# Urban Carbon Monoxide Trends During the Global Economic Recession

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## Background

- The Global Recession of 2008 – 2009 decreased fossil fuel combustion in the United States.
- Previous studies showed that the impact of the recession on urban nitrogen oxides (NOx) is detectable by satellite and ground monitors.
- The purpose of this project is to investigate whether such a trend can be detected via ground monitors or satellite sensors for carbon monoxide (CO).

## Methods

- EPA Air Quality System (AQS) ground data was averaged for July 6 to 9 am LST according to fips codes for nine US cities for each year 2005 through 2012 using a C Shell script.
- For each year, AIRS CO total column amounts were filtered by quality code and averaged using MATLAB over the coordinate box given by NASA's Mirador site for each city.
- A regional background CO column amount of 1.6e+18 molecules/cm$^2$ was estimated according to the columns found over an area of consistently low CO columns over the southern part of the Midwest, and this background was subtracted from the columns.
- Plots were generated using an R script.
- Atlanta was chosen as a focus because of its large interannual fluctuations in total CO columns, disparities between AIRS and AQS trends, and the competing influence of both marine and continental pressure zones on the upper-atmospheric transport that reaches this city.
- To account for disparities between AIRS and AQS trends, HYSPLIT 48-hour back trajectories were run at approximately the 500mb level (the level of highest sensitivity for AIRS) for every day of July for sets of years that showed inconsistent trends between the two datasets (specifically 2005 and 2006 as well as 2011 and 2012). NASA FIRMS NRT Fire Mapper was used to visualize biomass burning.
- Both the total CO column and the CO ground concentration were calculated for individual days.
- Relationships between the CO column or ground concentration and the amount of biomass burning in the upper-level transport source region were qualitatively compared.

## Interannual Variability in Ground and Space CO Observations

### Northeast

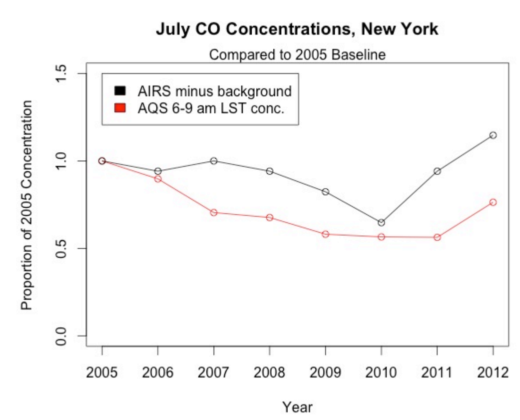



**Figure 1: New York City:** New York displayed a sharp decrease in ground concentration going into 2007 and another relatively large decrease going into 2009, a major year of the Recession. Ground concentrations rebounded in 2012. The total column detected by AIRS showed a similar trend except for disparities between 2006 and 2007 and between 2010 and 2011.

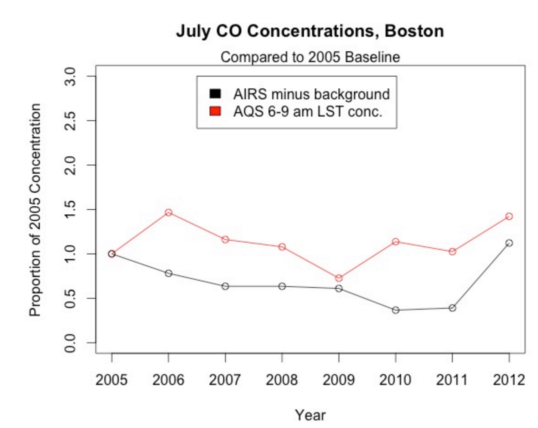



**Figure 2: Boston:** Boston showed sharp decreases in ground concentration in 2007 and 2009, much like New York. The ground concentration rebounded in 2010, dipped again in 2011, and rebounded again in 2012. AIRS column trends showed large disparities with the ground concentration trends between 2005 and 2006, between 2009 and 2010, and between 2010 and 2011.

### Mid-Atlantic

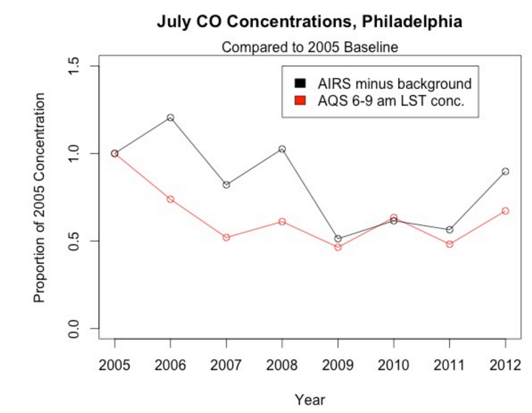



**Figure 3: Philadelphia:** Philadelphia's ground concentration displayed a strong decreasing trend through 2007 and decreases in 2009 and 2011 as well, with a strong rebound in 2012. The total column trends were fairly consistent with the ground concentration trends except for an increase in total column between 2005 and 2006.

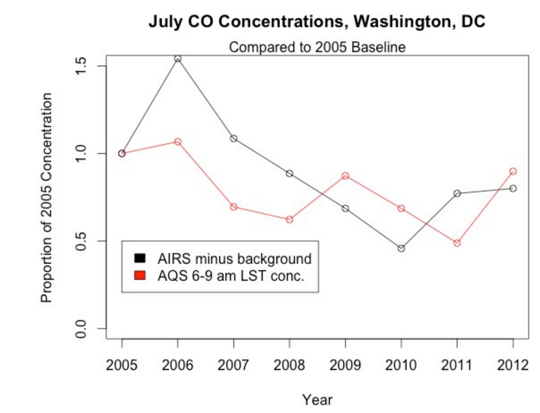



**Figure 4: Washington, DC:** The ground concentration of DC decreased sharply in 2007 and rebounded in 2009 only to fall again until a sharp rebound in 2012. The total column shows disparities with this trend between 2008 and 2009 and between 2010 and 2011 and does not show as dramatic of an increase between 2011 and 2012.

### Midwest

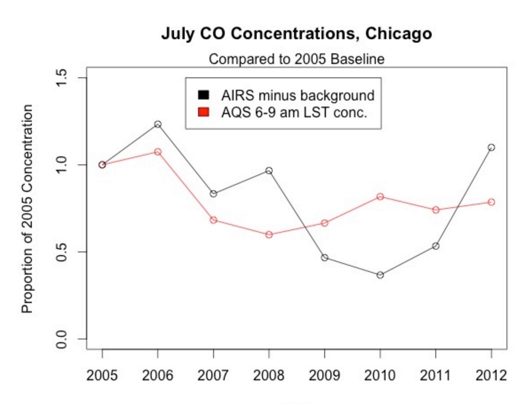



**Figure 5: Chicago:** The ground concentration in Chicago sharply decreased going into 2007, began to rebound between 2008 and 2009, and rebounded slightly in 2012 after a decrease going into 2011. The total column showed many disparities with these trends.

### West

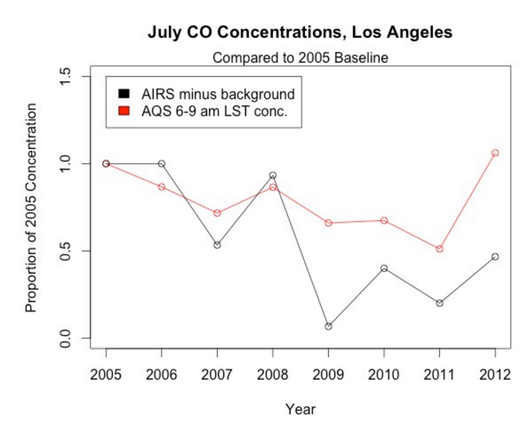



**Figure 6: Los Angeles:** The ground concentration in LA decreased through 2007 and again in 2009 and 2011 and then rebounded very sharply in 2012. The total column trend was fairly consistent with the ground concentration trend except between 2005 and 2006.

### Southwest

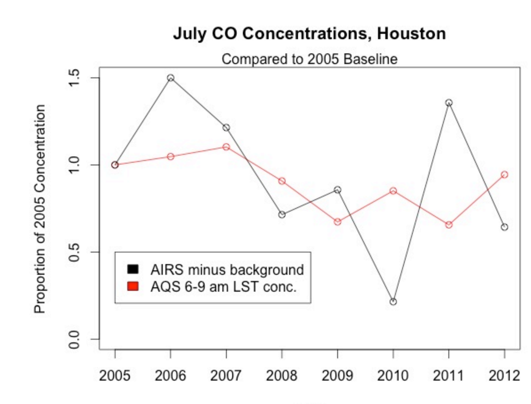



**Figure 7: Houston:** After a steady rise through 2007, the ground concentration in Houston decreased sharply through 2009 and decreased again in 2011, with rebounds in 2010 and 2012. The total column was inconsistent with the ground concentration in several years, specially from 2009 through 2012, during which time the total column was highly erratic. The total column dropped very low during 2010

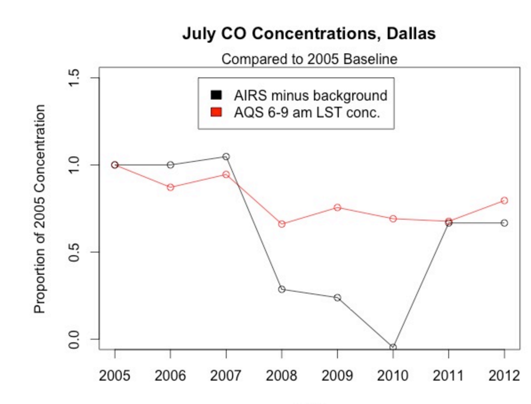



**Figure 8: Dallas:** The ground concentration in Dallas fell sharply going into 2008, rebounded going into 2009, and fell again until a rebound in 2012. The total column showed inconsistencies with the ground concentration in several years, although it reflected the rise going into 2007 and the subsequent sharp drop. As in Houston, the total column over Dallas was very low in 2010 (in the case of Dallas, slightly below the estimated background). These cities are very close to the region that was used to estimate the background and so generally had column measurements only slightly above the background.

### Southeast

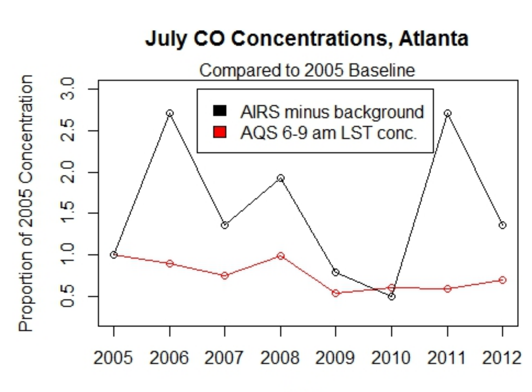
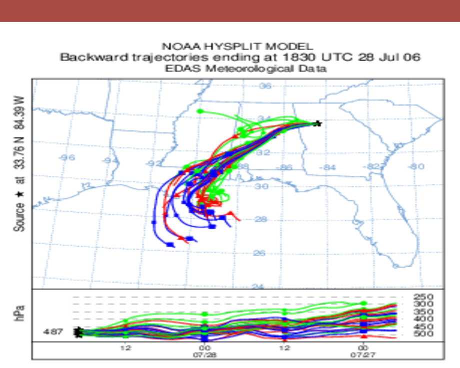
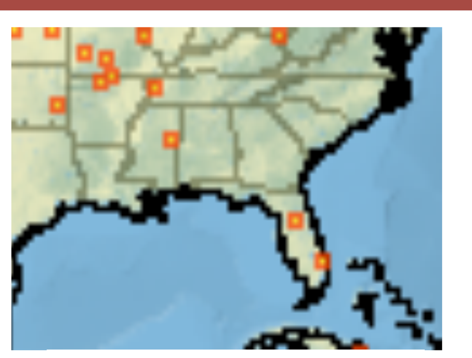



**Figure 9: Atlanta:** The ground concentration of Atlanta decreased through 2007 and again in 2009 (sharp) and 2011, with rebounds in 2008 and 2012. The total column was very erratic and displayed a wide range and many inconsistencies with the ground concentration trends. (Y axis scale has been altered to account for wide range of variation.

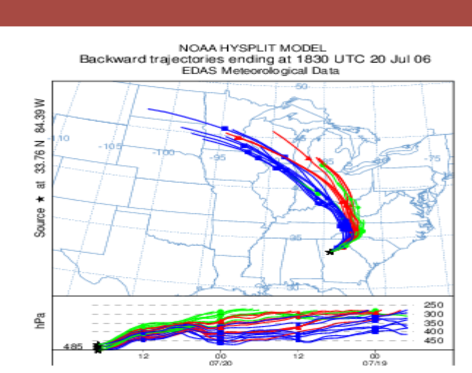
## Effects of Upper Level Transport and Regional Biomass Burning for Atlanta




Total CO column: 1.6052e+18 mol/cm$^2$, pixels=8; Ground concentration: 0.516917ppm (Image from HYSPLIT Model)



Biomass burning for July 26, 2006 (Image from https://firms.modaps.eosdis.nasa.gov/firemap/)




Column for July 20, 2006: 2.0198e+18 mol/cm$^2$, pixels=9; Ground concentration: 0.509ppm

BB for July 18, 2006

Dates in 2005 when upper-level transport came from a high-biomass burning region had AIRS CO column values comparable to those in 2006 with similar transport. However, July 2005 had many more dates during which upper-level transport came from the Gulf of Mexico rather than from inland. On those days, even if biomass burning occurred near Atlanta, the total column was much closer to the background CO levels. This seems to have held true with few exceptions. Ground data, however, did not show a relationship to the source region of transport or to biomass burning locations.

## Summary of Results

- An interannual CO trend corresponding to the Recession and subsequent recovery was detected by ground monitors across the cities.
  - Many cities experienced a decrease in ground CO concentration in 2007, 2008, or 2009, which were the hardest-hit years of the Recession shortly after the housing market collapse.
  - Many cities experienced another decrease in ground CO concentration in 2011.
  - Nearly every city experienced a rebound in ground CO concentration in 2012, a year of economic recovery, so abovementioned decreasing trends do not seem to be simply the result of a long-term decrease due to factors such as better technology or tighter emissions standards.
- There are disparities between AIRS trends and ground data trends in certain years.
  - Years that displayed a disparity in CO trend among many cities include 2006 and 2011.
- AIRS CO columns seem to be affected by other factors such as the source region of upper-tropospheric transport and the amount of biomass burning in the source region, as well as the amount of BB in the region of the city. Ground data does not show this relationship and so presumably is a marker of almost exclusively local emissions.
  - For example, the disparity between 2005 and 2006 in Atlanta may have been caused by large amounts of upper-level transport from the ocean in 2005 and large amounts of transport from BB-heavy regions in 2006.
  - Daily CO column calculations have shown that days with upper-level transport from over the ocean or from a region without major urbanization or biomass burning tend to have CO columns much closer to baseline values.
  - Daily CO ground concentration calculations do not show this relationship to source region of upper-level transport.

## Conclusion and Future Work

- Interannual variability in ground CO concentrations corresponding to changing economic conditions is detected in urban areas by ground monitors.
- Ground data reflects local emissions rather than transported emissions.
- The total CO column detected by AIRS is heavily affected by emissions (such as regional biomass burning emissions) that are transported at approximately a 500mb level.
- Future directions:
  - Trends may be rigorously statistically analyzed to draw quantitative conclusions.
  - GFED 3.1 daily data is currently being used to calculate biomass burning emissions in source regions,
  - In the future, $SO_2$ upper-tropospheric mixing ratios may be examined as a ratio with CO mixing ratios at this pressure level to determine a transported biomass burning signal.
  - It may also be helpful to run a multiple regression to determine relative effects of factors such as upwind CO column, upwind BB CO emissions, and BB emissions within a certain radius on the CO column detected by AIRS.

## Acknowledgements

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Please email Nina.Randazzo@noaa.gov or Daniel.Tong@noaa.gov with questions or comments.