Patterns of CO_2 Sensitivity to CO from Space and their Implications for Carbon Monitoring

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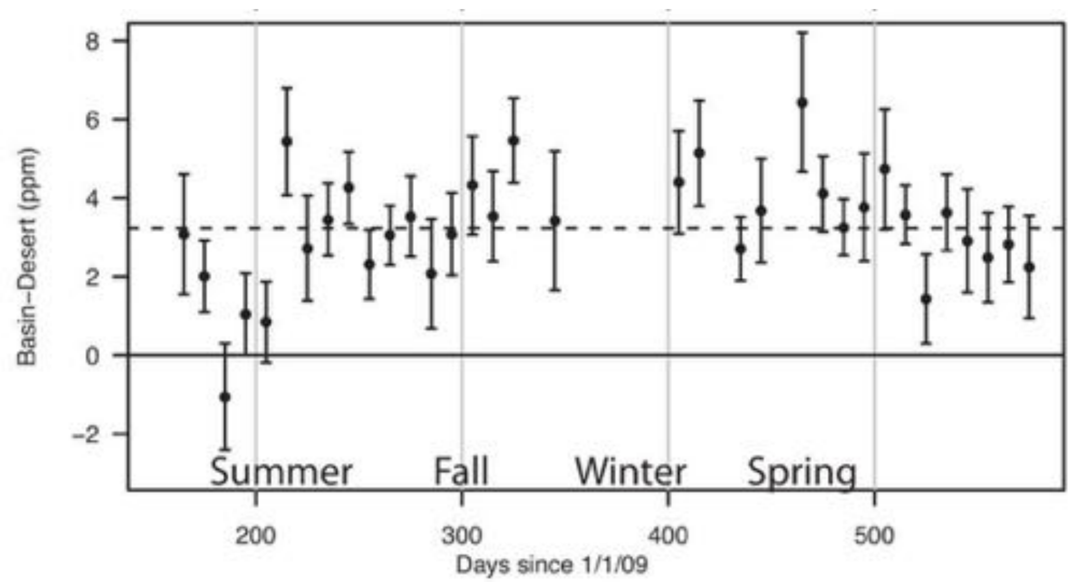
Measuring the carbon emissions of megacities

Riley M. Duren and Charles E. Miller

"Carbon monoxide can help disentangle the relative contributions of fossil-fuel and biogenic sources of carbon dioxide, by serving as a tracer of combustion activity."



GEOPHYSICAL RESEARCH LETTERS, VOL. 39

Space-based observations of megacity carbon dioxide

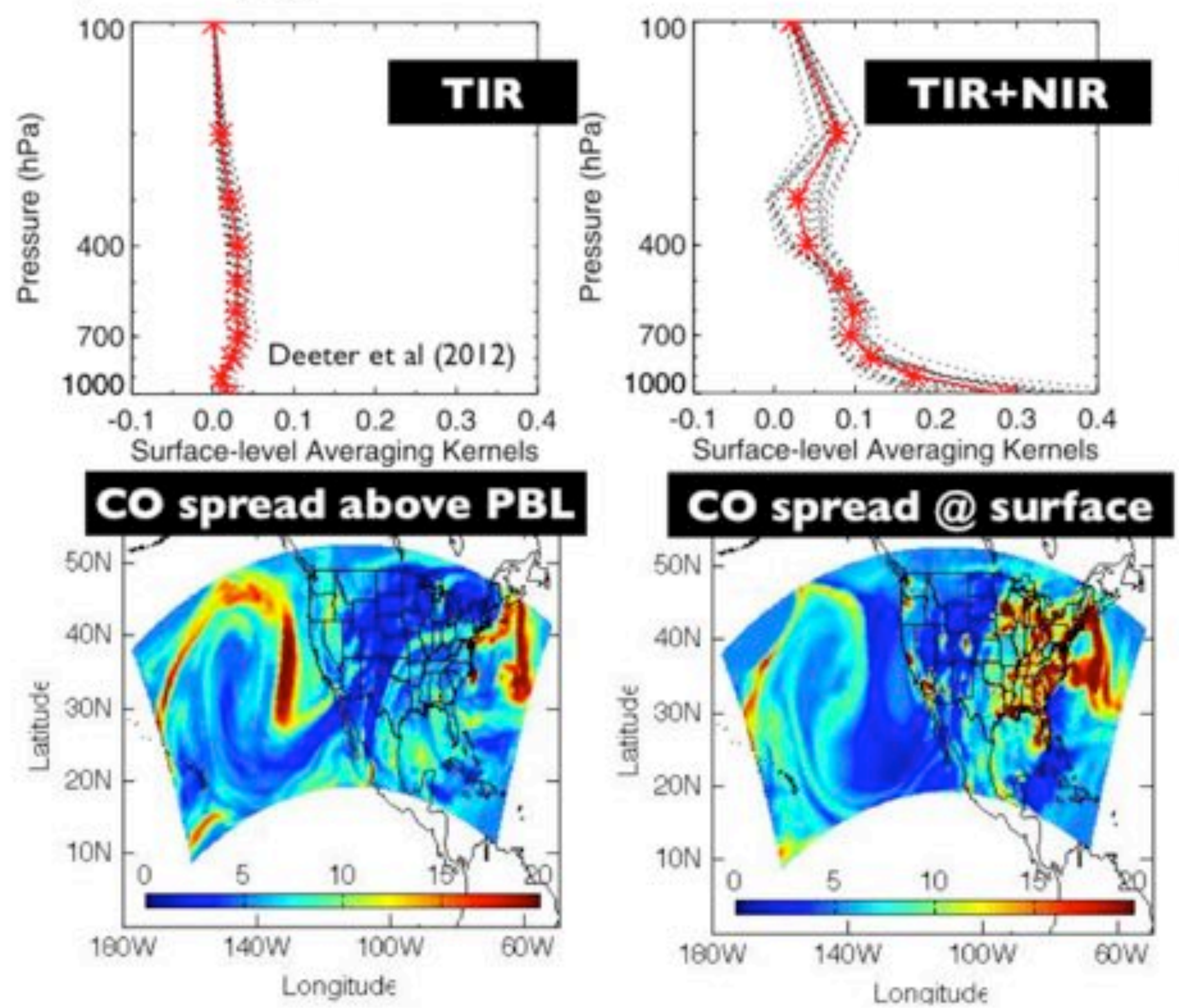
Eric A. Kort,[1,2] Christian Frankenberg,[2] Charles E. Miller,[2] and Tom Oda[3,4]

Why Add CO?

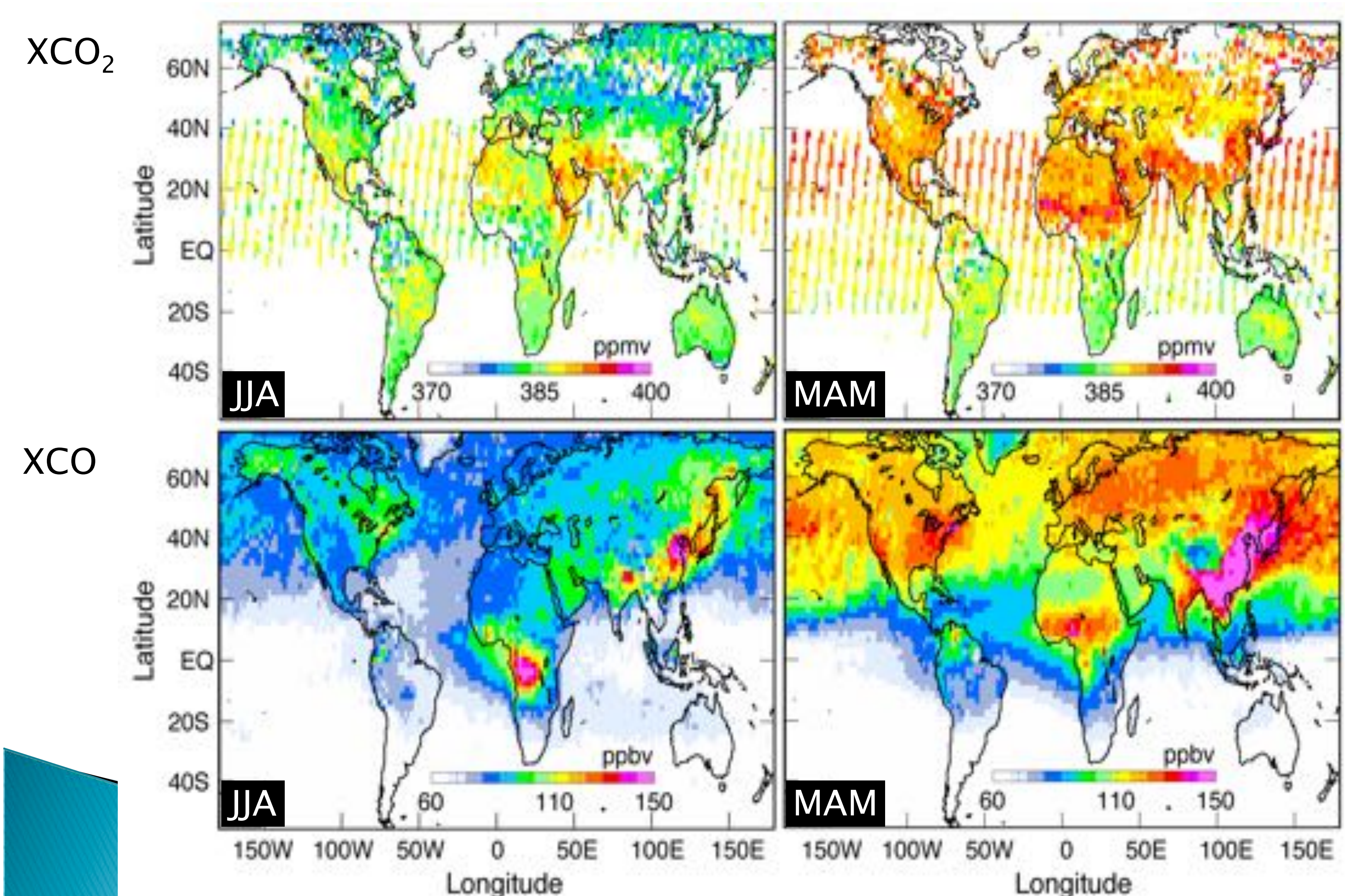
- Co-emitted with CO_2 in combustion
- Relatively well observed
- Short lifetime
- Surface sensitivity

FUEL + OXYGEN →
HEAT + WATER + CARBON +
CARBON MONOXIDE + CARBON DIOXIDE

Enhanced Surface Sensitivity – MOPITT

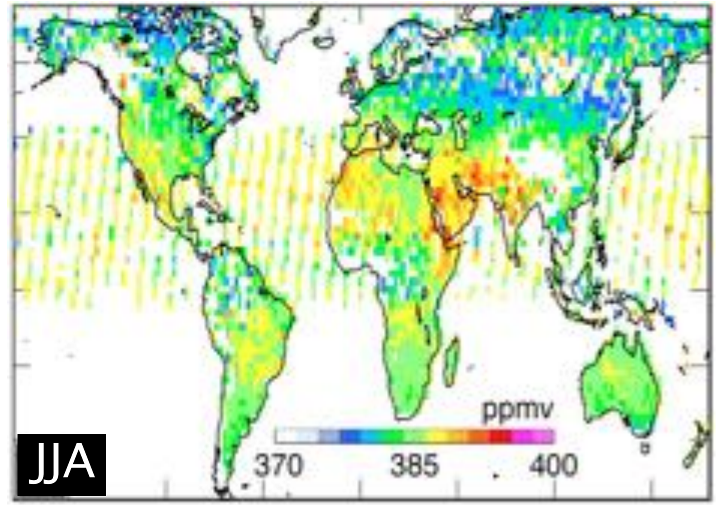


CO_2 and CO Retrievals



CO_2 Data

- GOSAT XCO_2 data products
- ACOS L2 algorithm v2.9
- QC screening as recommended



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Space-based observations of megacity carbon dioxide

Eric A. Kort,[1,2] Christian Frankenberg,[2] Charles E. Miller,[2] and Tom Oda[3,4]

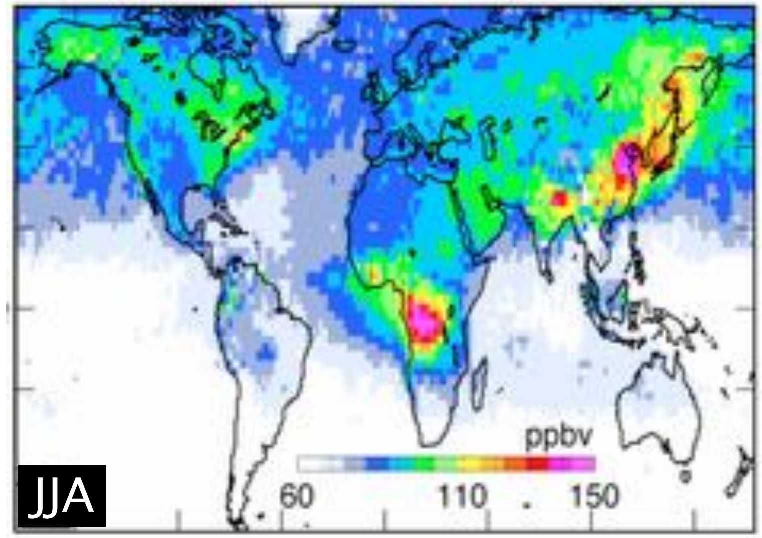
Atmos. Chem. Phys., 13

Towards constraints on fossil fuel emissions from total column carbon dioxide

G. Keppel-Aleks[1,2], P. O. Wennberg[1], C. W. O'Dell[3], and D. Wunch[1]

CO Data

- MOPITT v5 L2
- TIR and TIR/NIR
- QC screening as recommended



Validation of MOPITT Version 5 Thermal-Infrared, Near-Infrared, and Multispectral Carbon Monoxide Profile Retrievals for 2000-2011

M. N. Deeter,[1] S. Martínez-Alonso,[1] D. P. Edwards,[1] L. K. Emmons,[1] J. C. Gille,[1] H. M. Worden,[1] J. V. Pittman,[2] B. C. Daube[2] and S. C. Wofsy[2]

JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118

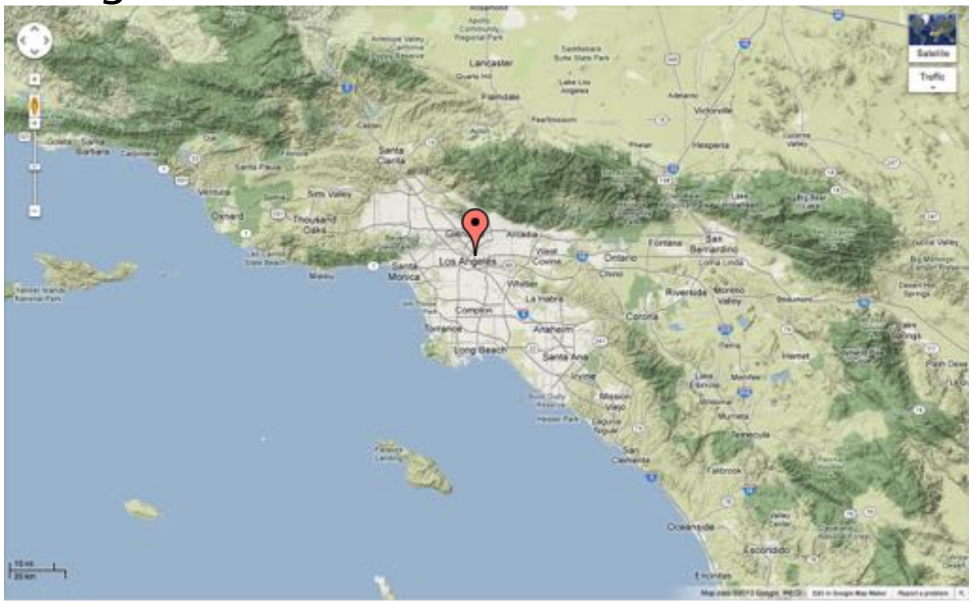
Impact of model errors in convective transport on CO source estimates inferred from MOPITT CO retrievals

Zhe Jiang,[1] Dylan B. A. Jones,[1,2] Helen M. Worden,[3] Merritt N. Deeter,[3] Daven K. Henze,[4] John Worden,[5] Kevin W. Bowman,[2,5] C. A. M. Brenninkmeijer,[6] and T. J. Schuck[6]

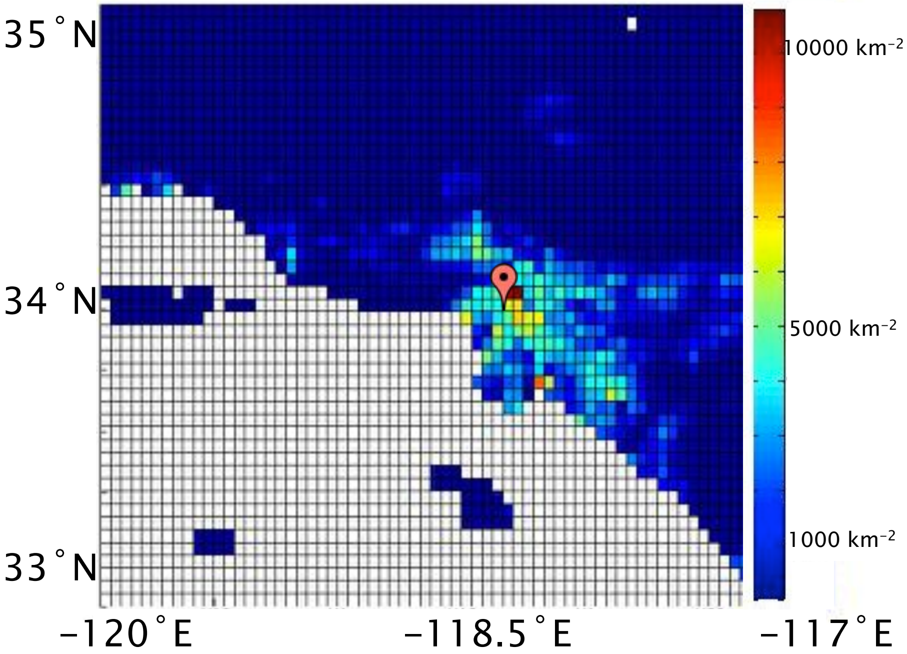
Urban Designations

- Representativeness error
- Anchored to population density
- 2.5' x 2.5' gridded data
- Pixels chosen through thresholding scheme

Google Earth

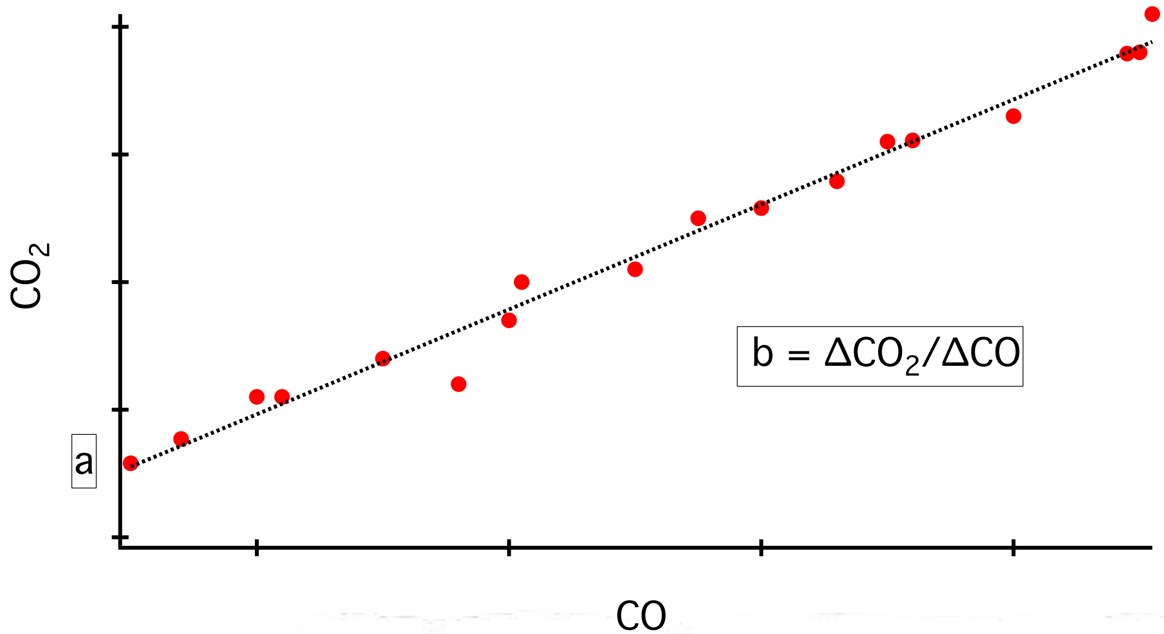


Population Density



NASA Socioeconomic Data and Applications Center
http://sedac.ciesin.columbia.edu

Regression Analyses



$$a = \bar{Y} - b\bar{X},$$

$$b = \frac{\sum W_i \beta_i V_i}{\sum W_i \beta_i U_i},$$

$$\sigma_a^2 = \frac{1}{\sum W_i} + \bar{x}^2 \sigma_b^2,$$

$$\sigma_b^2 = \frac{1}{\sum W_i u_i^2}.$$

Unified equations for the slope, intercept, and standard errors of the best straight line

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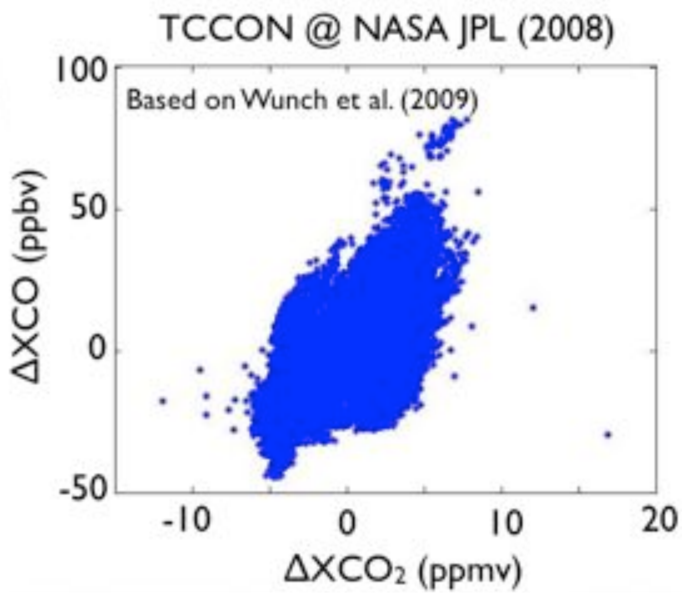
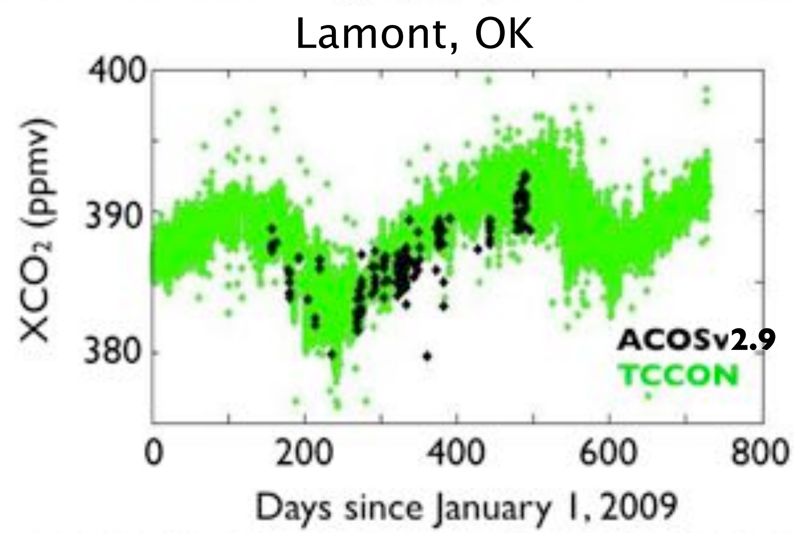
Department of Physics, University of Toronto, 60 Saint George St., Toronto, Ontario M5S 1A7, Canada

Margarita López Martínez and Jonás De Basabe Delgado[b]
Departamento de Geología, CICESE, km 107 Carr. Tijuana-Ensenada Ensenada, Baja California, México 22860



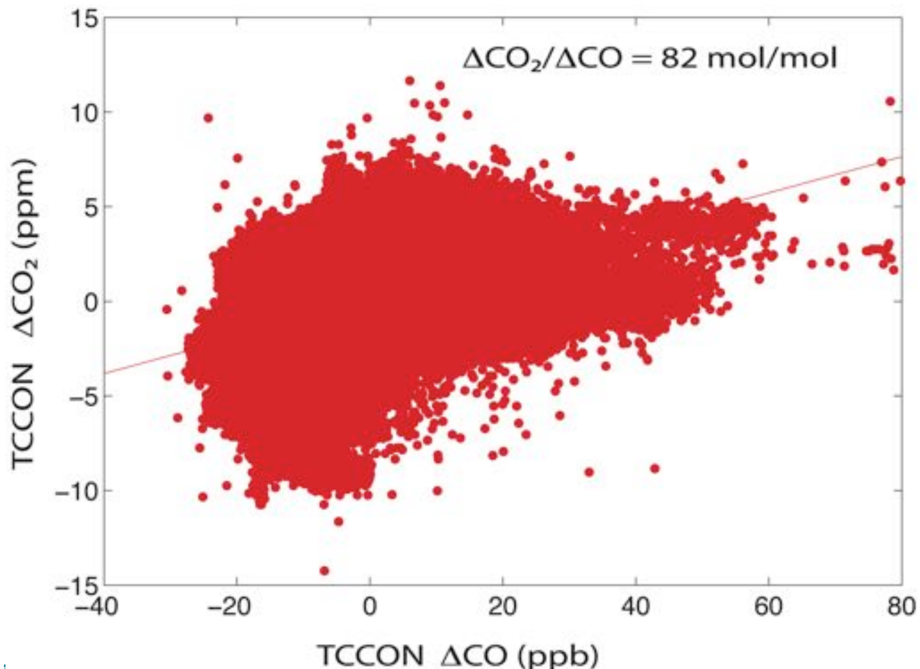


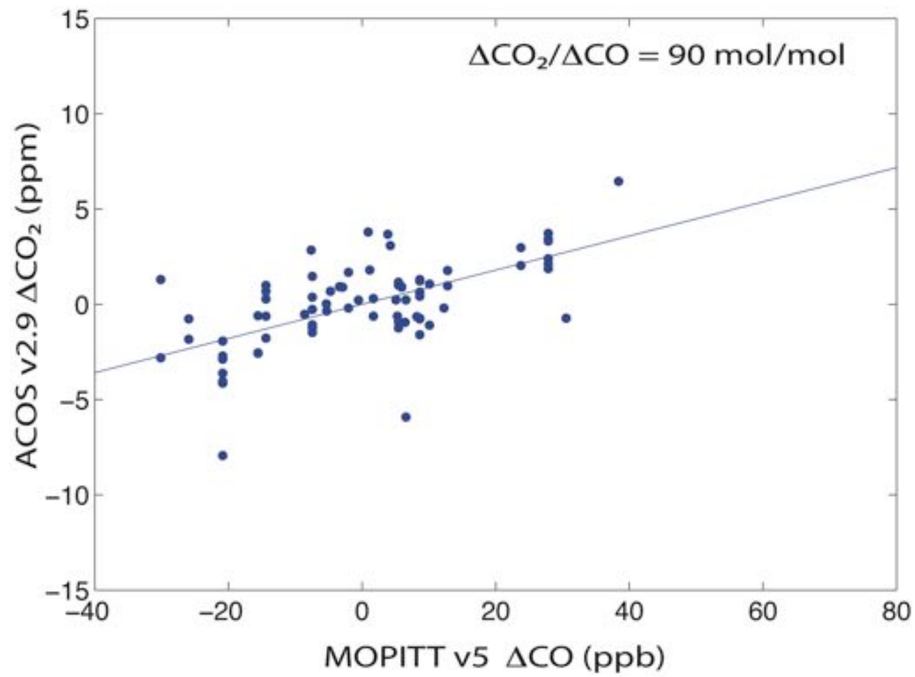
Comparison between TCCON and this analysis

Stations	TCCON $\Delta CO_2/\Delta CO$	ACOS v2.9/MOPITT v5 $\Delta CO_2/\Delta CO$		
		TIR/NIR	TIR-only	TIR/NIR and TIR-only
Lamont, OK, USA (36.61°N, -97.49°E)	81.79	89.93 (~10%)	99.57 (~22%)	93.76 (~15%)
Park Falls, WI, USA (45.95°N, -90.24°E)	113.58	80.97 (~29%)	124.42 (~10%)	97.38 (~14%)

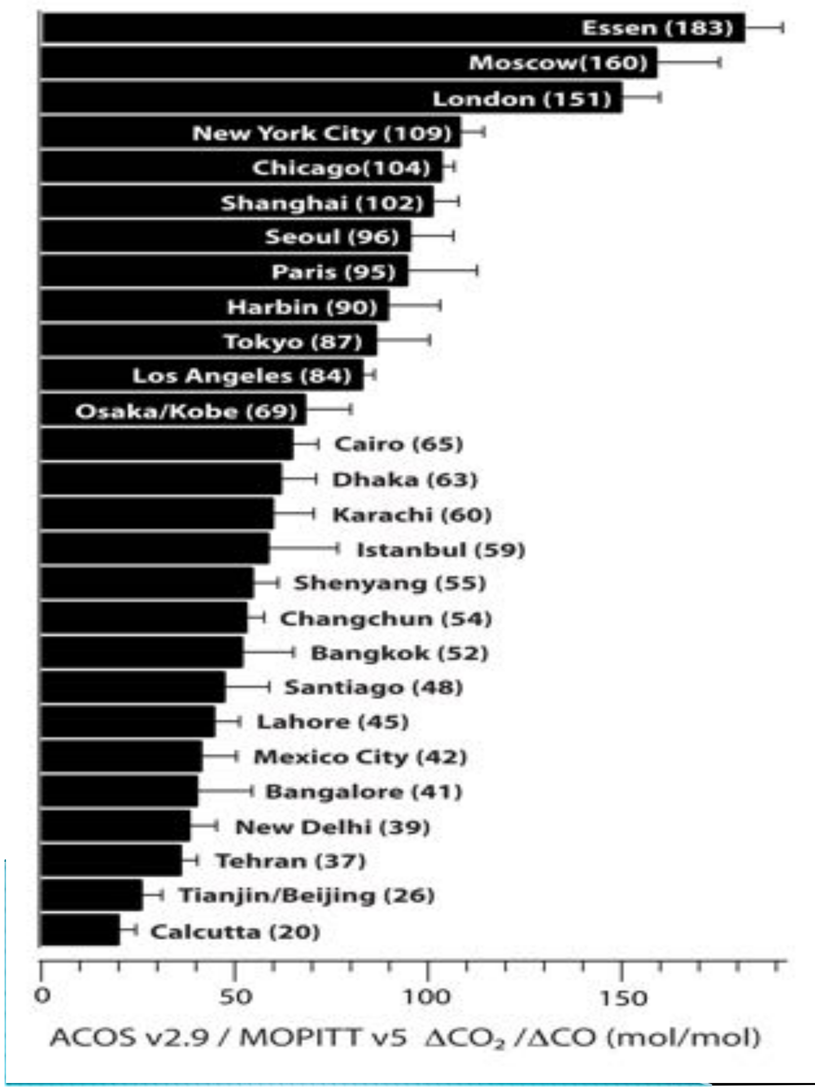
- Only investigated positive seasonal correlations
- 1° radius used
- Limited by GOSAT retrievals

Lamont, OK





Sensitivity over Megacities



Reference	Location	$\Delta CO_2/\Delta CO$
Suntharalingam et al. (2004)	Japan	60-80
	Northeast China	10-20
Zhang et al. (2009)	China	23
Turnbull et al. (2011)	China	21-22 ± 1
	Korea	77 ± 12
Wunch et al. (2009)	So.Cal. Basin	91 ± 17
Brioude et al. (2013)	So.Cal. Basin	75
Worden et al. (2012)	Eastern China	40-50 ± 55

- Population > 5 million people
- Trend in developed status
- Consistent with available literature
- May provide information regarding combustion characteristics of the urban location

Reference	Location	$\Delta CO_2/\Delta CO$
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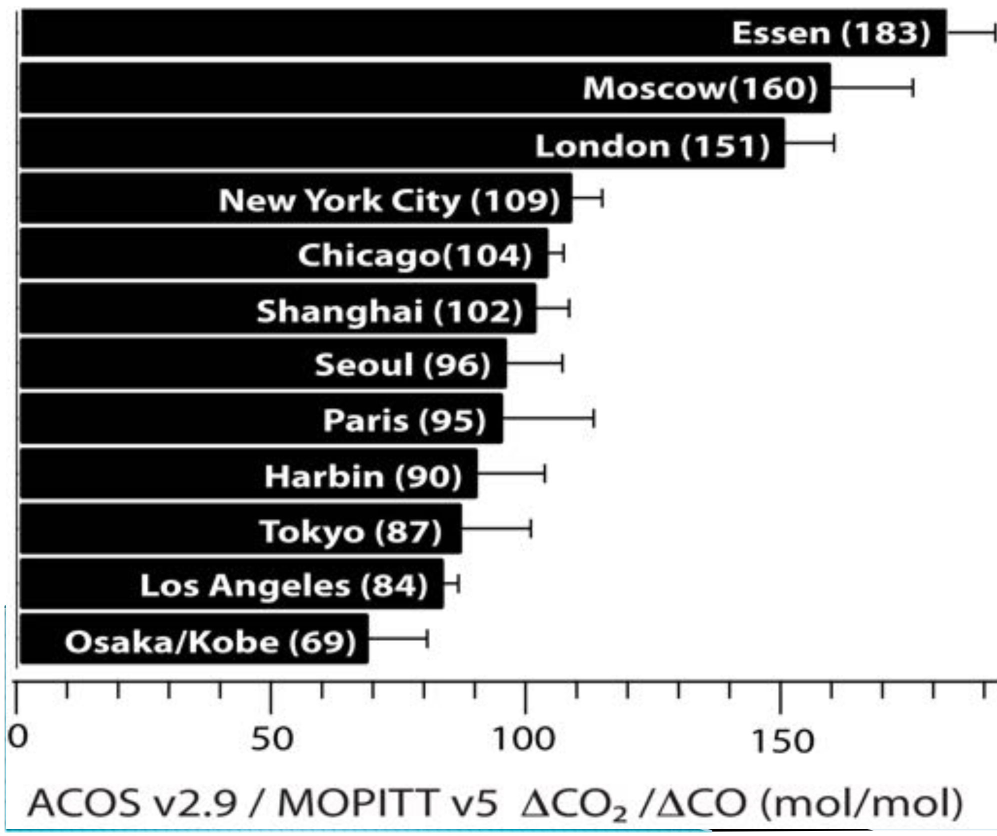
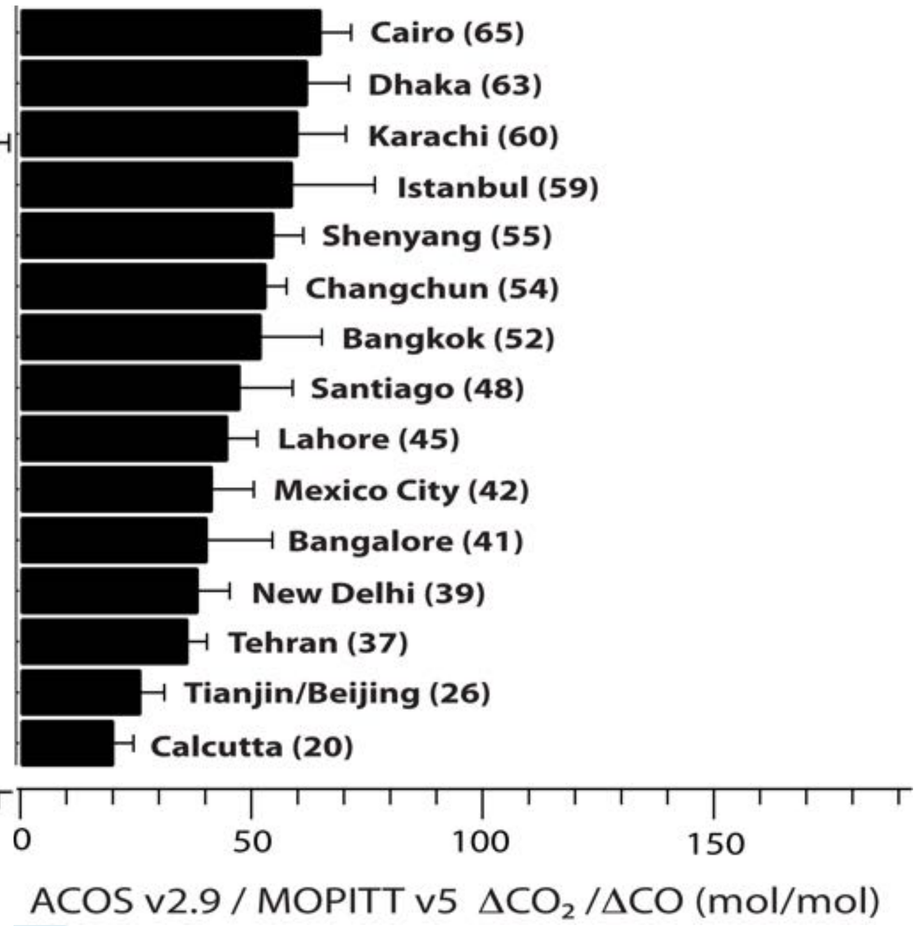
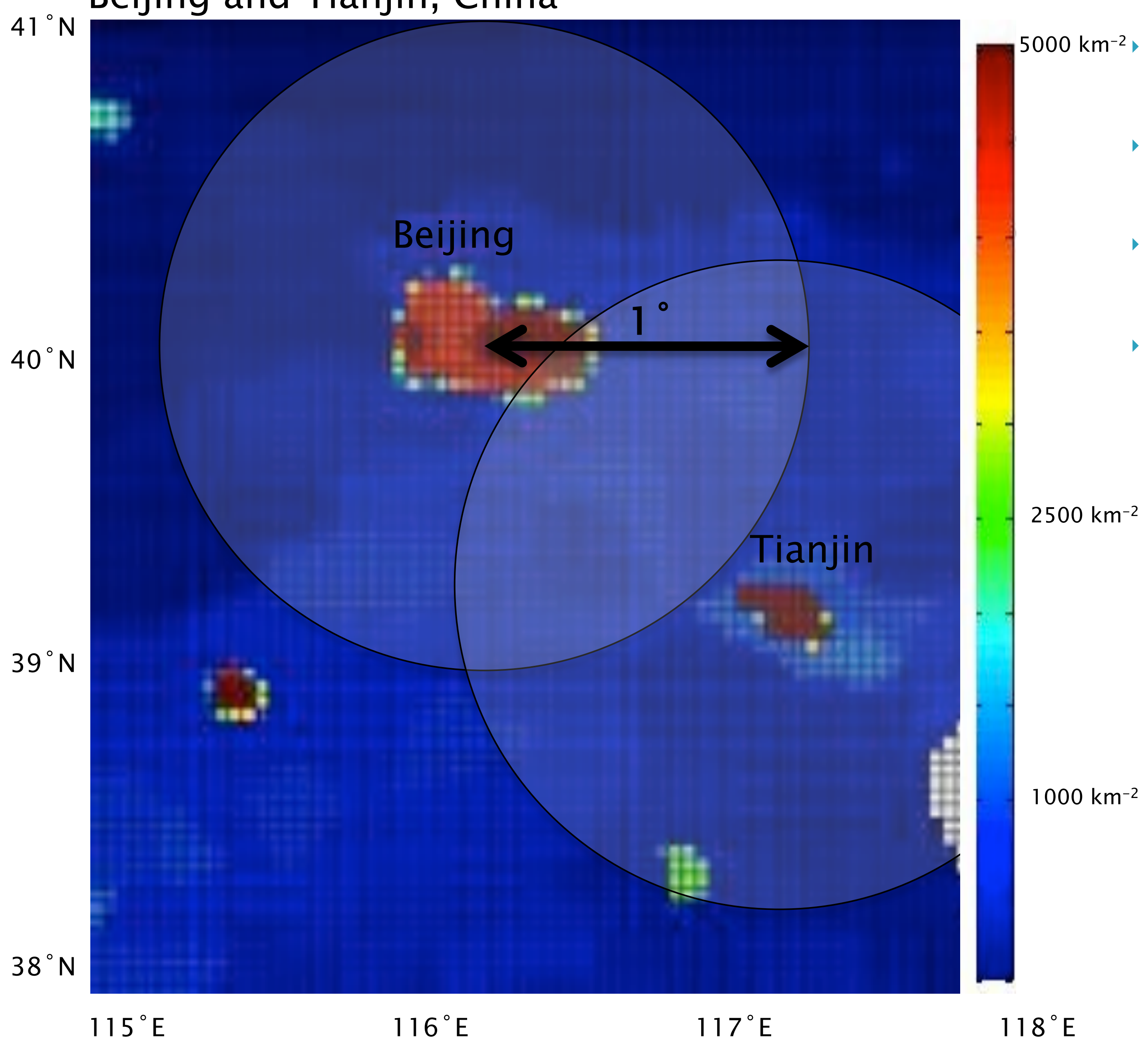
- Estimates sensitive to the definition of the urban region
- London is an exception due to large number of data and small variations across analysis
- Moscow exemplifies these issues due to limited data
- Tianjin and Beijing represent issues in defining spatial boundaries





Beijing and Tianjin, China

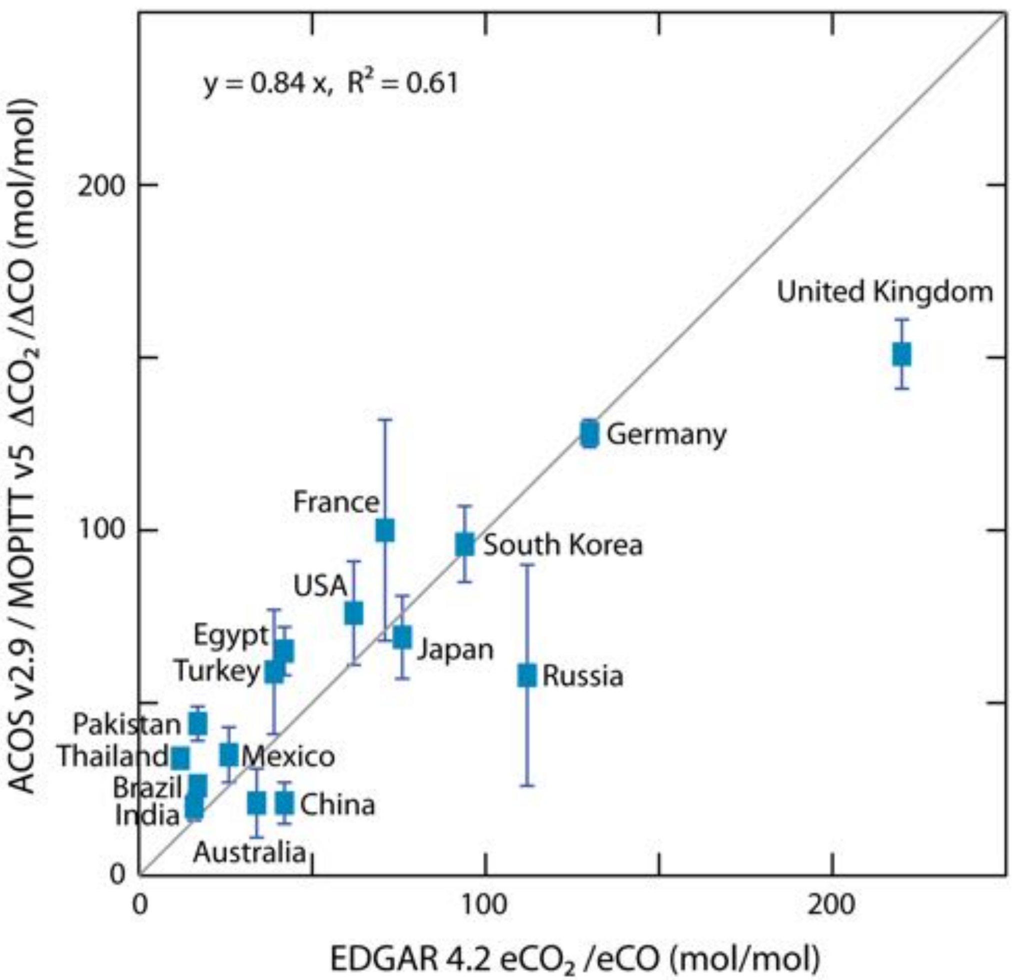


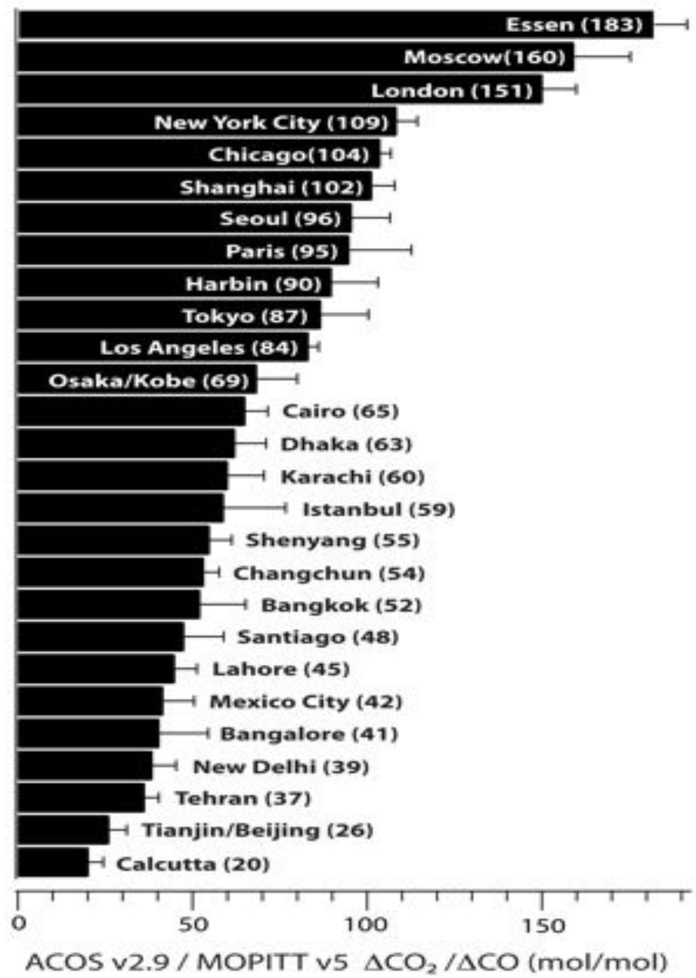
- Limits in the amount of data require an expansion of the effective footprint
- Over Beijing and Tianjin, this necessitates a combination
- Similar issues separating air sheds in India and Mexico City
- Lack of meteorological information

Sensitivity over Countries

- Trend in developed status
  - Australia and Brazil
- Uncertainty in Russia stems from limited data
- The U.K. estimate potentially stems from EDGAR CO underestimation
- Megacities are sometimes representative of the total anthropogenic signal

Comparison with EDGAR Estimates





Summary and Future Directions

- This study demonstrates the use of space based observations to augment anthropogenic CO_2 signal.
- Our estimates of CO_2/CO values are consistent within 20% of available literature, TCCON, and EDGAR.
- This lends support to how current and future observing systems may be designed, used, and augmented to enhance our ability to monitor and verify carbon emissions.
- This study motivates a multi-species tracer-transport inversions.
- Future work will include other combustion-related constituents such as NO_2

This research is funded by NASA