Temporal Variability of Carbon Dioxide Measured in Indianapolis, Indiana

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ABSTRACT

Four greenhouse gas measuring sites placed in either forest, agricultural, or urban setting in Indianapolis, Indiana were examined for their carbon dioxide readings during the afternoon. The study focused on overall growth, median, standard deviation, and diurnal cycles to find similarities and differences to better understand, measure, and model CO_2 in a given area. Smaller standard deviations in the winter afternoon were found compared to the summer afternoon. A general rise was found in afternoon winter CO_2 median since 2013. The urban site's diurnal cycle had a larger range of values as the agricultural site had the smallest. Winter diurnal cycle values were larger than summer diurnal cycle values.

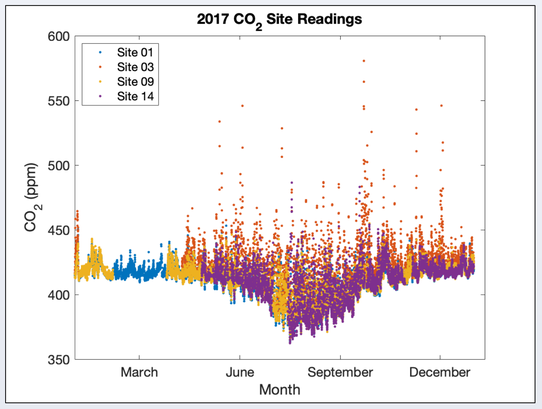


Figure 1. A graph of CO_2 for one year with all hours shows the common cycle of higher CO_2 readings in the winter and lower readings in the summer. Common patterns in this study are also shown such as the urban site 03 having larger CO_2 values than forest site 01. Site 03 can also be seen in this figure as having a larger standard deviation, which is a pattern observed most years.

INDIANAPOLIS FLUX EXPERIMENT







The Indianapolis Flux Experiment began in 2011 and currently runs 12 active sites for measurements in CO_2, CO, and CH_4. Currently, 12 sites are active and spread out around and in Indianapolis. Each site can be characterized as measuring a forest, agricultural, or urban area. Indianapolis was chosen as it is a relatively flat city, thus making measurements of gases more accurate.

Goals for the Indianapolis Flux Experiment include:

- Creation of modeling and evaluation techniques of greenhouse gases.
- Measurement of greenhouse gas reduction actions effectiveness
- Measure emission of greenhouse gases on urban scale

DATA COLLECTION

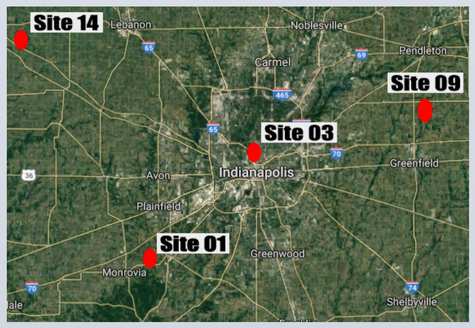


Figure 2. Of the 14 data sites, 12 currently active, sites 01, 03, 09, and 14 were examined. Site 1 is classified as a forest site and is roughly 30 miles outside of Indianapolis. Site 03 is considered an urban site and is located right in the city. Sites 09 and 14 are classified as agricultural sites and are located in farmland areas.

The data collected by the Picarro spectrometers is being collected every minute and is then averaged every hour by the on-site computer. The hourly averaged data of CO_2, CO, and CH_4 is then sent from the on-site computer to be reached remotely by researchers. Occasional software or hardware equipment issues may cause data to be missing. The spectrometers are calibrated by gas tanks located at the tower site that hold known amount of gases in them to ensure measurements are accurate.

RESEARCH METHODS

The programming language MATLAB was utilized in the analysis and figure creation of all data collected. Analysis began with creating a "real" data set, as when data is sent from the site missing data is skipped. This required creating a table of 24 hour-cycle from 2011 through mid-2018. Actual data was then moved to the initialized "real" data table so that missing data could exist as "Not a Number," making further coding more simple. Consideration also had to be taken as the time the data is set to is -5 GMT.

```
%% Site 01 Afternoon
load Site01

mask = ismember(Site01(:,4), 17:21);
afternoon_Site01 = Site01(mask,:);

x = (1:14305)';
y = afternoon_Site01(:,5);

plot(x,y,'.')
xlabel('Hours')
ylabel('CO2 ppm')
title('Site 01 Afternoon Hours')
xticks([1826 3656 5481 7306 9131 10961 12786])
xticklabels({'2012','2013','2014','2015','2016','2017','2018','2018'})
figure
```

Coding techniques included using turning arrays into tables, loops, functions, graphing, and logic masks. These techniques were used to quickly create averages, medians, standard deviations within specific parameters. Commands such as "find" became particularly useful when extracting specific data sets of days of the year or hours of the day. Troubleshooting often came with making sure the data made sense, such as the calculated median being much different than the calculated average. These problems often became apparent after graphing the data. MATLAB has the feature of giving the specific location of error in code, which made solving errors in coding simple.

RESULTS – AFTERNOON CARBON EMISSION

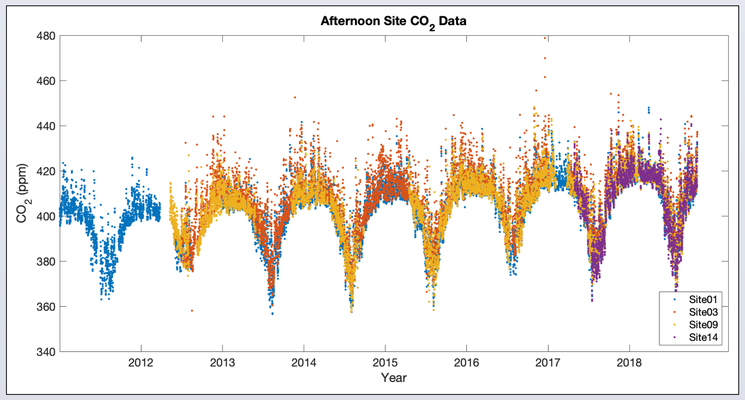


Figure 3. Overall, a general rise in CO_2 emissions is apparent, as the CO_2 lows of winter increase each year. This is attributed to the rise in human-caused CO_2 in the Northern Hemisphere. **A cyclical rise and fall is attributed to the winter having higher highs and lows of CO_2 measured and the summer having lower highs and lows.** Site 01's winter afternoon low rises every year. Mid 2016's low peak is the highest for site 01, site 03, and site 09. Indianapolis experienced a major drought in 2016 and 2012, contributing to summer low's being higher than usual.

RESULTS – VARIATION BETWEEN SITES

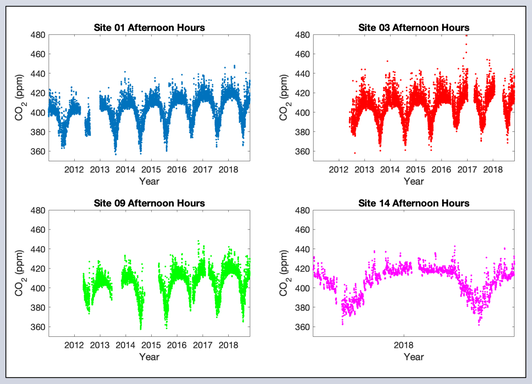


Figure 4. With each site having different location characteristics, their levels of CO_2 are different. Site 03 has a lower summer drawdown of CO_2, as its urban setting has little plant life and human-caused CO_2 emissions year round. Site 03 will also see the largest measurements of CO_2. In contrast, Sites 01 and 09 have larger range cycles, as the forest and farmland plant life can absorb more CO_2 in the summers. **However, high levels of CO_2 can still be seen in the winter as the rate CO_2 is absorbed slows down and decaying plant life releases CO_2.**

RESULTS- SUMMER AND WINTER MEDIAN AND STANDARD DEVIATION

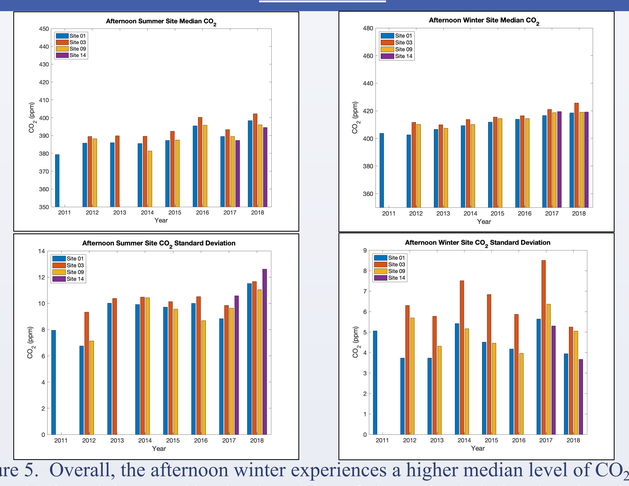


Figure 5. Overall, the afternoon winter experiences a higher median level of CO_2 in all sites. This is mainly caused by the slow down of plant growth during the winter in addition to leaves rotting and releasing CO_2. Site 03 experiences the highest levels of CO_2 during summer and winter, which can be attributed to human-caused CO_2 emissions.

Summer afternoons have a greater standard deviation in all sites. **Site 03 has the largest standard deviation in both summer and winter afternoons.** In the winter, there appears to be a cyclical pattern noticeable in sites 01, 03, and 09 of falling then rising in standard deviation. It also appears that the largest standard deviations reached by all sites appear during the same year.

RESULTS – COMPOSITE DIURNAL CYCLE JUNE-AUGUST

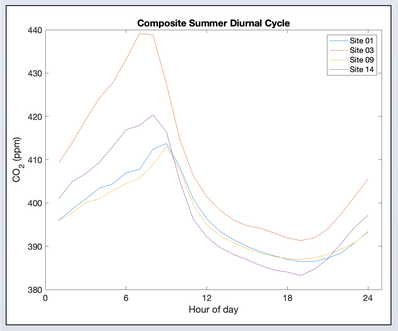


Figure 6. The diurnal cycle is the cyclical pattern of CO_2 emissions rising during the nighttime and falling during the day. This phenomenon is mainly caused by the tendency of plants to release more CO_2 at night than during the day during their respiration process. Composite data of June-August shows this to be true, as the CO_2 rises from 8 PM to 9 AM. **Site 03 reaches the highest amount of CO_2, as the urban site, additional CO_2 may be from human emissions.** Site 14, the agricultural site, reaches the lowest point of CO_2 at 7 PM, as additional CO_2 may be absorbed by crops and plants. **Site 03 experiences the largest change from day to night in CO_2 levels and site 09 experiences the smallest change.**

RESULTS – COMPOSITE DIURNAL CYCLE DECEMBER-FEBRUARY

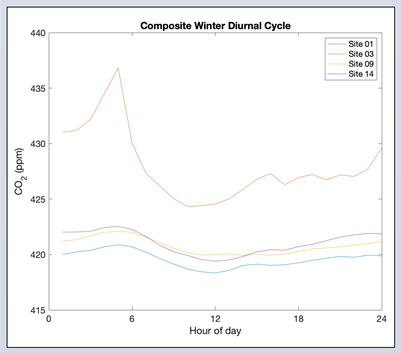


Figure 7. The winter experiences a smaller range in values in all sites and values are larger in all sites even at their lowest points in the afternoon. **Agricultural sites and the forest sites see much less range as there is less plant activity during the winter seasons. Urban site 03 still sees variation, however this may be partly due to human-caused emissions caused from heating homes to driving to work.** The agricultural site does not see the lowest values in the afternoon either, as crop growth in the winter comes to a halt and less CO_2 becomes absorbed.

SUMMARY

Characteristics of location, season, human activity, and plant life all contribute to variation in recorded carbon dioxide data. Overall trends include a rise in CO_2 emissions every winter afternoon and higher median CO_2 levels in the winter afternoon compared to summer afternoons. Summer afternoons have experienced larger differences in summer medians from year-to-year. The urban site has a larger range in diurnal cycle readings and the agricultural site has the smallest change.

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