



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

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

Submitted to:

**NIST Measurement Science and Engineering (MSE) Research Grant Programs  
The Office of Special Programs (OSP)**

**Greenhouse Gas (GHG) and Climate Science Measurements Grant Program**

Funding opportunity: 2014-NIST-MSE-01

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, “OCO<sub>2</sub> 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 CO<sub>2</sub>, 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

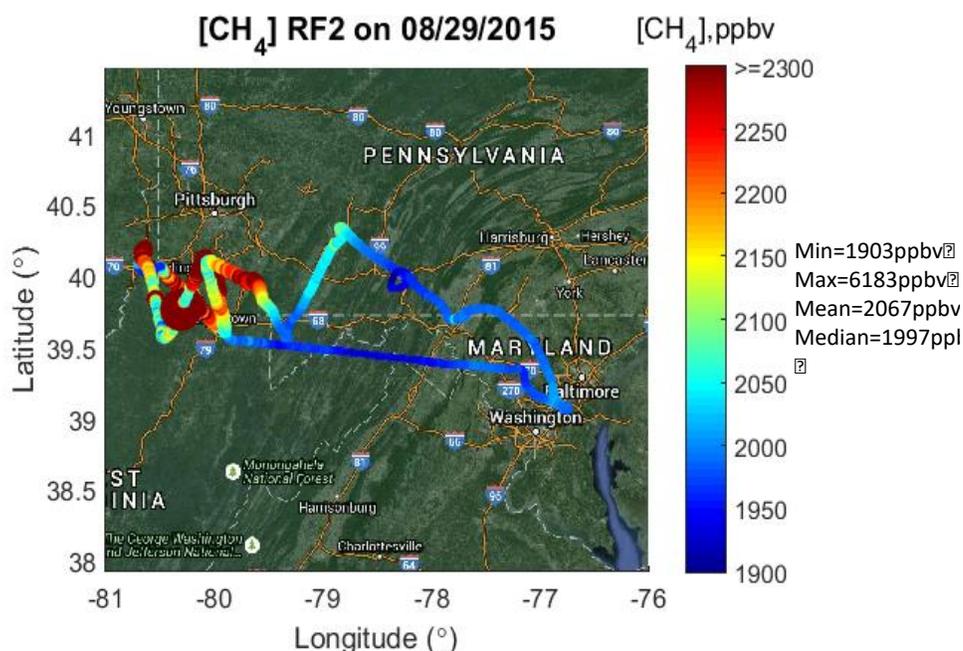
#### Accomplishments 4/1/15 to 9/30/15

This time was used to process and analyze prior aircraft data and to conduct flights to investigate CH<sub>4</sub> emissions from 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**

“Emissions of methane and other trace gases from the Marcellus gas formation from aircraft surveys” X. Ren, S. Ehrman, H. He, R. Salawitch, and R. Dickerson, JGR in preparation 2016.

**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 40<sup>th</sup> 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<sub>2</sub> sensors placed in a rooftop chamber, co-located with a laser cavity-ringdown spectroscopy (CRDS) CO<sub>2</sub> 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](http://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<sub>2</sub> and CH<sub>4</sub> fluxes for the region, and identifying the sources of CO<sub>2</sub> and CH<sub>4</sub>. We have used the NOAA HYSPLIT model as well as the mass balance approach for fluxes.

CO<sub>2</sub>:

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

Flight Date	Flux CO <sub>2</sub> (moles/s)	Flux CO <sub>2</sub> (metric tons/day)	Flux CO <sub>2</sub> (metric tons/day)	
	FLAGG-MD	FLAGG-MD	CEMS	
2/13/15	97,794	371,858	95,300	25.6 %
2/19/15	65,447	248,860	109,928	44.2 %
2/20/15	148,860	566,035	111,668	19.7 %
2/23/15	72,842	276,979	80,682	29.1 %
2/25/15	136,755	520,006	82,235	15.8 %
Mean	104,439	396,748	95,962	24.2 %

We see on average about 24% of the emissions originate from power plants (and the paper company).

CH<sub>4</sub>:

The table below compares CH<sub>4</sub> fluxes from Brown Station Landfill, Eastern Sanitary Landfill, Baltimore City, and the DC-Baltimore metropolitan area inferred from FLAGG-MD data to various inventories.

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

This preliminary analysis indicates 44% of the CH<sub>4</sub> 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<sub>2</sub> to be led by Doyeon Ahn, the other on CH<sub>4</sub> to be led by Jonathan Hansford.