Detection and Quantification of Urban Greenhouse Gas Emissions: Ground-based results from the INFLUX Experiment

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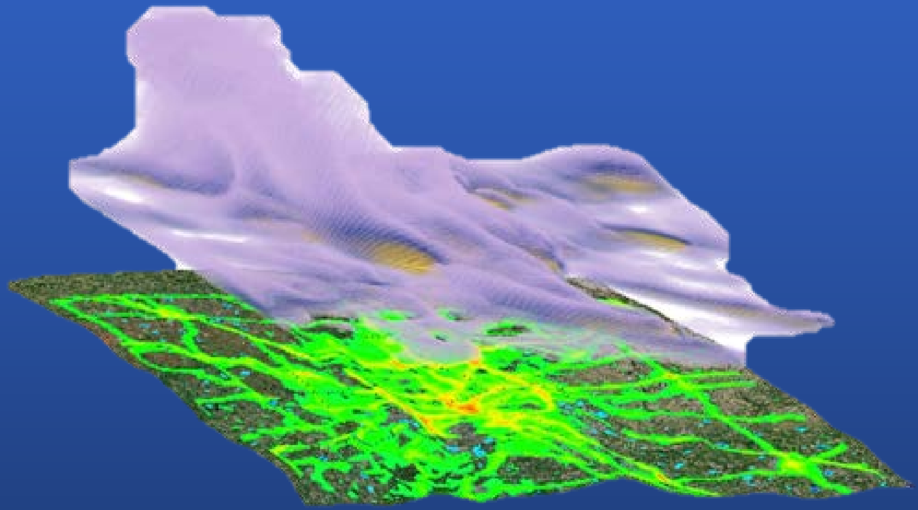

Map of road emissions from Hestia with atmospheric modeled CO2 concentration using the WRF-FDDA system (1km) on Oct 7th, 2011 at 5pm (LST)

NOAA GMD Annual Meeting, May 2014

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Goals of the Indianapolis Flux Experiment (INFLUX)

- Develop and assess methods of quantifying greenhouse gas emissions at the *urban scale*, using Indianapolis as a test bed.
- In particular:
  - Determine whole-city emissions of CO_2 and CH_4
  - Measure emissions of CO_2 and CH_4 at 1 km^2 spatial resolution and weekly temporal resolution across the city
  - Distinguish biogenic vs. anthropogenic sources of CO_2
  - Quantify and reduce uncertainty in urban emissions estimates

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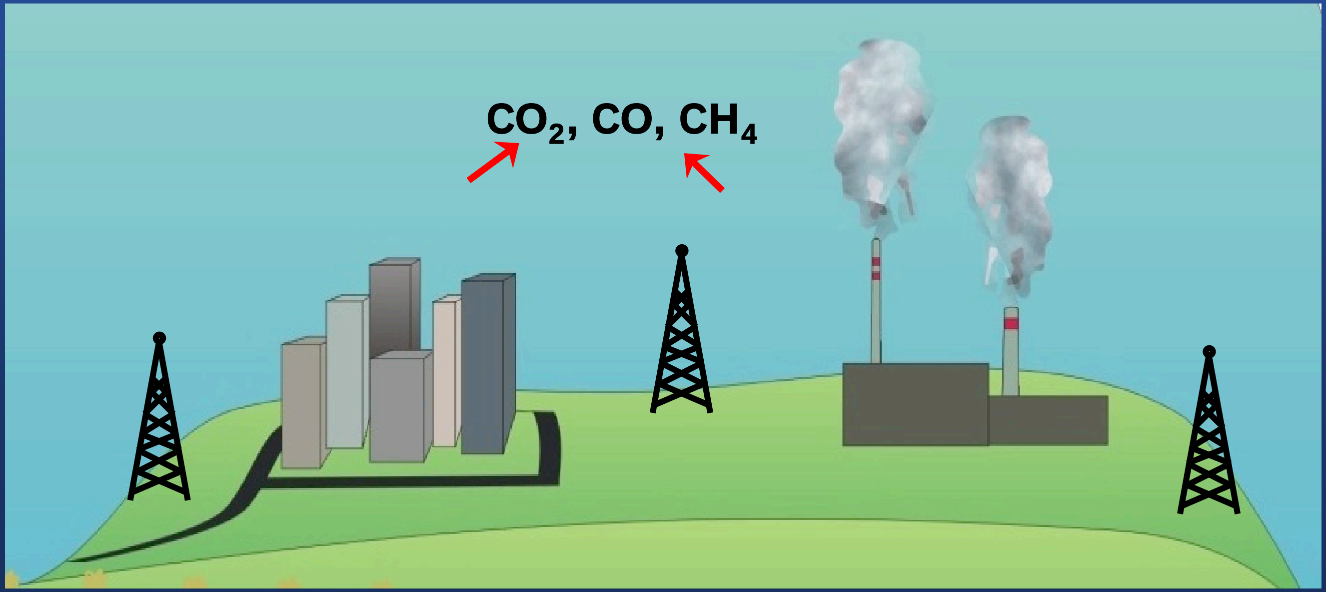
Atmospheric measurement of GHG emissions

- Compare to "Bottom-up" inventories using economic data and emissions factors
- Atmospheric methods have the potential to provide independent emissions estimates

Steps

- Measure GHG concentrations upwind and downwind of a source
- Model atmospheric transport (wind, mixing depth)
- Use an inversion to minimize the difference between modeled and observed GHG concentrations



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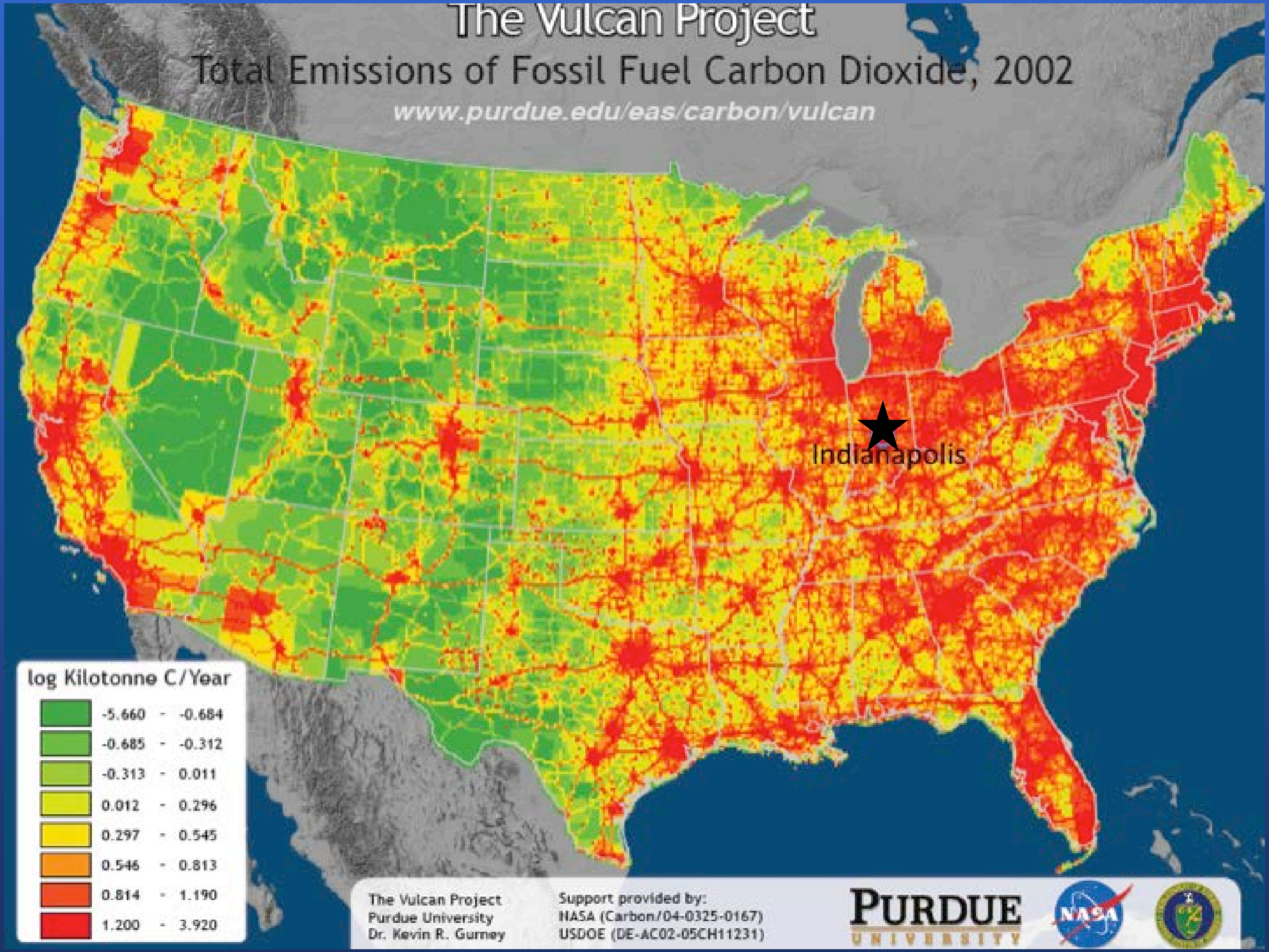
Vulcan and Hestia Emission Data Products



- Vulcan – hourly, 10km resolution for USA
- Hestia – hourly, 250 m resolution for Indianapolis, sector by sector

Kevin Gurney
Arizona State Univ

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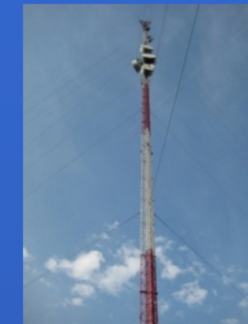
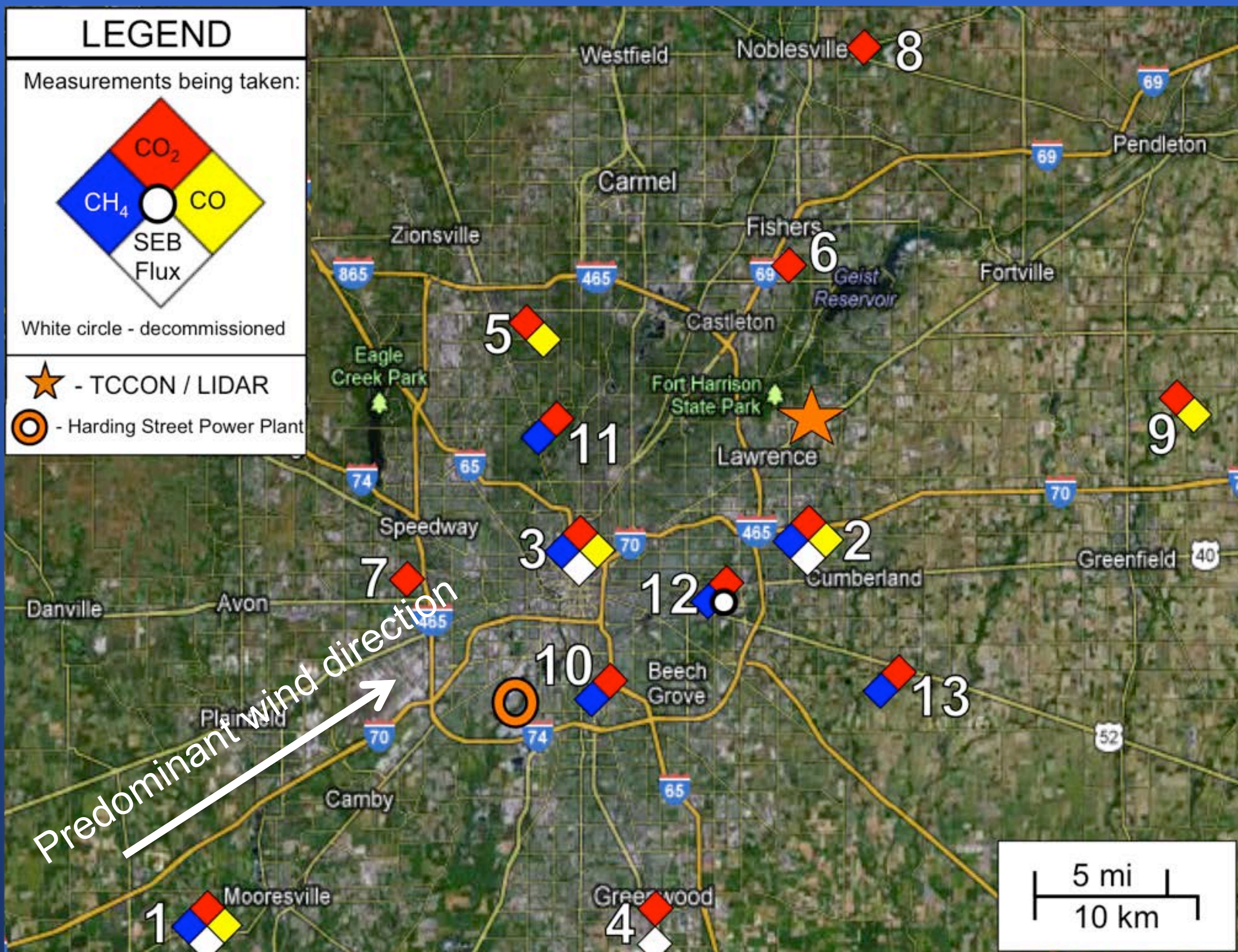
http://hestia.project.asu.edu/

INFLUX GROUND-BASED NETWORK





- Communications towers ~100 m AGL
- Picarro, CRDS sensors
- 12 measuring CO2, 5 with CH4, and 5 with CO

- NOAA automated flask samplers
- NOAA LIDAR
- Eddy flux at 4 towers

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High resolution inversion modeling system

- Atmospheric model WRF-Chem: 9km/3km/1km (nested mode)
- Model physics
  - Simple urban scheme within the NOAH Land Surface Model with the MYNN PBL scheme
- Coupled to Lagrangian Particle Dispersion Model (Uliasz, 1995)
- Bayesian Kalman matrix inversion
- Model assessment
  - 4 eddy flux towers
  - NOAA HALO and HURDL Doppler Lidars
  - Aircraft data
  - Radiosonde campaign: 9-17 June

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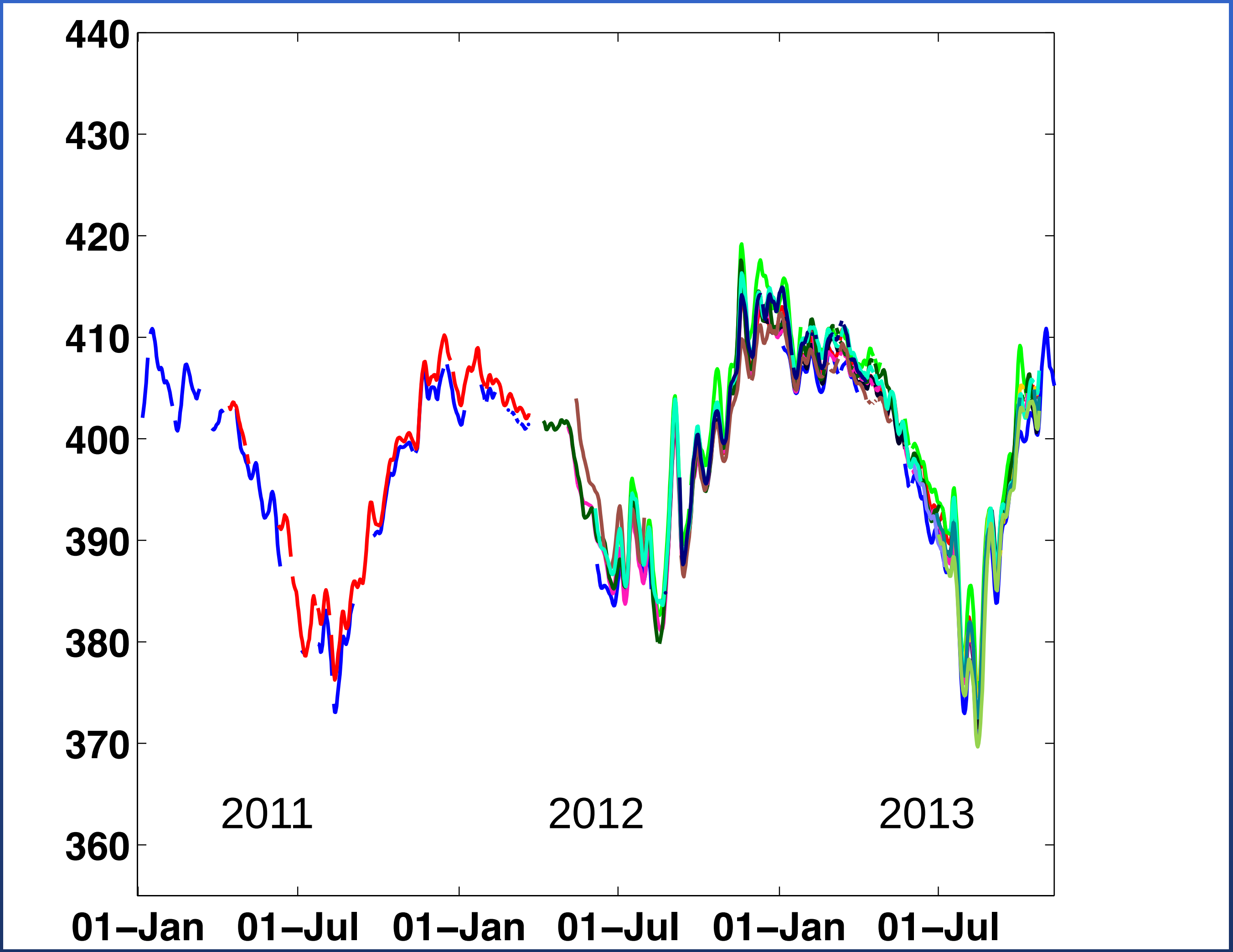
Tower observations: [CO2] at INFLUX sites

- Afternoon [CO2] with 21-day smoothing
- Seasonal and synoptic cycles are evident
- Site 03 (downtown): high [CO2]
- Site 01 (background): low [CO2]



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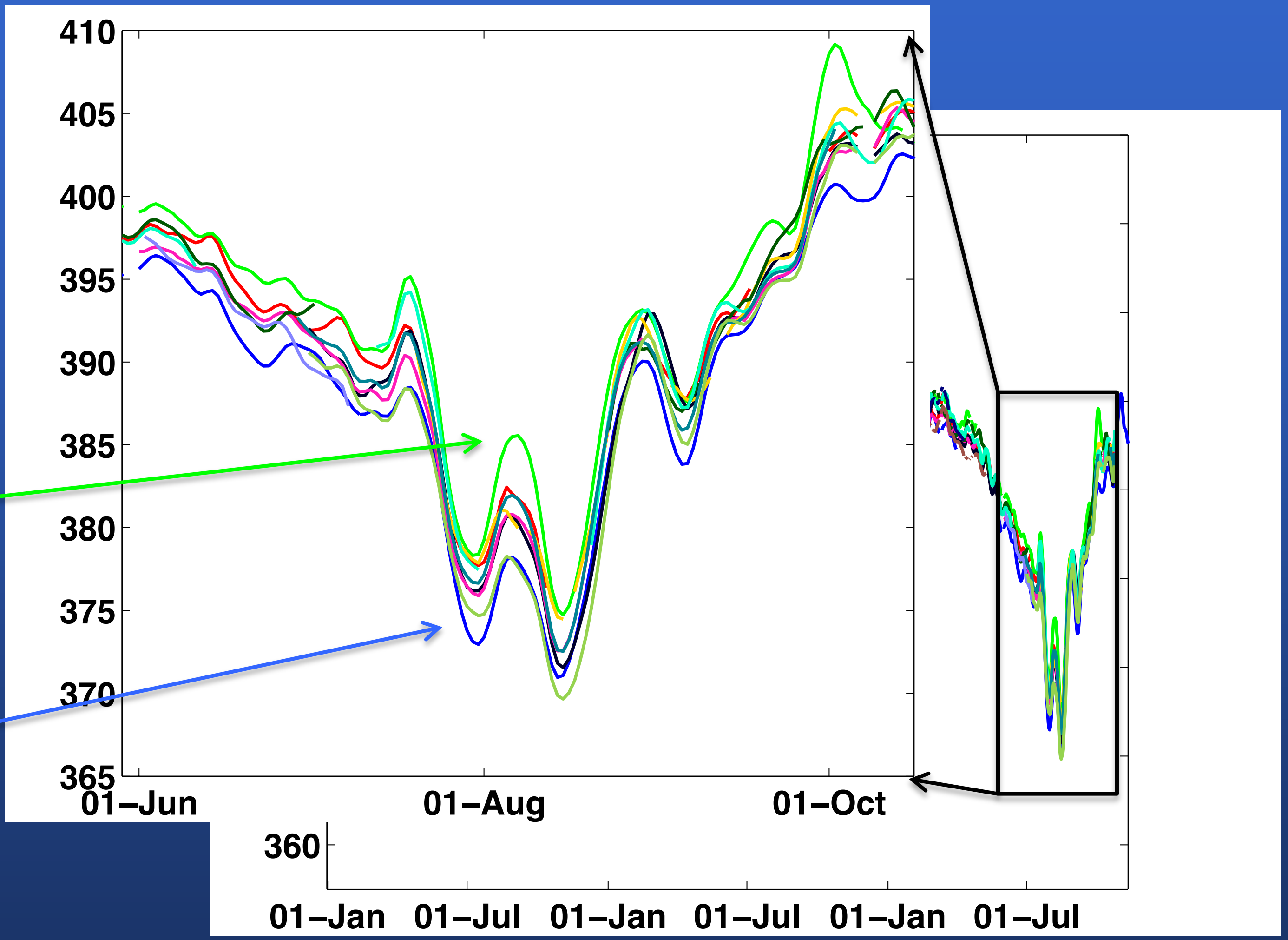

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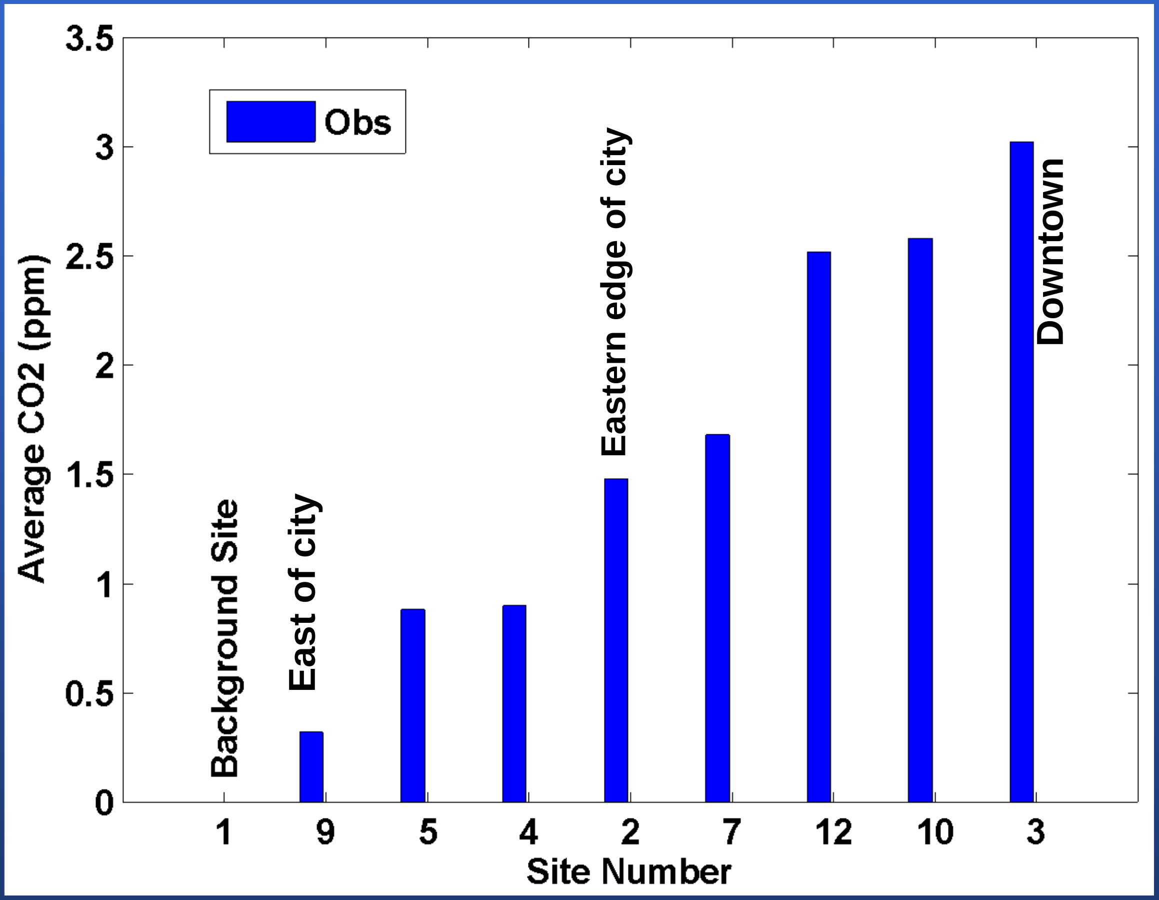
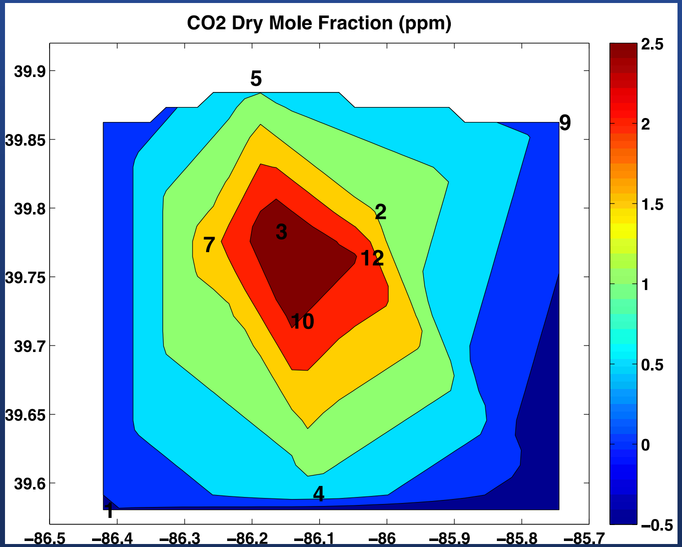
Spatial Structure of Urban CO2

Average [CO2] above background site

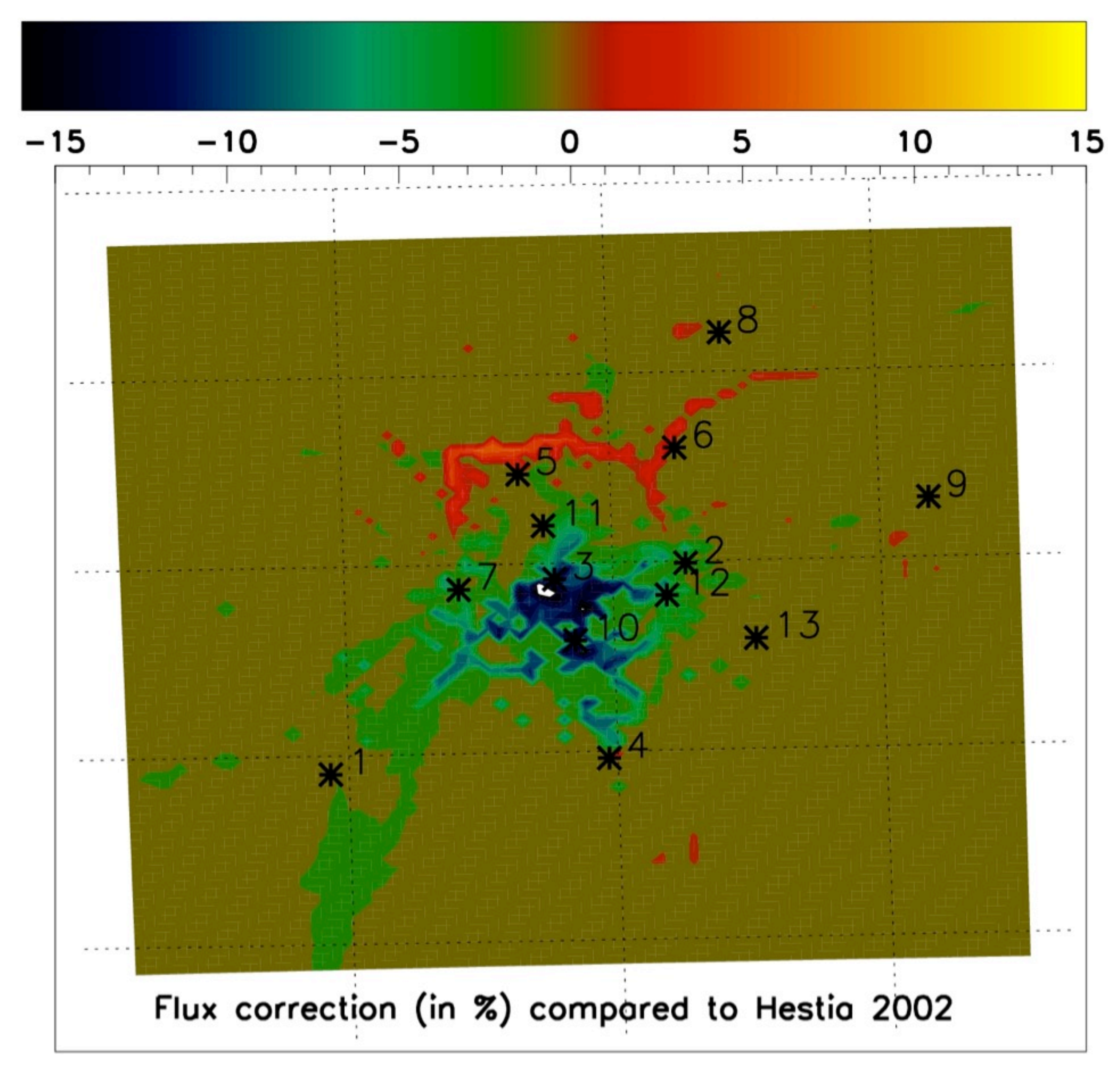


- Site 09 measures 0.3 ppm larger than Site 01 (on average; changes with wind direction)
- Site 03 (downtown site) measures larger [CO2] by 3 ppm



Afternoon daily values, 1 Jan – 1 April 2013

Inversion results: spatial pattern of flux correction



- Spatial pattern of emissions corrections (in %)
- **Prior: Hestia 2002**
- Tower observations for Sept – Dec 2012
- Inversion decreased emissions by up to 15% compared to Hestia 2002 in downtown region

Lauvaux et al, in prep

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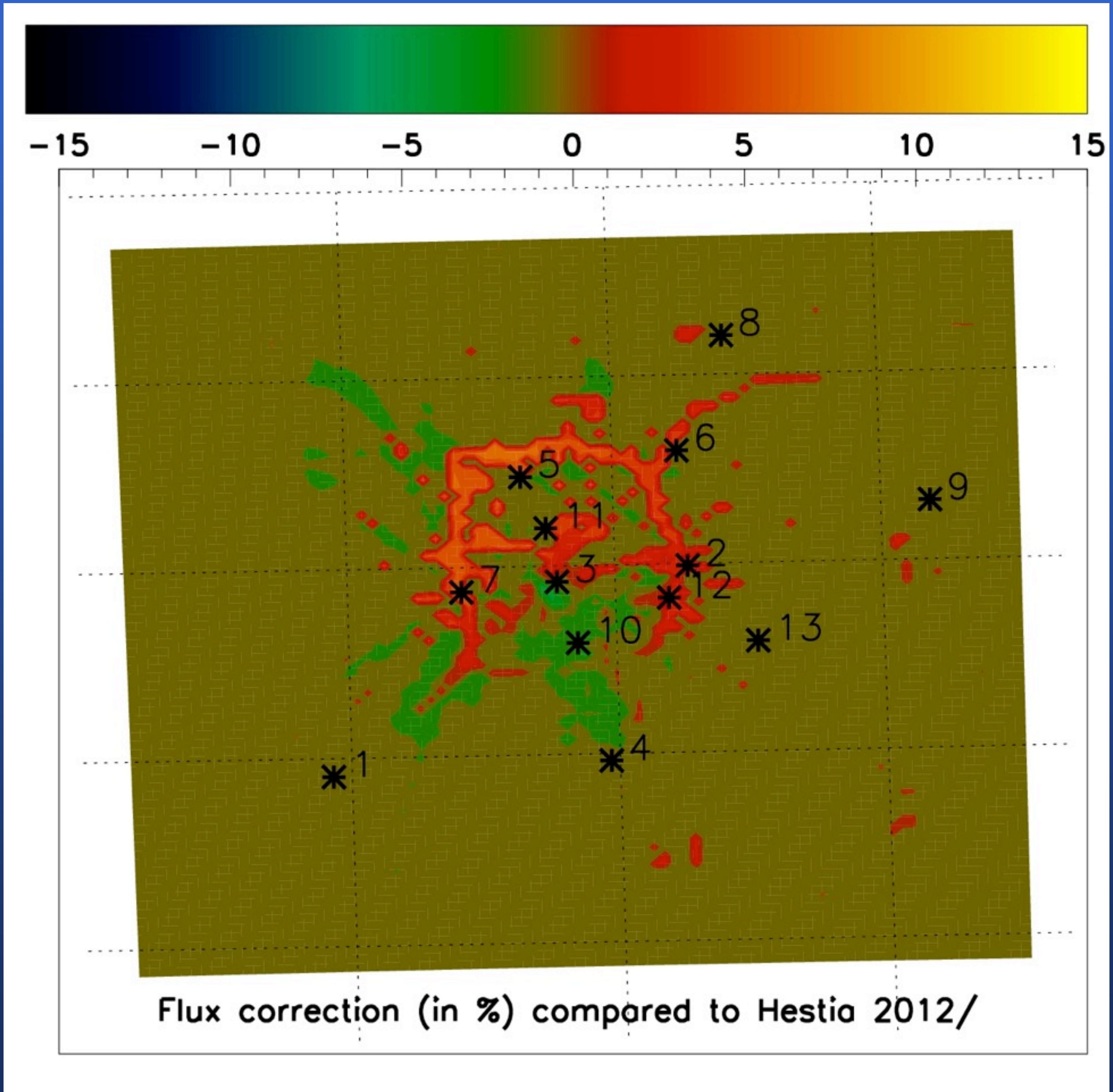

- **<u>Prior: Hestia 2012</u>**
- Tower observations for Sept – Dec 2012

- Corrections of -5 to +5% rather than up to 15% change when using Hestia 2002/2011 as a prior

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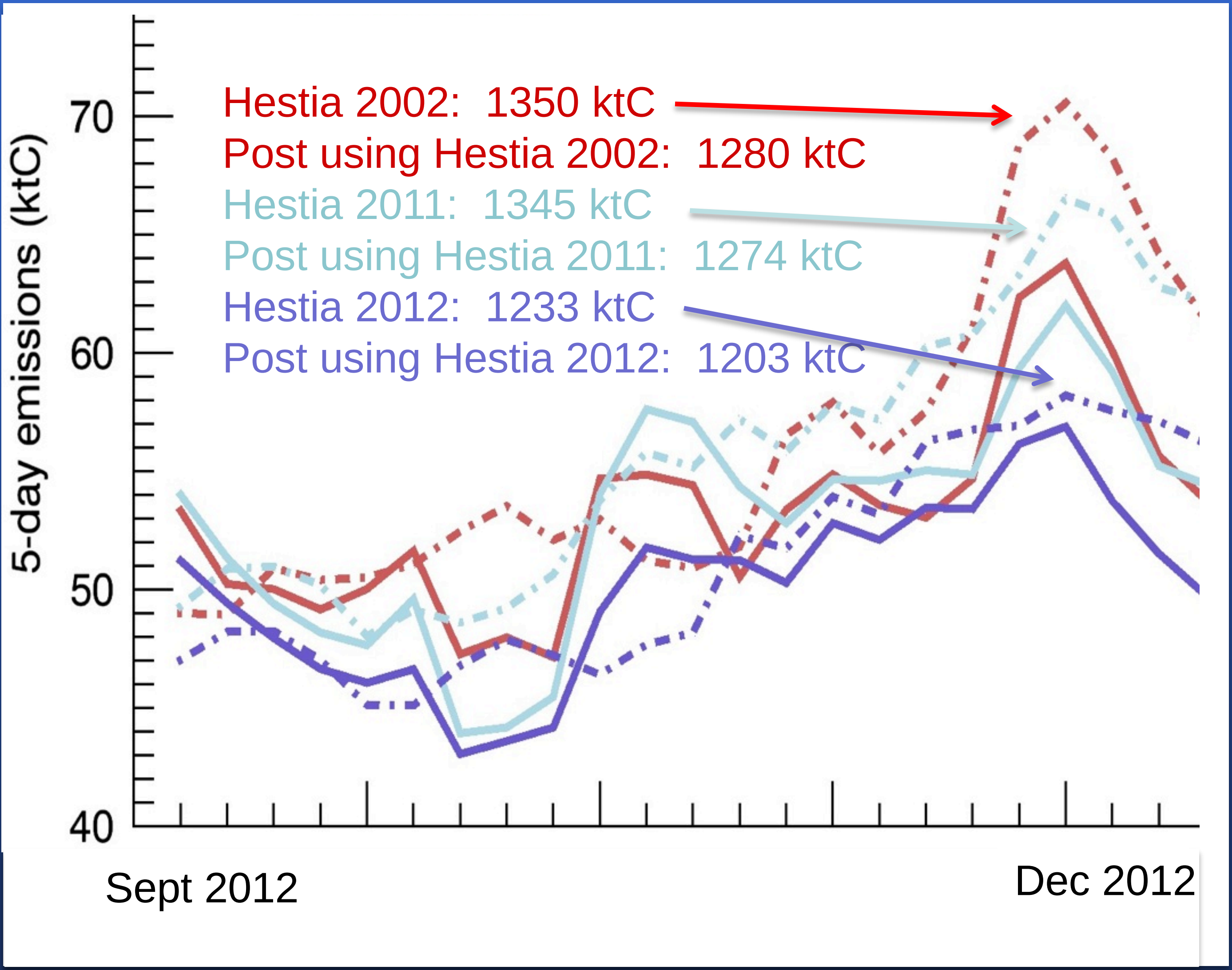
Inversion results



- Using 2012 tower data
- Inversion with different priors
  - Hestia 2002
  - Hestia 2011
  - Hestia 2012
- Inversion converges to value towards 2012 values

Lauvaux et al, in prep

How different is the emissions estimate using a different prior?

- ODIAC nightlight-based CO2 emissions product (Tomohiro Odo)
  – Uses national petroleum and natural gas usage as total and distributes using nightlight data from satellite
  – Also incorporates power plant database
  – Available 1992 – 2012 worldwide

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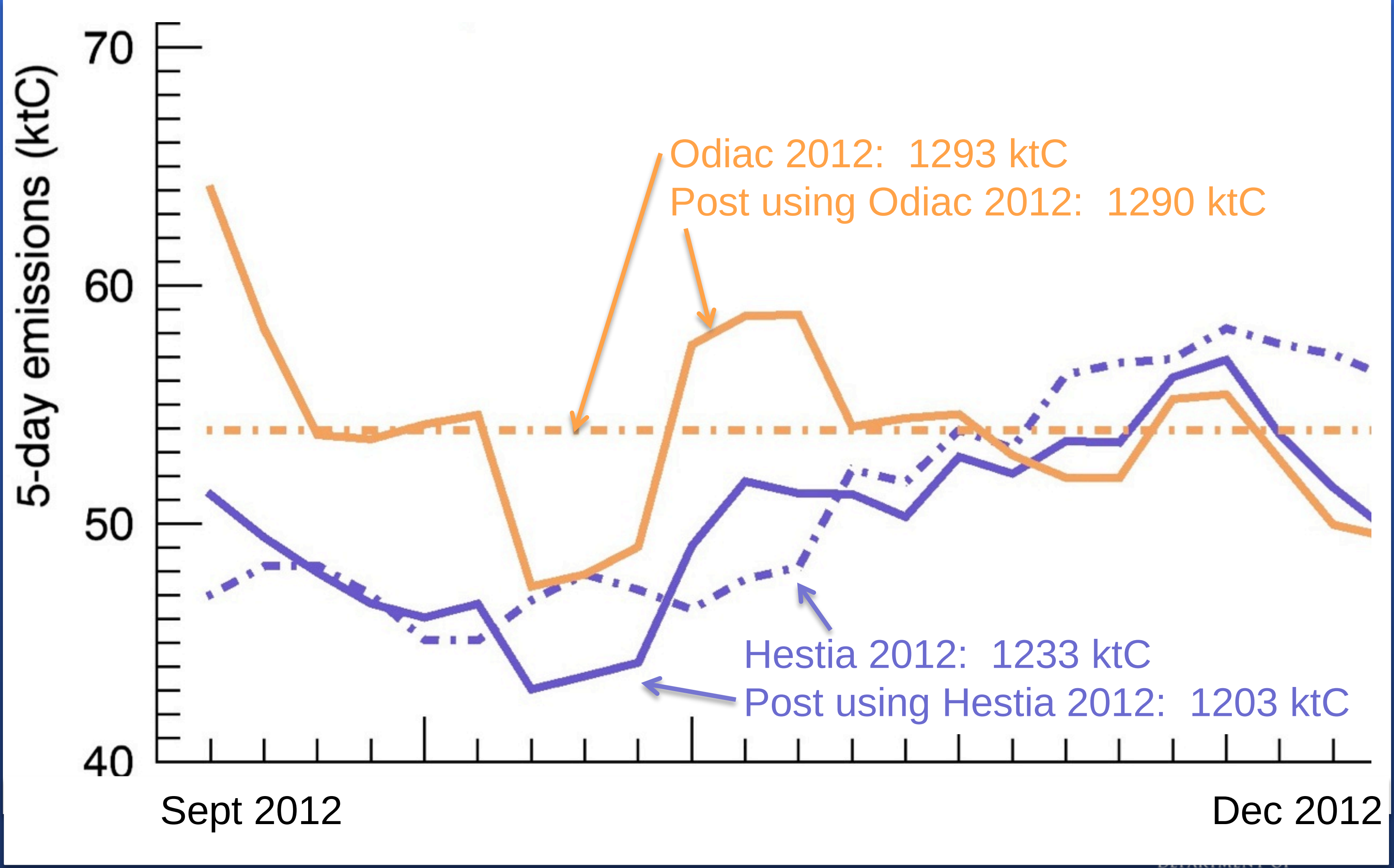
Hestia vs CDIAC Nightlight emissions product as prior



Posterior results are the within 10% of each other throughout the period, and 7% different overall

Conclusions

- Tower observations detect a clear urban signal in CO_2 (buried amid lots of synoptic "noise"). Differences vary greatly with weather conditions.

- Inversion converges to value towards Hestia 2012, whichever version of prior estimate is used

For more information, see http://influx.psu.edu