FY 2015 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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AOSC, UMCP
For the Period 1 October 2015 to 31 March 2016

Summary

This is the third technical report for the FLAGG-MD – a project to develop the measurement science and technology of greenhouse gases and their flux. Reports, presentations and data sets can be downloaded from the FLAGG-MD website

http://www.atmos.umd.edu/~flaggmd/

Aircraft Measurements

Xinrong Ren & Hao He CI's

Accomplishments 10/1/15 to 3/31/16

A series nine of aircraft flights were performed over Baltimore-Washington and Indianapolis, IN between 2/8/16 and 3/8/16. Data are downloadable from the website. A major achievement of this campaign was the evaluation of a new coordinated flight pattern in which the Cessna flew many profiles while the Duchess flew level transects. Profiles provide better information on the spatial distribution of trace gas concentrations while transects provide better information on winds. The combination of the two should yield superior flux determination. Figures 1 & 2, below, show the flight track and CO_2 from the UMD Cessna research aircraft as it performed coordinated flights with the Purdue Duchess.

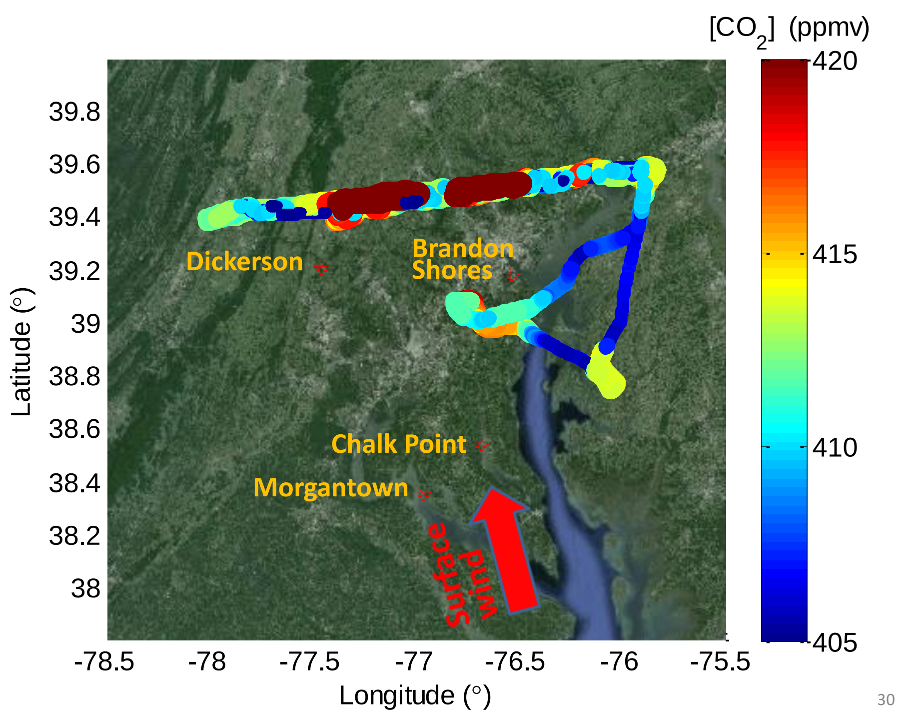

Figure 1. Flight track of UMD Cessna (coordinated with the Purdue Duchess) colored by CO_2 mixing ratio February 19, 2016.

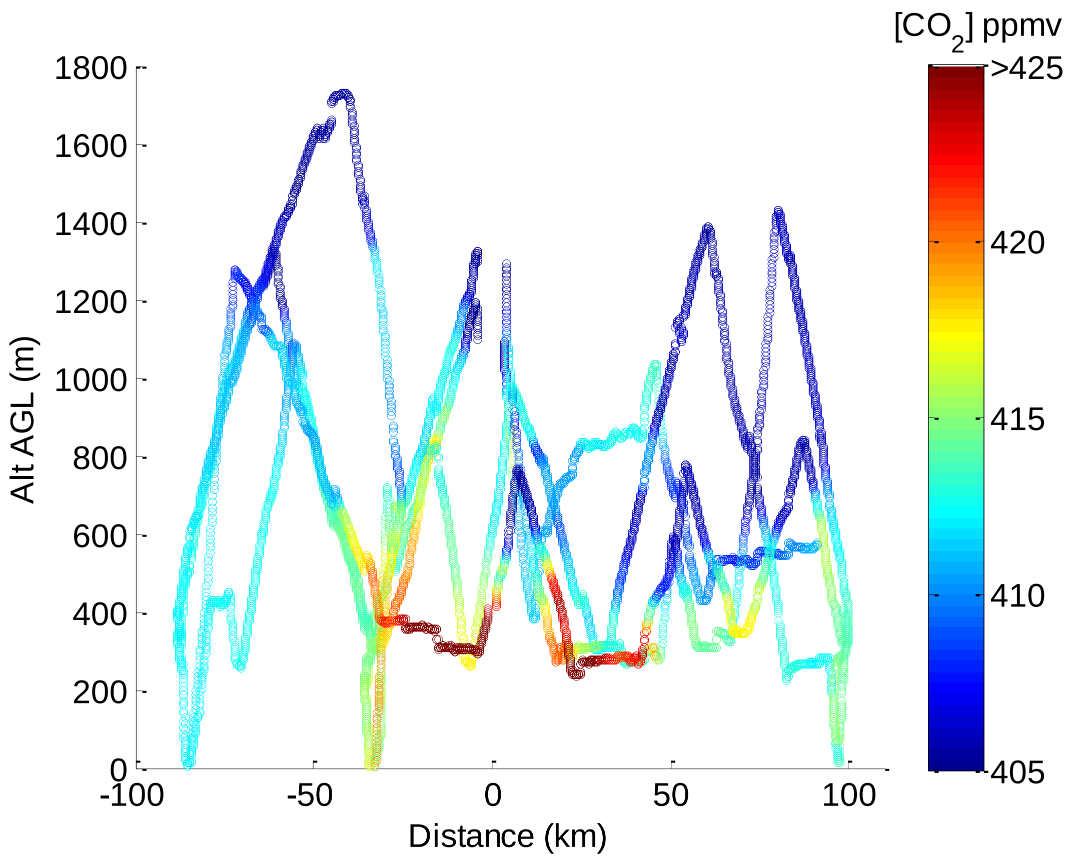

Figure 2. CO_2 concentrations as a function of altitude and position on the downwind leg of RF1. The Cessna focused on spatial coverage of trace gases while the Duchess focused on accurate wind vectors.

Anticipated Publication: "Aircraft measurements of the flux of greenhouse gases from the Baltimore/Washington metropolitan area," D. Ahn, R. J. Salawitch, X. Ren, T. Chai, M. Cohen, H. He, A. Karion, A. Stein, B. Stunder, and R. R. Dickerson, *JGR* to be submitted 2016.

Black Carbon Analysis

Accomplishments 10/1/15 to 3/31/16

Graduate student Courtney Grimes, working with NIST scientists C. Zangmeister continued comparisons of commercial BC analyzers PSAP and Aethalometer to photoacoustic and other state of the science NIST instruments. She successfully defended her Ph.D. Prospectus and has advanced to candidacy. She determined the absorption efficiency for various diameters of BC particles. Future work includes analysis of air filter samples collected in Hebei, China in 2016.

Climatology

K. Vinnikov, CI
P Stratton, GRA

Accomplishments 10/1/2015 - 3/31/2016.

Produced climatologically homogeneous data sets for 2010-2015 for Beltsville, MD, Piney Run, MD and 2012- 2015 for Horn Point, MD composed of half hourly wind vector components U & V at altitudes from 200 m to 4000 m above ground with increment 100 m; see Figure 3 below. Next, selected wind statistics were obtained: means of wind speed (scalar, U-zonal, V-meridional, vectoral); vectoral mean wind direction, standard deviation of wind speed, wind roses. These Climatic Statistics depend on altitude, time of a day (hour), and season (month).

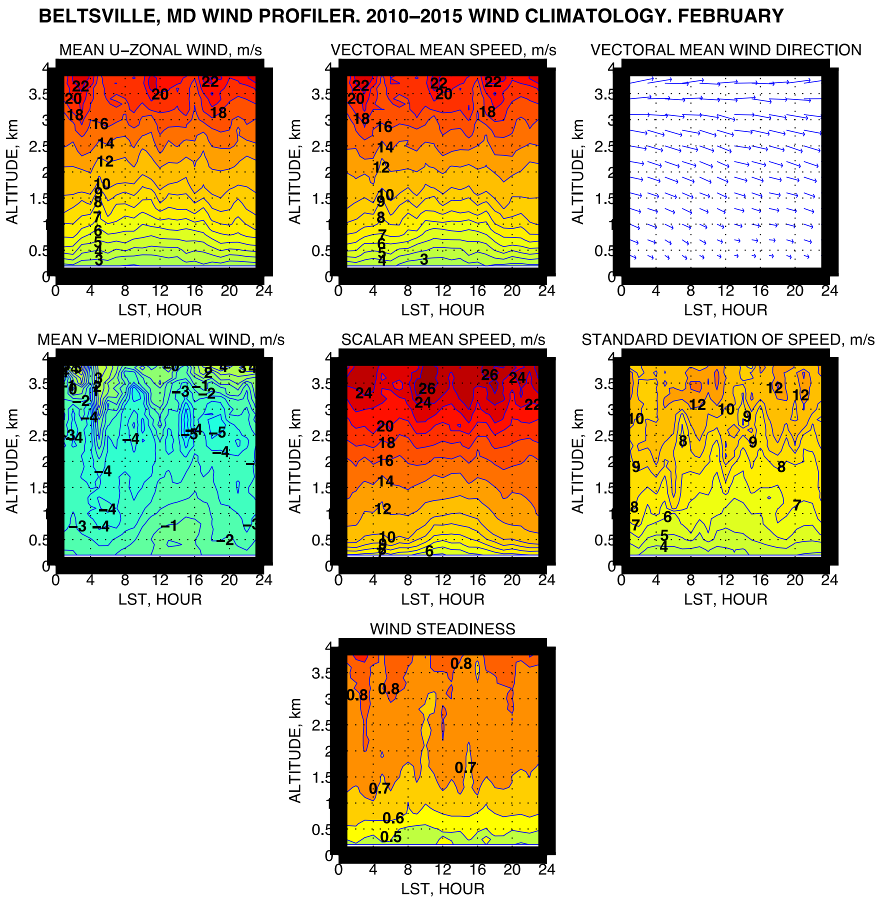

Figure 3. Example of climatological analysis of winds from the Beltsville, MD radar profiler. Mean winds are NW with a local minimum near the surface in summer. Average scalar wind speeds are above the optimal for flux determination (~5 m/s).

Work Plan

4/1/2016 – 12/31/2016. The previously obtained MD boundary layer wind data and their climatic analysis will be applied for planning and optimization of schedule of research airplane observational flights to obtain more accurate and minimally biased estimates of the greenhouse gases fluxes over Washington-Baltimore corridor. Will help evaluate the wind profilers with rawinsondes as described above.

Planned paper: Vinnikov, K. Y., R. R. Dickerson, X. Ren, and J. Dreessen, (2016), "Maryland wind climatology from wind profilers evaluation and applications" in preparation.

Data Assimilation & High Resolution (Mesoscale) WRF Modeling

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

Accomplishments 10/1/15 to 3/31/2016

During this period, we continued to improve the WRF-LETKF data assimilation system. To further improve the meteorological field estimates, our first task focused on the development of the multi-resolution LETKF data assimilation system. This system takes advantage of the nested feature of the WRF model, and is built with the flexibility to easily adjust the resolution changes as the modeling and availability of the computational resources improve. The initial implementation for the Indianapolis area used the dual-resolution at the 13.5 and 4.5 km horizontal-resolution domains and carefully evaluated against the independent and dependent observations. The system has a comprehensive uncertainty assessment capability based on the ensemble spread for each resolution. Our second task focused on the extension of the system capacity to not only estimate but also make a 72-h high resolution forecast. The forecast starting from the WRF-LETKF high-resolution analysis is shown to outperform any other 72-h forecast in every aspect. Our third task is a case study of a moderate air pollution event occurring on 1 October 2014; this was highly correlated to a northerly low-level jet. The WRF-LETKF data assimilation and forecast system captured well the intensity and location of the northerly, low-level jet over Indianapolis, thus providing some good insight into the event.

Papers are currently in preparation:

1. Shou Y., D.-L. Zhang, K. Ide and R.R. Dickerson. 2016a: Numerical case study of a northerly low-level jet during the INFLUX field experiment (in preparation)
2. Shou Y., D.-L. Zhang, K. Ide and R.R. Dickerson. 2016b: Linkage between a northerly low-level jet and air pollution over Indiana (in preparation).

C-Cycle Modeling, LETKF, & Low-Cost Sensors

Ning Zeng and E. Kalnay, CIs
Ariel Stein, NOAA Collaborator
Cory Martin, GRA

Accomplishments 10/1/15 to 3/31/16

Low-Cost Sensors: We continued our calibration and evaluation work. Approximately 20 K30 sensors were placed in a rooftop chamber, co-located with a laser cavity-ringdown spectroscopy (CRDS) CO_2 analyzer Los Gatos FGGE. Environmental variables of atmospheric pressure, temperature and humidity were measured simultaneously using the Bosch BMP, later BME sensor. We maintained field sensor packages at Trinity Washington U, Howard U and private houses. Temperature and humidity are measured simultaneously. Data were collected throughout the period 10/1/15 to 3/31/16. After noise reduction, calibration and environmental correction for atmospheric pressure, temperature and humidity, the root mean square (RMS) difference between K30 and a Los Gatos FGGE was typically below 5 ppm. The sensors appear to be subject to RF interference (non-Gaussian noise) and tests for shielding are underway. We also successfully tested a K30-pi package on the Cessna research aircraft and on a balloon to the height of ~30 km. Analysis is ongoing. A paper is in preparation.

LETKF:

In collaboration with NOAA's Air Resources Laboratory, ARL, we have begun to generate ensembles of WRF runs to act as the basis of back trajectories using ARL's HYSPLIT code. The Data Assimilation code was obtained from YiXuan Shou and applied to the NOAA model. The work will be carried out in collaboration with Fong (Fantine) Ngan of ARL. The back trajectories will be used to, for example, evaluate plumes of GHG's observed from the research aircraft.

Papers pending:

Martin, C. R., N. Zeng, X. Ren, R. R. Dickerson, K. J. Weber, B. N., Turpie. 2016, Performance and Environmental Correction of a Low-Cost NDIR CO_2 Sensor. In preparation for *Atmospheric Measurement Techniques*.

Remote Sensing and Analysis of Aircraft Observations

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

Accomplishments 10/1/15 to 3/31/16

We gave a presentation at the 2016 Orbiting Carbon Observatory-2 Science Team meeting in Pasadena, CA entitled Validation of OCO-2 using FLAGG-MD. This 17-slide talk was based on analysis of data collected during winter 2015. The most important figure of interest to the OCO-2 team was a comparison of the probability density of the column average, dry air mole fraction of CO_2 (XCO_2) shown below:

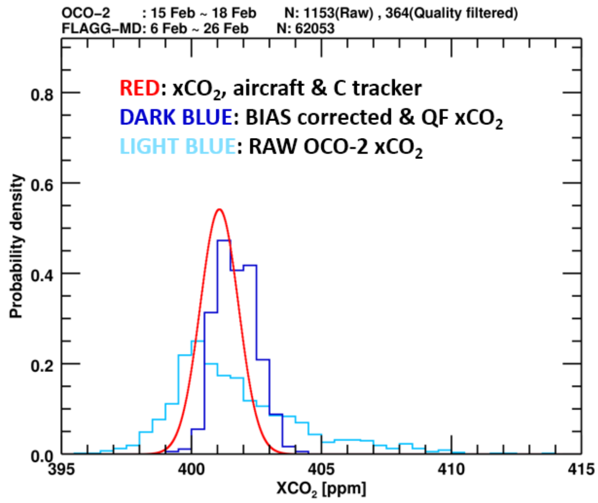

Figure 4. Probability distribution functions of the dry air mixing ratio of CO_2 from the aircraft augmented with C tracker, and OCO-2 with and without bias correction.

The red line shows the probability density function (PDF) of XCO_2 found using FLAGG-MD CO_2 over the altitude range sampled, combined with CO_2 from carbon tracker for higher altitudes. The two blue curves show PDFs of xCO_2 from OCO-2, from the raw retrievals (light) and from retrievals that have been correction for biases using the ground based TCCON (Total Carbon Column Observing Network) (dark). All of the samples were obtained over Maryland, for the same times during the winter 2015 flights.
The agreement between the red and dark blue curves is spectacular!

Work Plan

We intend to repeat the analysis for the 2016 flights.
A figure like the one above will appear in an OCO-2 validation paper.