Sensitivity of Flux Accuracy to Setup of Fossil Fuel and Biogenic CO_2 Inverse System in an Urban Environment

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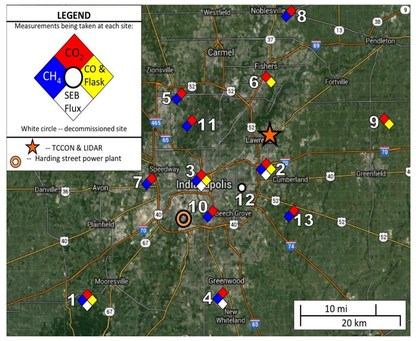
Introduction



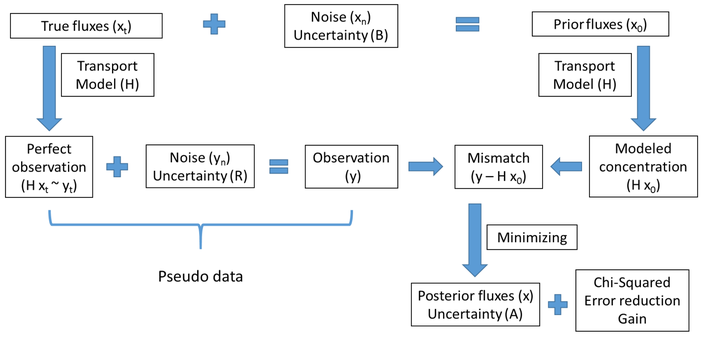
- The Indianapolis Flux Experiment (INFLUX) is intended to quantify anthropogenic sources of CO_2 and CH_4 over Indianapolis.
- Aircraft, automobile and a high-density surface tower network are used to detect the spatial distribution and temporal variation of urban greenhouse gas (GHG) emissions
- A regional inversion system has been built to infer urban GHG emissions using these data

Questions

- Q1: How does the presence of biogenic fluxes affect the estimation of fossil fuel fluxes?
- Q2: What is the effect of adding fossil fuel measurements on flux retrieval accuracy?
- Q3: What is the benefit to the result from reducing the error of model-data mismatch?
- Q4: Which parameter in the prior flux noise has the largest impact on the precision and accuracy of the urban inverse emissions?

Methods

Observing System Simulation Experiments (OSSEs)



- How to generate the pseudo fossil fuel concentration measurements in the OSSEs?

Transport model (h)	Prior fluxes (x_f: fossil fuel fluxes x_b: biogenic fluxes)	Concentrations (Y_T: total concentration Y_F: fossil fuel concentration)
• $H = [h \quad h]$	$X_0 = \begin{bmatrix} x\_f \\ x\_b \end{bmatrix}$	$H*X_0 \sim Y = [Y\_T]$
• $H = \begin{bmatrix} h & h \\ h & 0 \end{bmatrix}$	$X_0 = \begin{bmatrix} x\_f \\ x\_b \end{bmatrix}$	$H*X_0 \sim Y = \begin{bmatrix} Y\_T \\ Y\_F \end{bmatrix}$

- Q1: How does the presence of biogenic fluxes affect the estimation of fossil fuel fluxes?
- Q2: What is the effect of adding fossil fuel measurements on flux retrieval accuracy?
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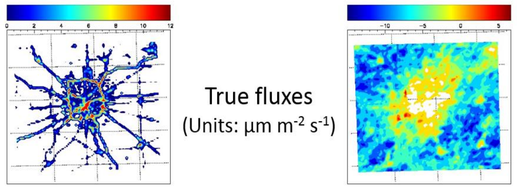
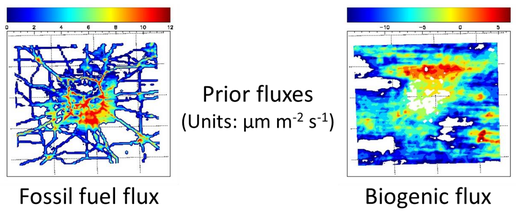
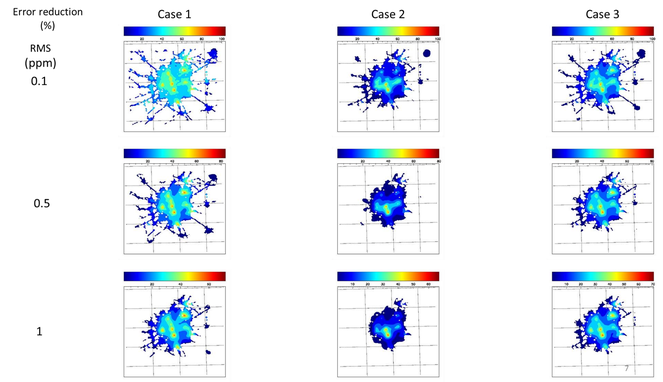


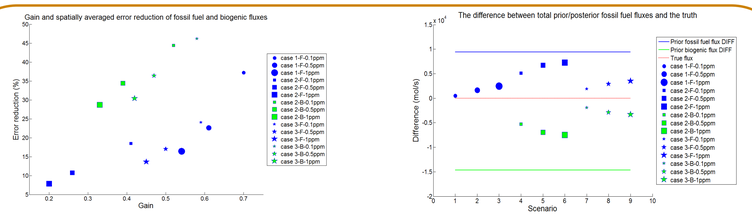
- Three different physical configurations
  - Case 1: without biogenic flux, total concentration measurements (e.g. fossil fuel concentration)
  - Case 2: with biogenic flux, total concentration measurements
  - Case 3: with biogenic flux, total & fossil fuel concentration measurements
- For each configuration, there are three kinds of error for the model data mismatch: 0.1ppm, 0.5ppm, 1ppm
- Totally, there are 9 kinds of different scenarios
- Evaluation indicator
  - Chi-Squared = $(y - Hx_0)^T (HBH^T + R)^{-1} (y - Hx_0)$
  - Error reduction = $(1 - \frac{posterior\ uncertainty}{prior\ uncertainty}) * 100\%$
  - Gain = $1 - \frac{|posterior\ fluxes - true\ fluxes|}{|prior\ fluxes - true\ fluxes|}$



	Pseudo observation		Prior fluxes (Fossil fuel & Biogenic)		
	Time (13-19 LST)	Root mean square (ppm)	Bias (μm m^{-2} s^{-1})	RMS (μm m^{-2} s^{-1})	Spatial correlation length (km)
Case 1	10 days 7 hours/day	Total: 0.1/0.5/1	Fossil fuel: 3	Fossil fuel: 2	Fossil fuel: 5
Case 2	10 days 7 hours/day	Total: 0.1/0.5/1	Fossil fuel: 3 Biogenic: -2	Fossil fuel: 2 Biogenic: 4	Fossil fuel: 5 Biogenic: 10
Case 3	10 days 7 hours/day	Total: 0.1/0.5/1 Fossil fuel: 1/1.5/2	Fossil fuel: 3 Biogenic: -2	Fossil fuel: 2 Biogenic: 4	Fossil fuel: 5 Biogenic: 10

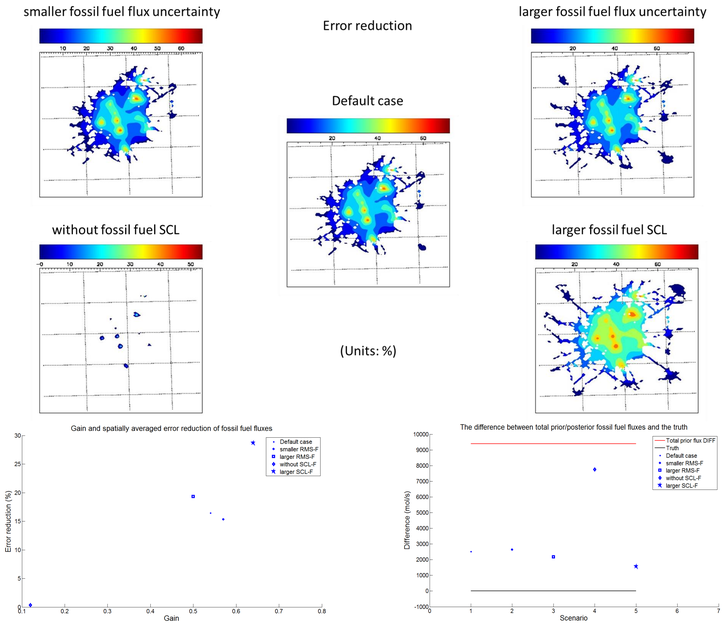
Results





- Q4: Which parameter in the prior flux noise has the largest impact on the precision and accuracy of the urban inverse emissions?

	Pseudo observation		Prior fluxes (Fossil fuel & Biogenic)		
	Time (13-19 LST)	Root mean square (ppm)	Bias (μm m^{-2} s^{-1})	RMS (μm m^{-2} s^{-1})	Spatial correlation length (km)
Default case	10 days 7 hours/day	Total: 1	Fossil fuel: 3	Fossil fuel: 2	Fossil fuel: 5
smaller fossil fuel flux uncertainty	10 days 7 hours/day	Total: 1	Fossil fuel: 3	Fossil fuel: 1	Fossil fuel: 5
larger fossil fuel flux uncertainty	10 days 7 hours/day	Total: 1	Fossil fuel: 3	Fossil fuel: 4	Fossil fuel: 5
without fossil fuel flux SCL	10 days 7 hours/day	Total: 1	Fossil fuel: 3	Fossil fuel: 2	Fossil fuel: 0
larger fossil fuel flux SCL	10 days 7 hours/day	Total: 1	Fossil fuel: 3	Fossil fuel: 2	Fossil fuel: 10



Conclusions

- The presence of biogenic fluxes significantly weakens the ability to estimate fossil fuel emissions in an urban environment.
- Having additional fossil fuel concentration measurements could compensate for the effect caused by the presence of biogenic fluxes.
- The performance of inversion system is sensitive to the spatial correlation length in prior flux noise. Larger spatial correlation length significantly increases the ability to retrieve the correct emissions.