Diurnal and Seasonal Changes of CO_2 in Berkeley California

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Background

Carbon dioxide (CO_2) is the primary greenhouse gas (GHG) emitted from human activities. Fig. 1 shows the molecular structure of greenhouse gases. Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle. There are natural sources of atmospheric CO_2 such as volcanic outgassing, combustion of organic matter and the respiration process. Fig. 2 shows how plants take in carbon dioxide (CO_2) from the atmosphere during photosynthesis, and release CO_2 back into the atmosphere during respiration. Man-made sources of carbon dioxide include burning of fossil fuels and industrial processes like cement making. Humans are altering the carbon cycle—both by adding more carbon dioxide to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. There is undeniable evidence that global levels of carbon dioxide are increasing in the atmosphere. In 1957 Dave Keeling chose Mauna Loa volcano to measure CO_2 levels for much of the Northern Hemisphere. Graph 1 exhibits that higher levels of CO_2 occur during the winter months. One of NASA satellites, AQUA, hosts the instrument, the Atmospheric Infrared Sounder (AIRS) shown in fig. 9, which detects the effects the changes in concentration of this greenhouse gas (GHG). In Oakland, California, scientists from the University of California, Berkley have placed several monitoring stations around the city to monitor ground CO_2. The network of ground stations shown in fig. 4 is known as the Berkley Atmospheric CO_2 Observing Network (BEACON).

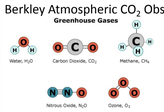


Figure 1: Types of Greenhouse Gases

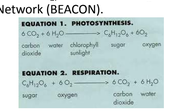
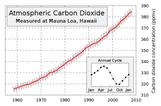


Figure 2: Formulas for Photosynthesis and Respiration



Graph 1: CO_2 Increases in the Past 5 Decades

BEACON

Berkeley Atmospheric Carbon Dioxide Observation Network (BEACON) is a project at the University of California that is making an effort to decrease carbon emissions. There are miniature sensors continuously monitoring and transmitting carbon dioxide levels to a central data server exhibited in figure 5.

Figure 6 and Figure 7 indicate where CO_2 hourly data was collected at various elevations and environments. The three sites were strategically chosen for this research project. Skyline is a residential area with an elevation of 357 meters shown in green, Chabot is in a wooded area with an elevation of 464 meters shown in blue and Laurel is in an urban area with an elevation of 65 meters shown red. All the CO_2 graphs are colored-coded to distinguish these specific sites.

The data collected at Skyline, Chabot and Laurel indicate how the sources and "sinks" affect CO_2 levels measured by the sensor modes. Forests (sinks) typically remove high concentrations of carbon dioxide during photosynthesis (day) and covert into sugars releasing oxygen in the troposphere (night). The data collected from the BEACON's network in the last year has shown that the cyclic change of carbon dioxide could be caused by the diurnal variation of vegetation growing in three sites (Chabot, Skyline and Laurel). In the spring, the growth of plants uses carbon dioxide so the level of this GHG should typically decrease. During the fall, growth ceases so this causes carbon dioxide to increase. The two-dimensional view of the carbon dioxide seasonal variation in graphs 3 and 4 show this trend in the summer of 2012 throughout winter of 2013.

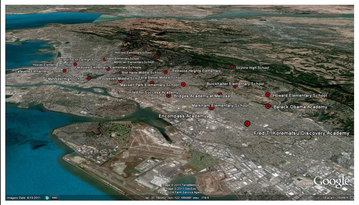


Figure 3: Berkeley, California

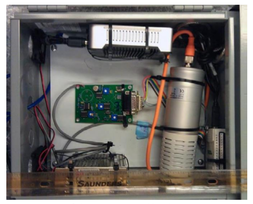


Figure 5: One of the Sensors Used by the BEACON Team

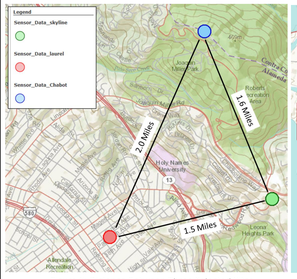


Figure 6: Distance Between Three Selected Sites

Figure 7: Geographical Locations of Three Selected Sites

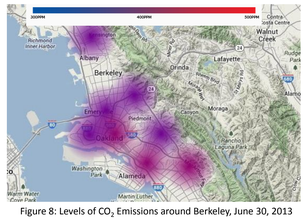


Figure 8: Levels of CO_2 Emissions around Berkeley, June 30, 2013

Figure 4: Sensors Strategically Placed by BEACON

Acknowledgements

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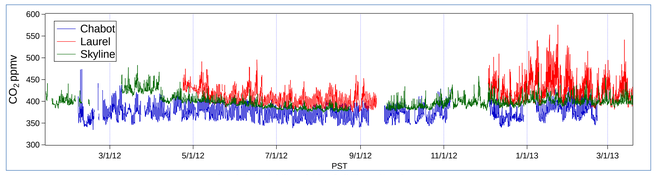
CO_2 Data Showing Diurnal and Seasonal Cycles from 2012-2013

Description of Graphs

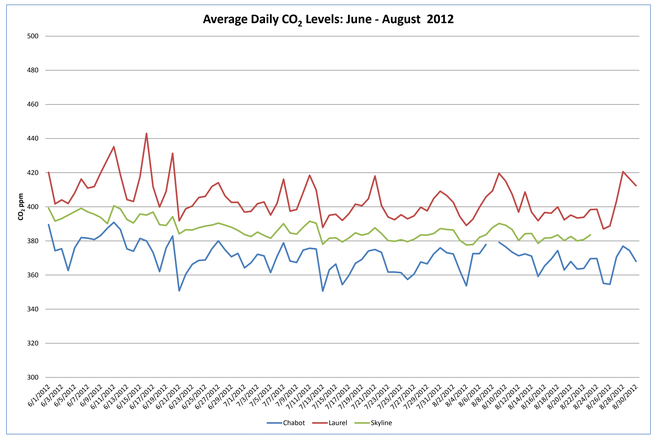
Graph 2: High levels of carbon dioxide could be caused by anthropogenic emissions from increased heating during the winter.

Graph 3 and 4: Laurel's data indicates high levels of carbon dioxide during January. Skyline's levels peak during the winter season. There is a typical seasonal pattern occurring with Chabot's data (peaks or no peaks).

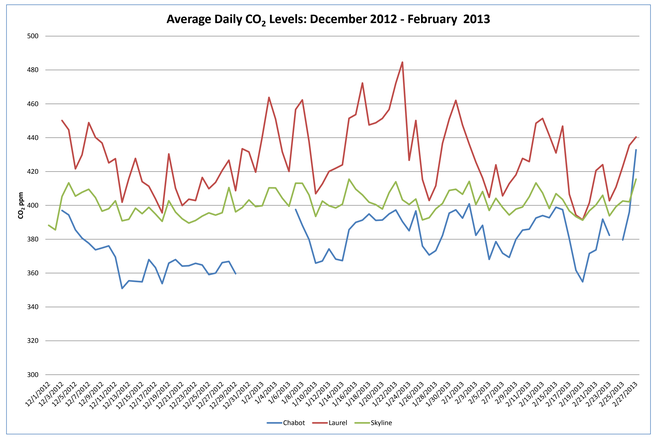
Graphs 5-10: Diurnal variability may demonstrate characteristic patterns due to different wind directions, weather conditions and "sinks" located in the urban environments surrounding the CO_2 sensory sites. Seasonal levels of carbon dioxide peaked during the noon hour. There was no difference between weekend and weekday data that indicated higher concentrations of carbon dioxide mixing with other GHGs (NO and NO_2)due to traffic.



Graph 2: Variability of CO_2 of all Three Sites for 1 Year

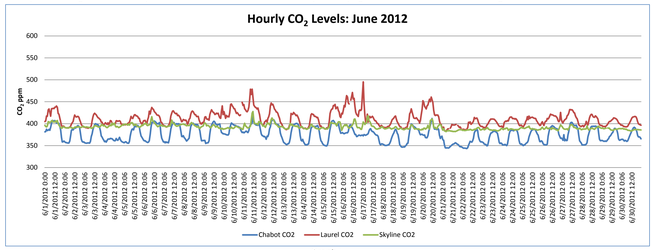


Graph 3: Summer Variability for CO_2

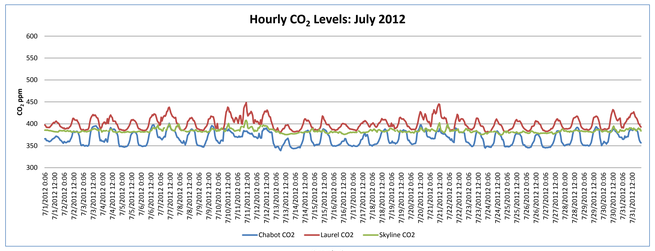


Graph 4: Winter Variability for CO_2

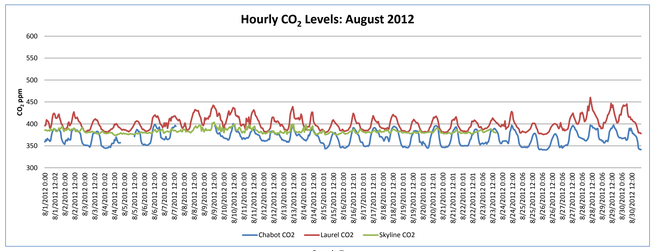
Graphs 5 through 10 show the patterns of carbon dioxide influenced by anthropogenic emissions that are occurring in short-term diurnal variations.



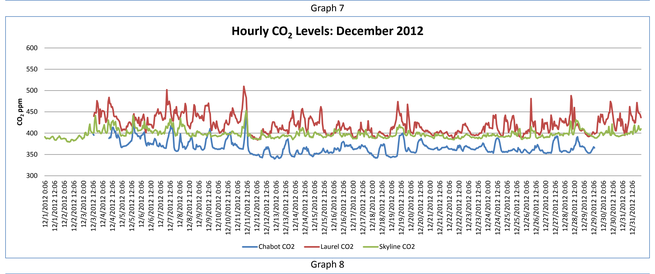
Graph 5



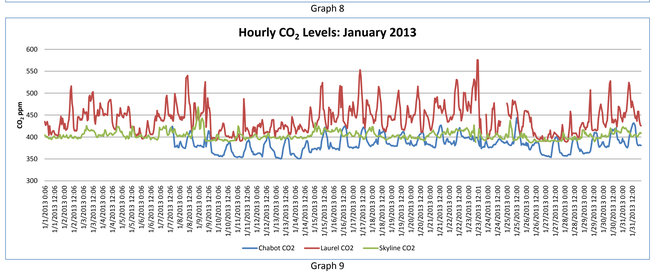
Graph 6



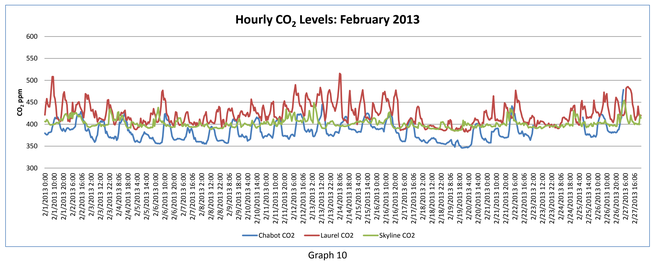
Graph 7



Graph 8



Graph 9



Graph 10

AIRS

AIRS (Atmospheric Infrared Sounder) is one of the six instruments aboard the AQUA satellite. AIRS uses infrared technology that provides an accuracy of 1.5 ppm and 2 ppm in obtaining readings of CO_2 in the troposphere (fig. 9). The AIRS instrument collects daily data in the mid-troposphere at altitudes between 15,000 to 30,000 feet and a global latitude range of 60S to 90N. Carbon dioxide has an affinity for certain colors or wavelengths of light that actually make the energy in the molecules vibrate. AIRS measures the infrared light that is given off by these molecules. Carbon dioxide absorbs the infrared light from the surface and sends it back to space at a lower energy rate. In April 2013 (fig. 11), AIRS calculated CO_2 levels that reached up to 397 ppm with peaks up to 400ppm. Due to anthropogenic effects on increased levels of GHG's, AIRS data on CO_2 is vital in understanding global climatic changes.

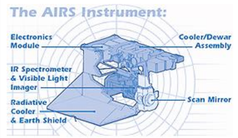
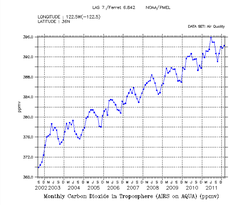
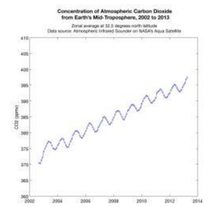


Figure 9: AIRS Infrared Technology that Creates 3-D Maps and Graphs for Displaying CO_2 Concentrations

Satellite	AQUA – AIRS
Measurements	The Atmospheric Infrared Sounder Greenhouse gases – Carbon Dioxide
Launch date	May 4, 2002
Accuracy	<0.2% absolute error
Recurrent period	Daily, day and night
Spatial sampling	14km at nadir
Mission life	5 years

Figure 10: Technical Specifications of AIRS


Graph 11: AIRS Footprint over Oakland, CA



Graph 12: Steady Increase of CO_2 (GHG)

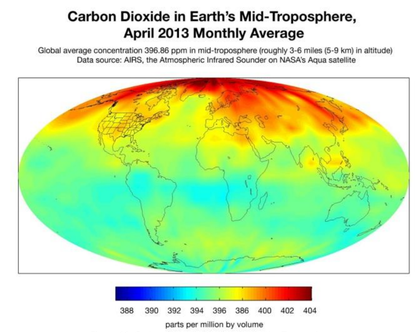


Figure 11: Carbon Dioxide Distribution in the Troposphere

Conclusion

While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution. CO_2 concentrations have increased from about 280 parts per million to over 390 parts per million. Ground-based global network measurement sites have observed an increase in atmospheric CO_2 levels by almost 20% over the past 50 years. Using instruments like the Atmospheric Infrared Sounder (AIRS), researchers are able to correlate the data in measuring changes of carbon dioxide during seasonal cycles, identifying sources of emissions and sinks of CO_2 in specific locations like California (graph 11). Many natural factors influence CO_2 mixing ratios such as parameters like wind direction, night or early morning inversions and daily changes in atmospheric boundary layer (ABL) mixing have a typical short time influence; air temperature, sunshine duration and vegetation activity show up as seasonal factors. The data collected by BEACON indicates CO_2 is increasing by 75 ppm during inversion hours possibly from traffic and anthropogenic emissions. BEACON's data also shows a higher concentration of the GHG than AIRS, however, NASA's data continuously exhibits that carbon dioxide is increasing 2 ppm each year. Monitoring systems strategically positioned across the globe are essential for observing CO_2 to identify sinks and sources of emissions during diurnal and seasonal cycles.

References

AIRs, Jet Propulsion Laboratory, http://www-airs.jpl.nasa.gov/
The Berkley Atmospheric Carbon Dioxide Observation Network, http://beacon.berkeley.edu/sites/sensorsite.aspx?site=ginko
Mauna Loa Carbon Dioxide Annual Mean data, http://www.epa.gov/climatechange/ghgemissions/gases/co2.html
http://mynasadata.larc.nasa.gov/