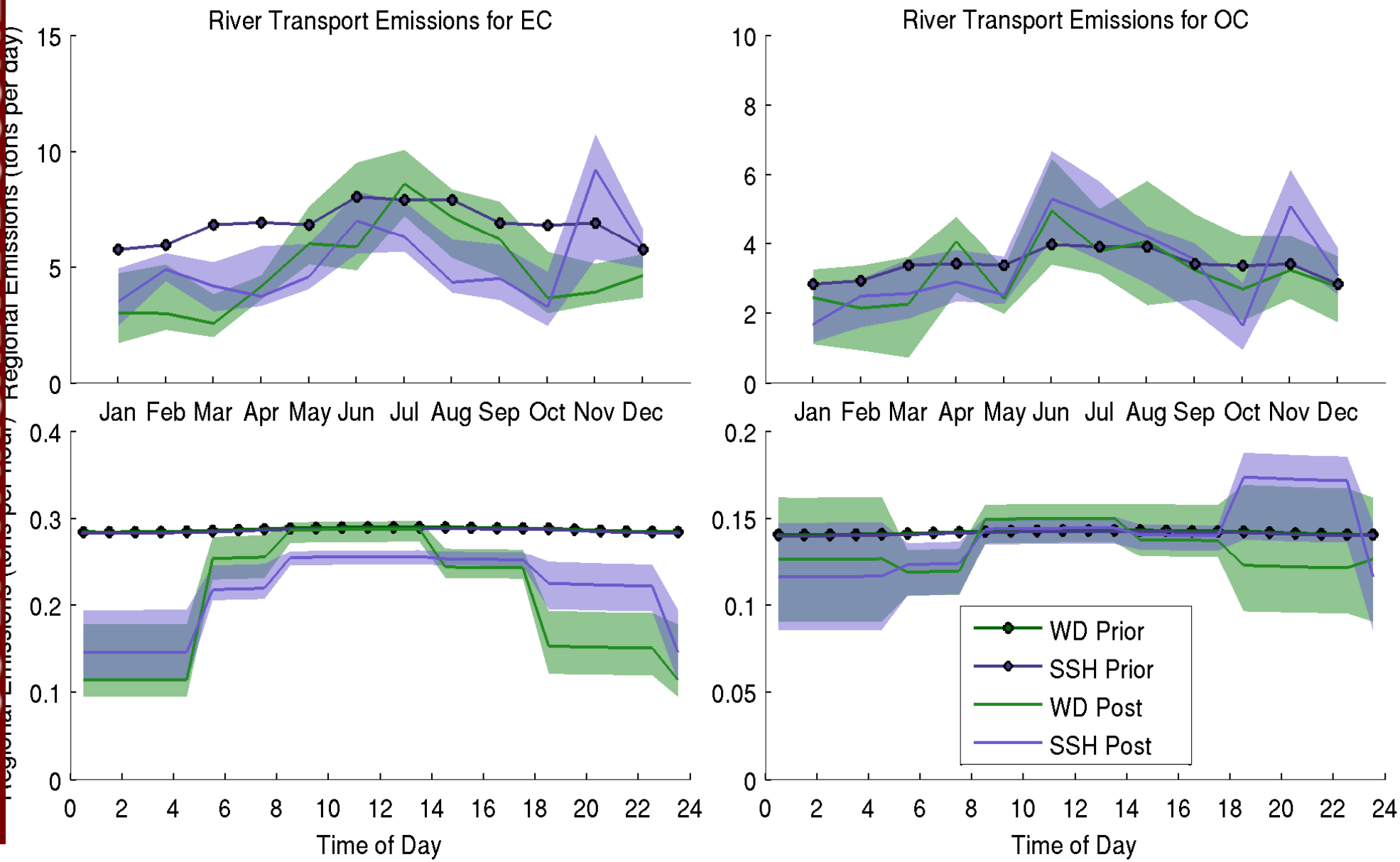




Diurnal and Monthly Emission Profiles for “Marine/Aircraft/Rail”

LADCO Prior Inventory shown with Solid Markers

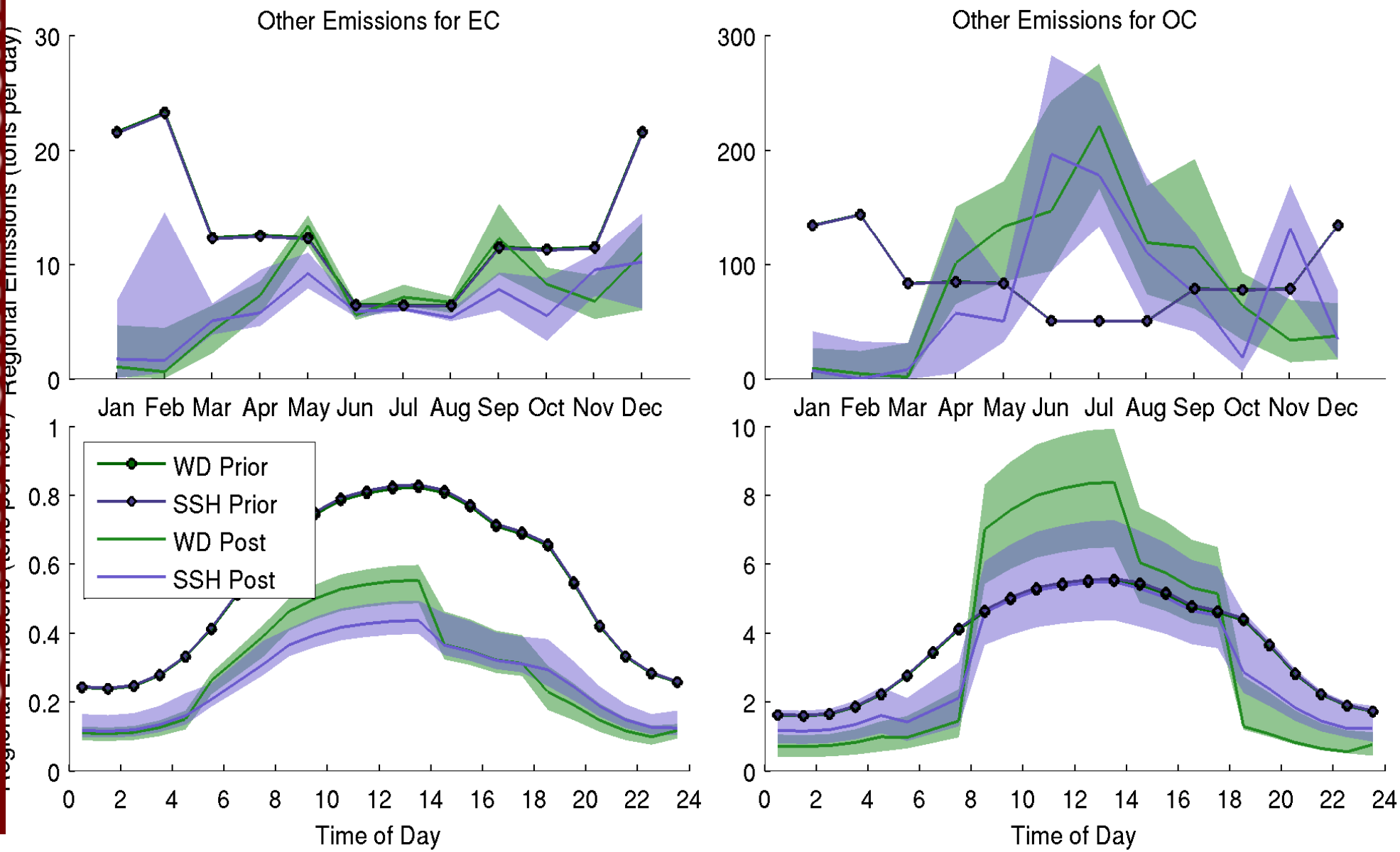
Inverse Model Range based on Bootstrapping shown with Shading



Diurnal and Monthly Emission Profiles for "Other" Emissions

LADCO Prior Inventory shown with Solid Markers

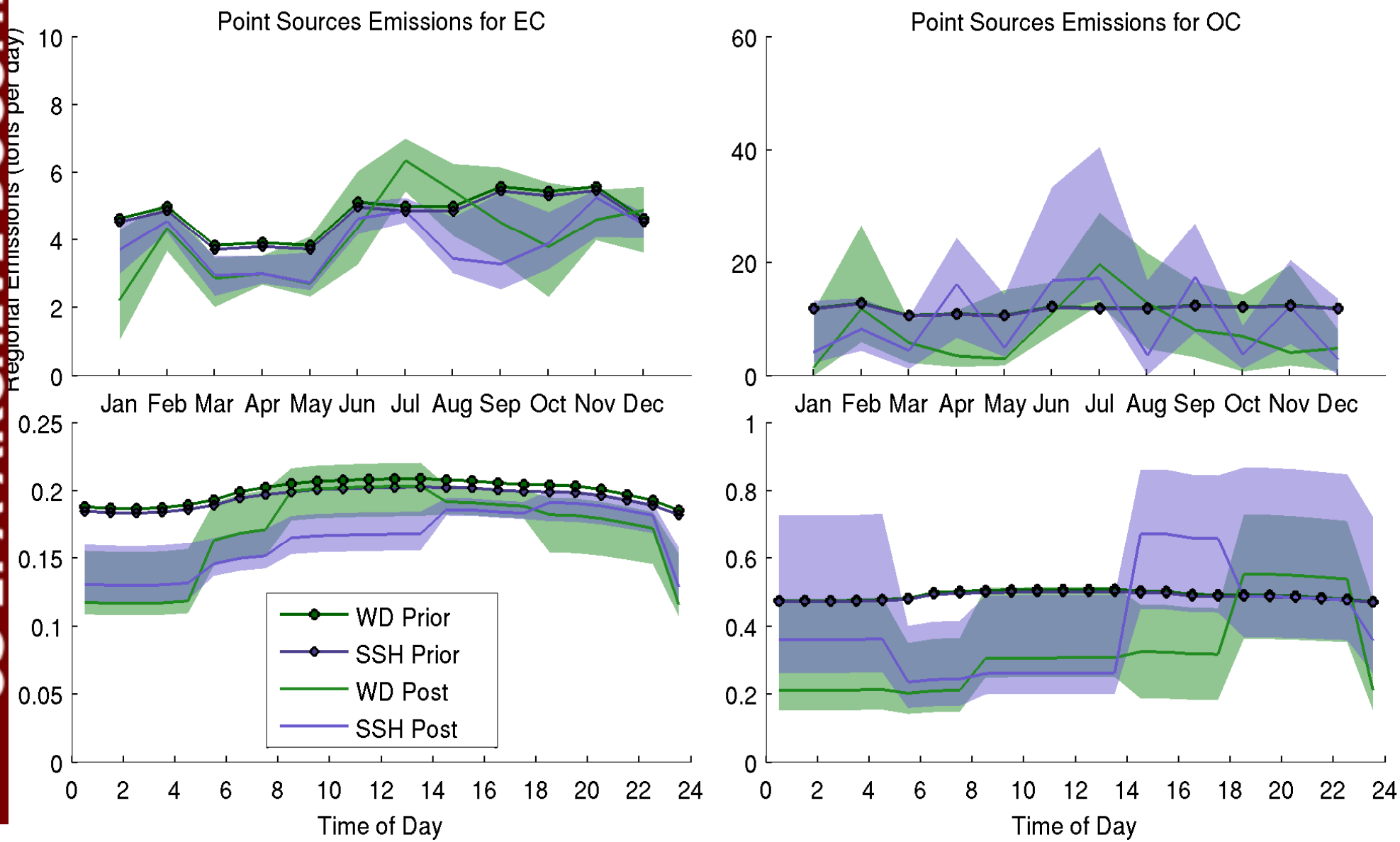
Inverse Model Range based on Bootstrapping shown with Shading



Diurnal and Monthly Emission Profiles for Point Source Emissions

LADCO Prior Inventory shown with Solid Markers

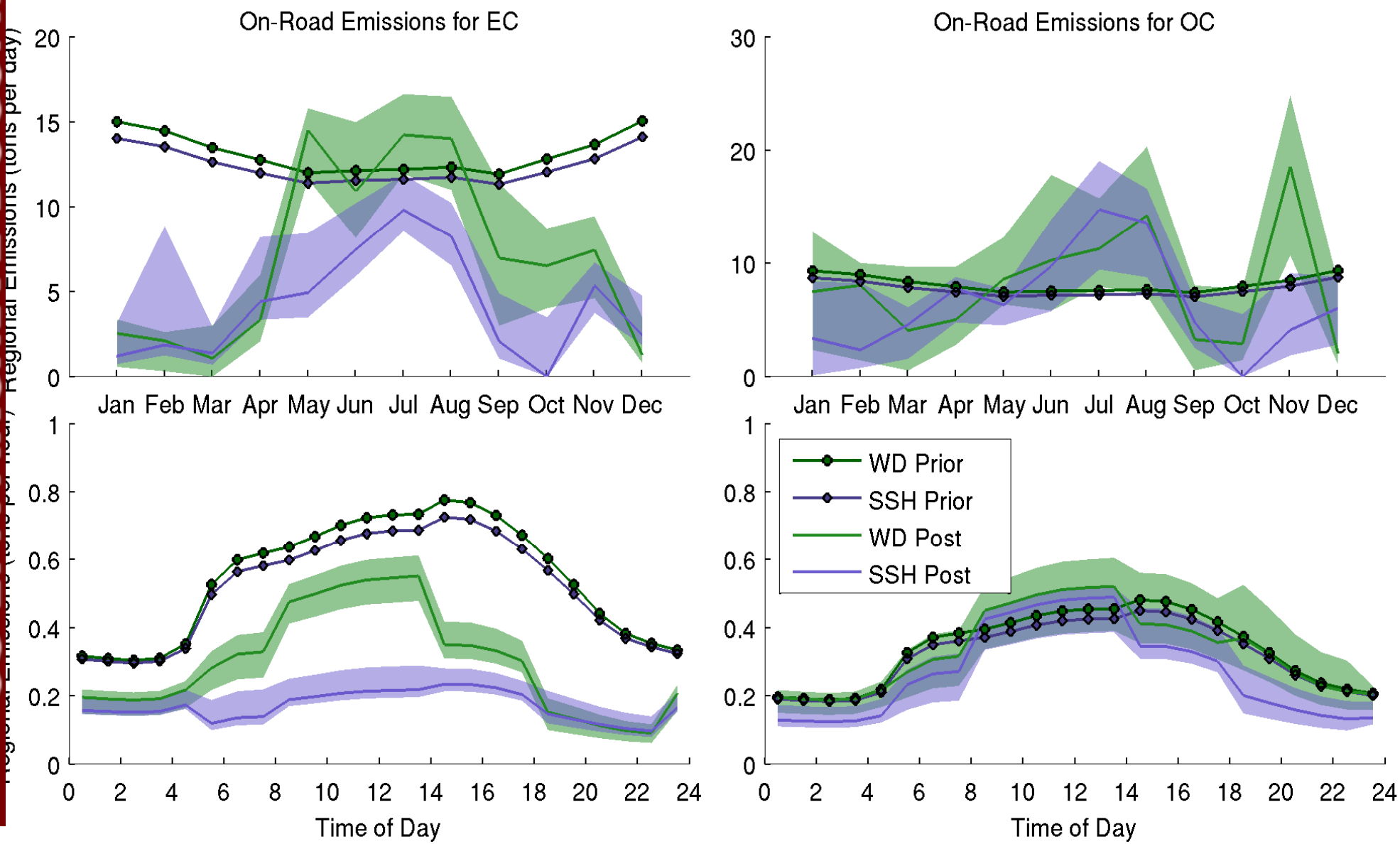
Inverse Model Range based on Bootstrapping shown with Shading



Diurnal and Monthly Emission Profiles for On-Road Emissions

LADCO Prior Inventory shown with Solid Markers

Inverse Model Range based on Bootstrapping shown with Shading



EC / OC Emissions using East – St. Louis Supersite Hourly Measurements

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- Diurnal and Monthly Emission Profiles can be estimated from Year-long Hourly Measurements using an Inverse Model
- There is agreement between the inverse model and the inventory for most source types
- Non-Road emissions in particular have good agreement – although inverse results suggest a bigger decrease in the week-ends
- On-Road emissions have the largest discrepancy: the summer seems OK, but in the winter and on weekends the model has trouble matching the inventory

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD 83455701

http://www.i