FY 2014 Technical Report
Fluxes of Greenhouse Gases in Maryland: FLAGG-MD

A Project to Characterize Carbon Gas Emissions in the Baltimore/Washington Area

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James Whetstone, PM

By
Russell R. Dickerson, PI
Eugenia Kalnay, CI for Modeling
Kayo Ide, CI for Data Assimilation
Xinrong Ren, CI for Observations
Ross J. Salawitch, “OCO2 and Climate Change Maryland” Liaison
Kostya Vinnikov, CI for Climatology
Ning Zeng, CI for C-Cycle Modeling
DaLin Zhang, CI for Mesoscale Meteorology

AOSC, UMCP
For the Period 1 April to 30 September 2015
Summary

This is the second technical report for the FLAGG-MD – a project to develop the measurement science and technology of greenhouse gases and their flux. The project involves direct measurements of GHG’s from a research aircraft, estimates of fluxes and emissions based on those measurements and winds, development of numerical models to better estimate winds and dispersion, climatological analysis for meteorology and statistical analysis of observations, evaluation of low-cost sensors for CO₂, data assimilation for meteorological variables as well as carbon, BC analysis, and links to remote sensing. These are combined to advance the measurement technology of GHG fluxes as well as to determine the emissions and transport of GHGs from Indianapolis and the Baltimore /Washington area.

Aircraft Measurements

Xinrong Ren & Hao He, CI’s

Accomplishments 4/1/15 to 9/30/15

This time was used to process and analyze prior aircraft data and to conduct flights to investigate CH₄ emissions form oil and gas operations in the eastern US. Figure 1 shows the flight track of the UMD Cessna research aircraft as it performed one of three flights over the Marcellus Shale formations in August 2015. These flight hours were funded by the National Science Foundation, using equipment funded by NIST for FLAGG-MD. The mass-balance approach is used to estimate the flux of methane as a fraction of the total natural gas production we obtained values between 3 and 7%, similar to those obtained by the Purdue group (Caulton et al., PNAS, 2014), but much higher than reported by Peischl et al., JGR, 2015.

Results are available at the RAMMPP web site http://www.atmos.umd.edu/~rammpp/archives/ArchiveFlightData.html and will be copied to the FLAGG-MD site.
Figure 1. Flight tracks of UMD Cessna colored by methane mixing ratios. Substantial increases in mixing ratios were observed near and downwind of oil and gas operations.

**Planned Publications**


**Black Carbon Analysis**

Graduate student Courtney Grimes, working with NIST scientists C. Zangmeister has begun comparisons of commercial BC analyzers PSAP and Aethalometer to photoacoustic and other state of the science NIST instruments. They discovered a sensitivity of the calibration to coating on particles. They also investigated Carb-O-Jet as a potential commercial reference material. Initial results are encouraging.
Climatology

K. Vinnikov, CI.
Phil Stratton, GRA

Accomplishments 4/1/2015 - 9/30/2015.
Developed an approach for homogenization and preprocessing of wind profilers multi-year observations for statistical study of boundary layer wind regime in Maryland. Profilers have continuous high-resolution observations, but appear to have never been fully evaluated for precision and accuracy. Results presented and discussed at 40th Annual Meeting of American Association of State Climatologists, Cape May, NJ on June 2015.

Data Assimilation & High Resolution WRF Modeling

Kayo Ide & DaLin Zhang, CI’s
YiXuan Shou, visiting Scientist

Accomplishments 1 April to 30 Sept 2015:
During this period, our effort focused on modeling of meteorological conditions over the Indianapolis area with the following two foci: i) improvement of the WRF-ARW model coupled with a multi-layer urban canopy model; ii) development of the WRF-LETKF data assimilation system. The WRF-ARW model for the Indianapolis area uses four nested domains with the highest horizontal resolution of 500 m and 51 vertical levels. The time period for the case study is from 1200 UTC 29 September to 1200 UTC 2 October 2014. The modeling study shows that albedo and emissivity are the two key parameters in energy balance, therefore use of the observed land surface parameters helps improve the real case simulations. It is found that the moisture effect is critical in the PBL height modeling through the estimation of turbulent kinetic energy. This effect can be better represented by the use of virtual potential temperature, leading to the improved surface wind simulation. The WRF-ARW model simulation by itself, however, is found to underestimate the horizontal wind speeds during daytime and overestimate the surface temperature during nighttime for the test case. To generate the best possible high-resolution meteorological fields and also determine the corresponding uncertainties, the WRF-LETKF data assimilation system is implemented using 54 ensemble members for the 13.5 km horizontal-resolution domain by carefully tuning the ensemble parameters. Preliminary results suggest that the WRF-LETKF system improves the meteorological field estimation through the effective ingestion of mesoscale information in the observations.
C-Cycle Modeling & Low-Cost Sensors

Ning Zeng, CI
Cory Martin, GRA

Accomplishments 4/1/15 to 9/30/15:
We tested K30 CO\textsubscript{2} sensors placed in a rooftop chamber, co-located with a laser cavity-ringdown spectroscopy (CRDS) CO\textsubscript{2} analyzer Los Gatos FGGE. We continued to refine the Raspberry Pi-K30 data collection package. Undergraduate students worked on wiring, soldering, and assembling hardware. A user data interface webpage was developed as part of the original project website sense.umd.edu, which allows a user/station manager to view and download data. We also tested the Pi-K30 package on a Parrot quadcopter (loaned), and flew it to 15 meter high due to limited lifting power.

Combining Modeling and Aircraft Observations for Flux Calculations

Ross Salawitch, CI
Doyeon Ahn, Jonathan Hansford, Xinrong Ren, Russ Dickerson

Accomplishments 4/1/15 to 9/30/15:
Our effort has been focused on calculation of CO\textsubscript{2} and CH\textsubscript{4} fluxes for the region, and identifying the sources of CO\textsubscript{2} and CH\textsubscript{4}. We have used the NOAA HYSPLIT model as well as the mass balance approach for fluxes.

CO\textsubscript{2}:
The table below compares CO\textsubscript{2} fluxes from Maryland inferred from the FLAGG-MD data to the amount of CO\textsubscript{2} emissions from power plants and the Luke paper company, based on Continuous Emission Monitoring System (CEMS) data:

<table>
<thead>
<tr>
<th>Flight Date</th>
<th>Flux CO\textsubscript{2} (moles/s)</th>
<th>Flux CO\textsubscript{2} (metric tons/day)</th>
<th>Flux CO\textsubscript{2} (metric tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FLAGG-MD</td>
<td>FLAGG-MD</td>
<td>CEMS</td>
</tr>
<tr>
<td>2/13/15</td>
<td>97,794</td>
<td>371,858</td>
<td>95,300</td>
</tr>
<tr>
<td>2/19/15</td>
<td>65,447</td>
<td>248,860</td>
<td>109,928</td>
</tr>
<tr>
<td>2/20/15</td>
<td>148,860</td>
<td>566,035</td>
<td>111,668</td>
</tr>
<tr>
<td>2/23/15</td>
<td>72,842</td>
<td>276,979</td>
<td>80,682</td>
</tr>
<tr>
<td>2/25/15</td>
<td>136,755</td>
<td>520,006</td>
<td>82,235</td>
</tr>
<tr>
<td>Mean</td>
<td>104,439</td>
<td>396,748</td>
<td>95,962</td>
</tr>
</tbody>
</table>

|                  |                               |                                      | 24.2 %                                 |

CO\textsubscript{2}:
We see on average about 24% of the emissions originate from power plants (and the paper company).

CH$_4$:
The table below compares CH$_4$ fluxes from Brown Station Landfill, Eastern Sanitary Landfill, Baltimore City, and the DC-Baltimore metropolitan area inferred from FLAGG-MD data to various inventories.

<table>
<thead>
<tr>
<th>Unit: t CH$_4$/yr</th>
<th>2011 MDE Inventory</th>
<th>2014 EPA Inventory</th>
<th>CarbonTracker</th>
<th>Mass Balance (FLAGG-MD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown Station</td>
<td>7,236</td>
<td>4,851</td>
<td>n.a.</td>
<td>28,448 ± 8,561</td>
</tr>
<tr>
<td>Eastern Sanitary</td>
<td>1,122</td>
<td>4,357</td>
<td>n.a.</td>
<td>17,566 ± 13185</td>
</tr>
<tr>
<td>Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltimore City</td>
<td>6,136</td>
<td>11,645</td>
<td>3,400</td>
<td>40,195 ± 21626</td>
</tr>
<tr>
<td>DC-Baltimore metropolitan area</td>
<td>39,929</td>
<td>22,376</td>
<td>47,439</td>
<td>105,590 ± 34,845</td>
</tr>
</tbody>
</table>

This preliminary analysis indicates 44% of the CH$_4$ flux in the region is from the two landfills.

**Work Plan**
The next focus of our analysis is rigorous treatment of uncertainties in the flux estimates. Once this is completed, we will be submitting two papers, one on CO$_2$ to be led by Doyeon Ahn, the other on CH$_4$ to be led by Jonathan Hansford.