FLAGG-MD

Fluxes of Greenhouse Gases in Maryland

Greenhouse and Other Trace Gases from the Baltimore-Washington Area: Results from the Winter 2015 Aircraft Observations

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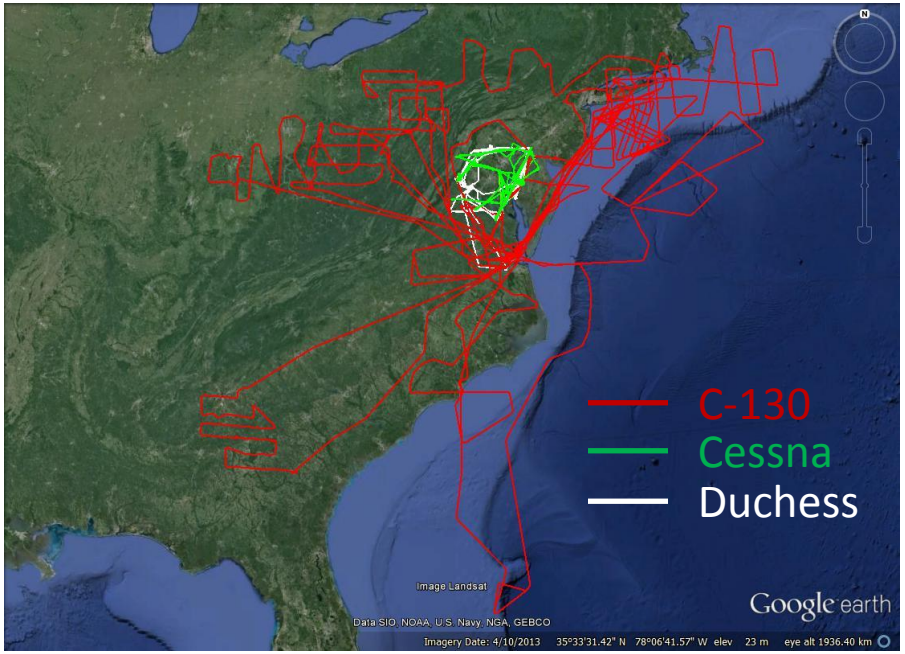
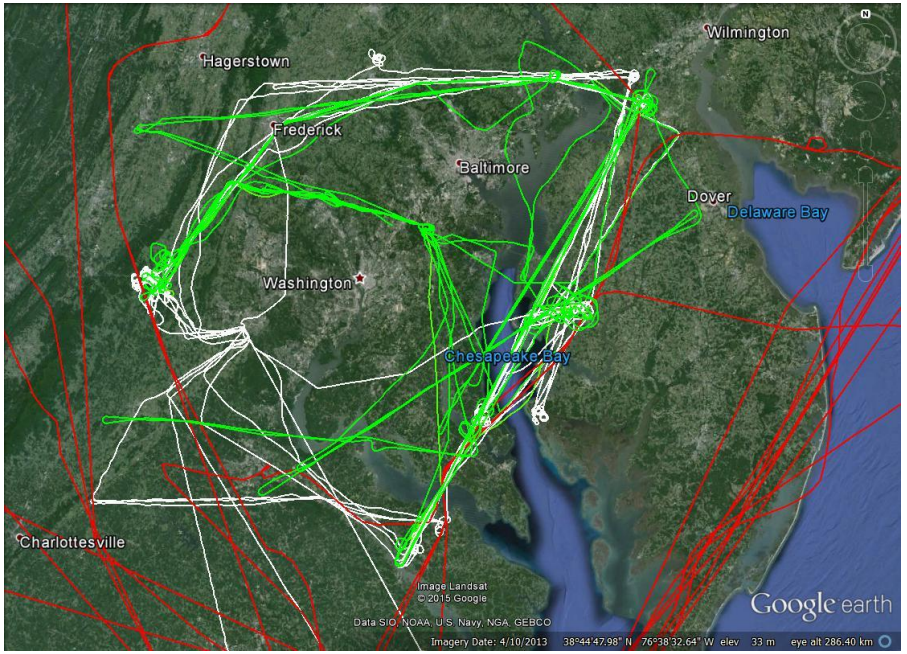
Motivation

- Urban greenhouse gas (GHG) emissions contribute to the majority (~70%) of the anthropogenic GHG emissions.
- Quantification of urban greenhouse gas (GHG) emissions is important for establishing scientifically sound and cost-effective policies for mitigating GHGs.
- Discrepancies between observations and model simulations of GHGs suggests uncharacterized sources in urban environments.

Flight Area



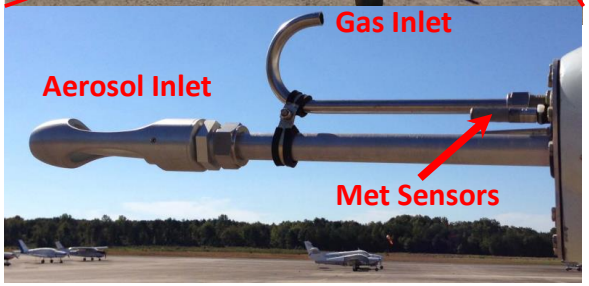


- ***Where:*** the Baltimore-Washington Metropolitan Area
- ***When:*** UMD Cessna: 2/6 – 2/26, 2015
  Purdue Duchess: 2/16-3/12, 2015
- ***What:*** aircraft observations of GHGs, other trace gas, and aerosol scattering & absorption.

FLAGG-MD - Fluxes of Greenhouse Gas Emissions in Maryland

Mass Balance Experiment with Two Aircraft

UMD Cessna 402B Research Aircraft



New Picarro
$CO_2/CH_4/CO/H_2O$ analyzer

GPS Position (Lat, Long, Altitude)

Met (T, RH, P, wind speed/direction)

Trace gases:

- O_3: UV Absorption, modified TECO
- SO_2: Pulsed Fluorescence, modified TECO
- $CH_4/CO_2/CO/H_2O$: Cavity Ringdown, Picarro
- NO_2: Cavity Ring Down, Los Gatos
- NO: Chemiluminescence, modified TECO

Aerosol Optical Properties:

- Scattering: b_{scat} (@450, 550, 700 nm), Nephelometer
- Absorption: b_{ap} (565 nm), PSAP
- Black Carbon: Aethalometer

Data Acquisition: 1 sec

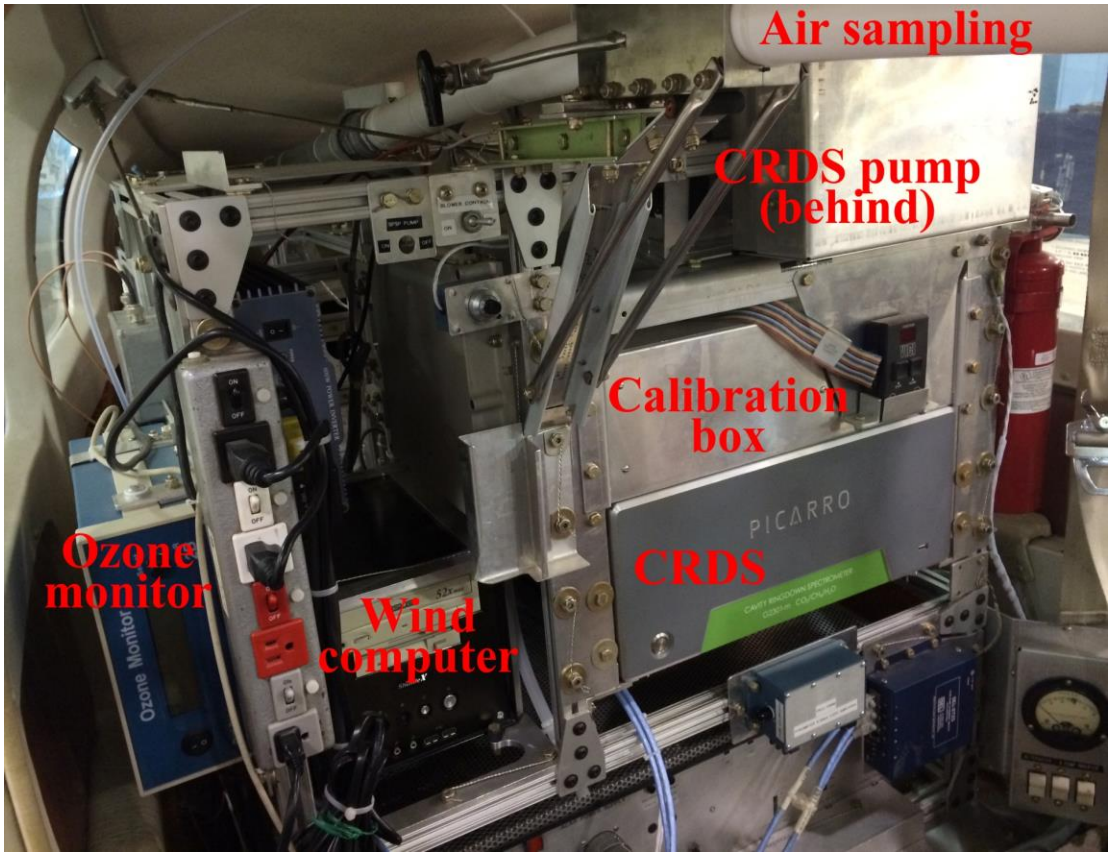
Purdue ALAR (Airborne Laboratory for Atmospheric Research)

Beechcraft Duchess
Light twin engine

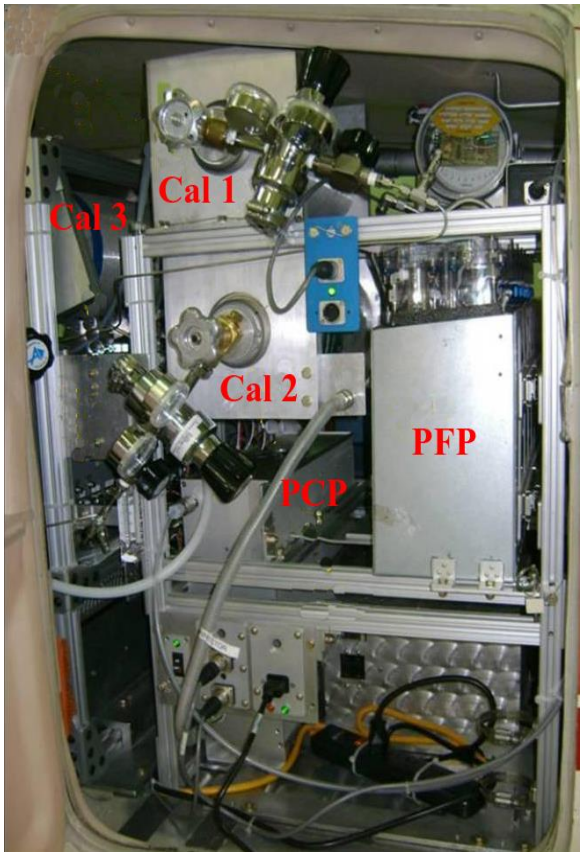
BAT: Best Air Turbulence probe
up to 50 Hz turbulence wind

Purdue Duchess Research Aircraft

Front View



Back View



GPS Position (Lat, Long, Altitude)

Met (T, RH, P, 3-D wind by BAT)

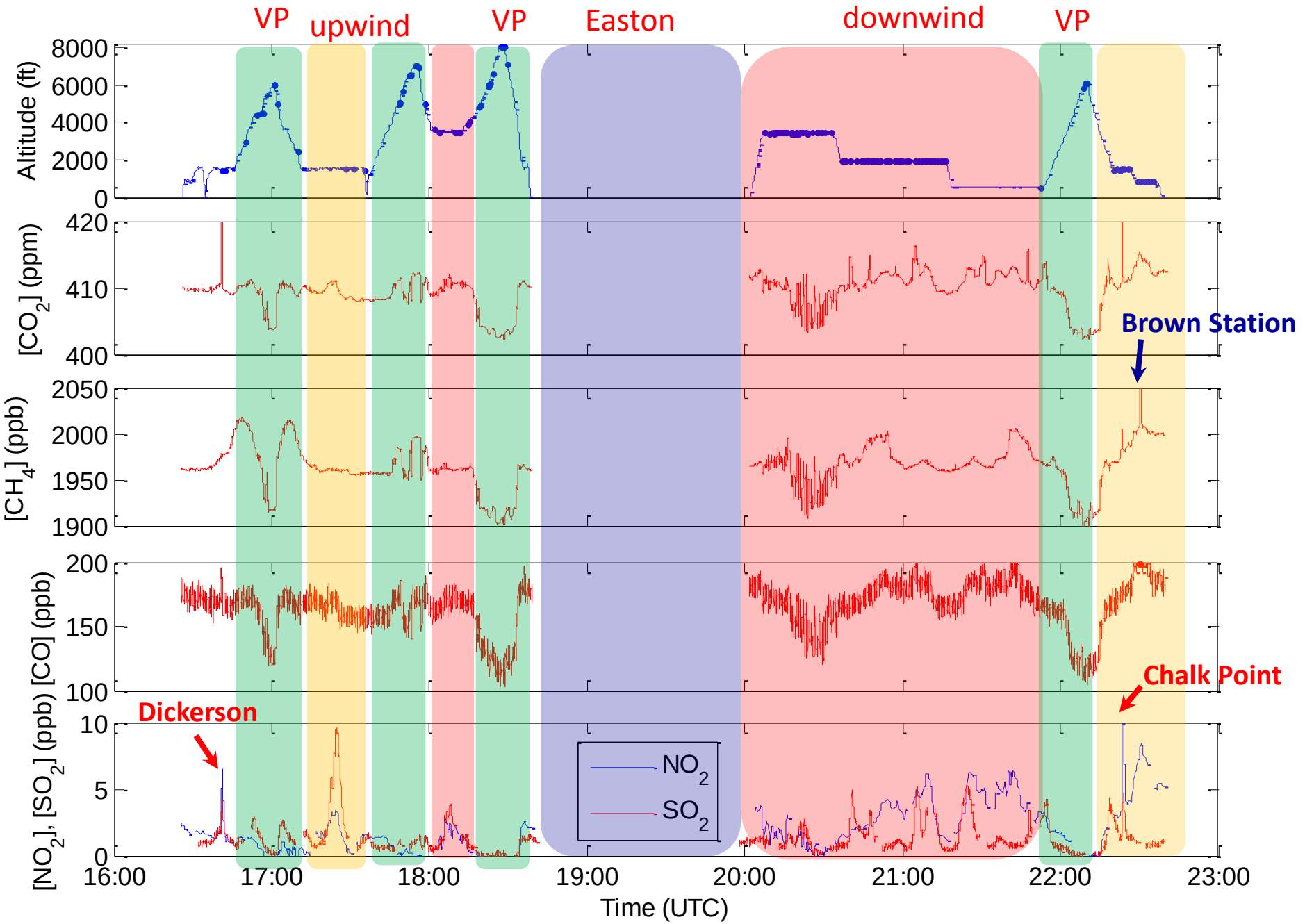
Trace gases:

O_3: UV Absorption, 2B Technology

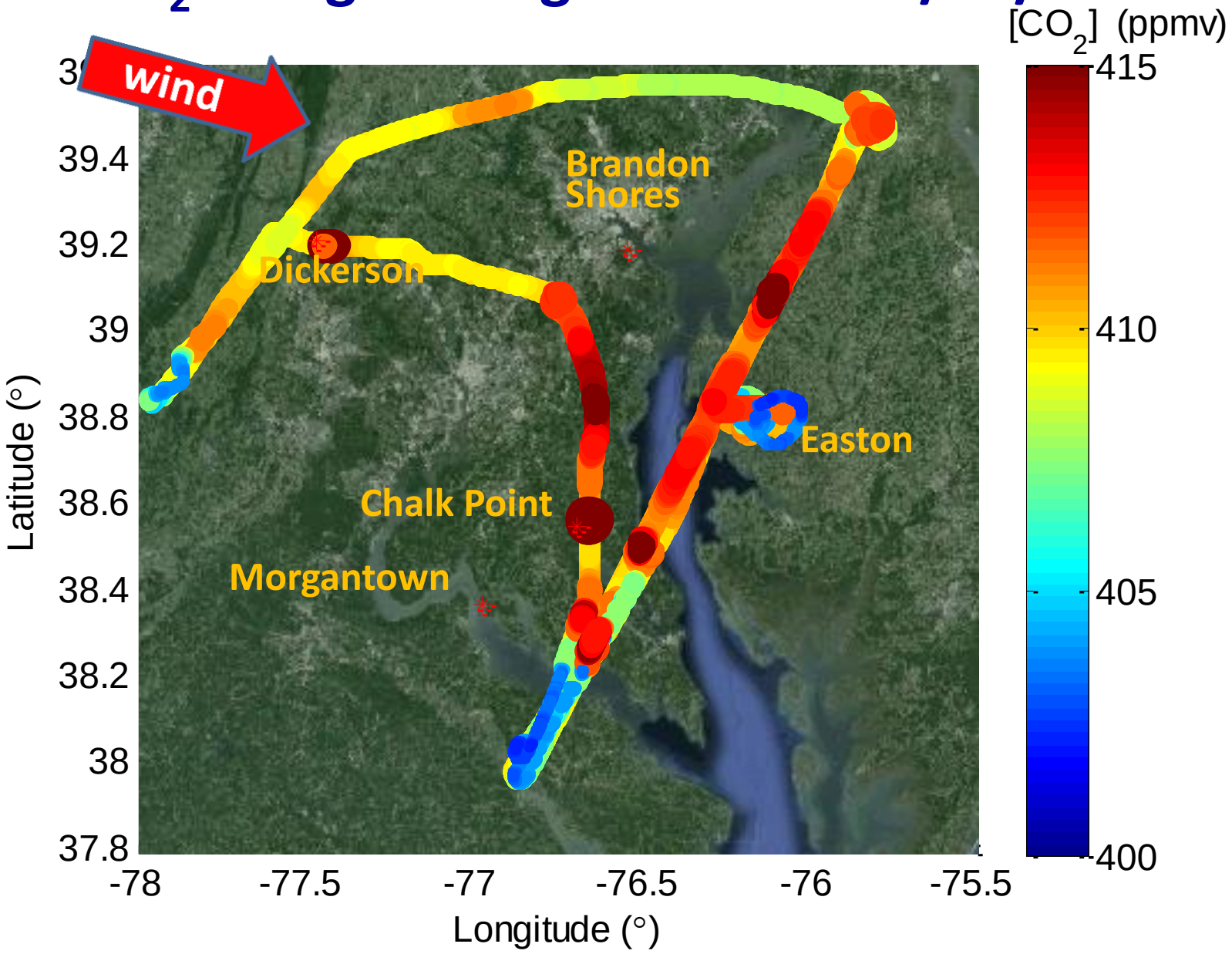
CH_4/CO_2: Cavity Ring Down, Picarro

NO_2: Cavity Ring Down, Los Gatos

Time Series of CO_2, CH_4, CO, SO_2 and NO_2 on 2/20/15

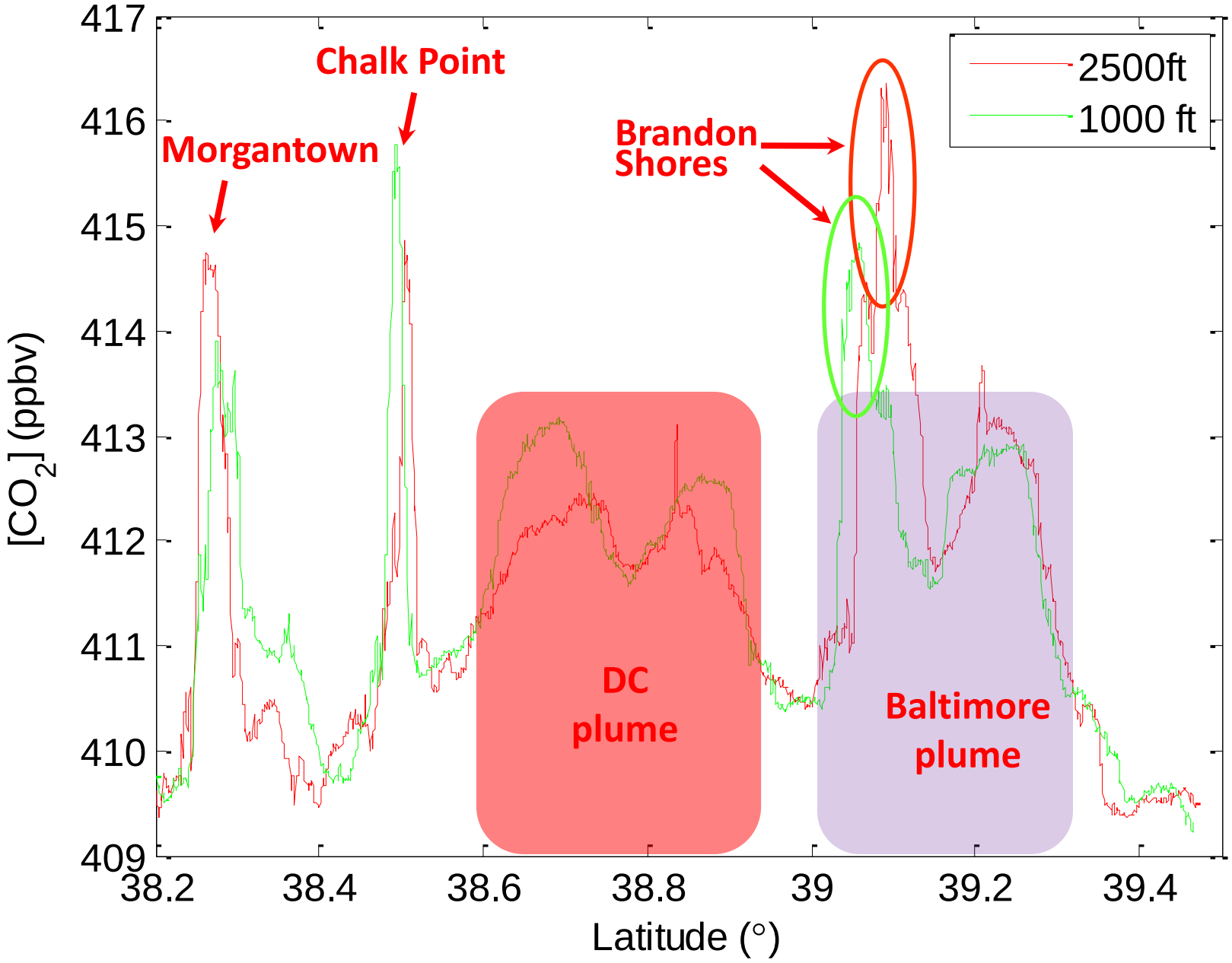


CO_2 along the Flight Track on 2/20/15

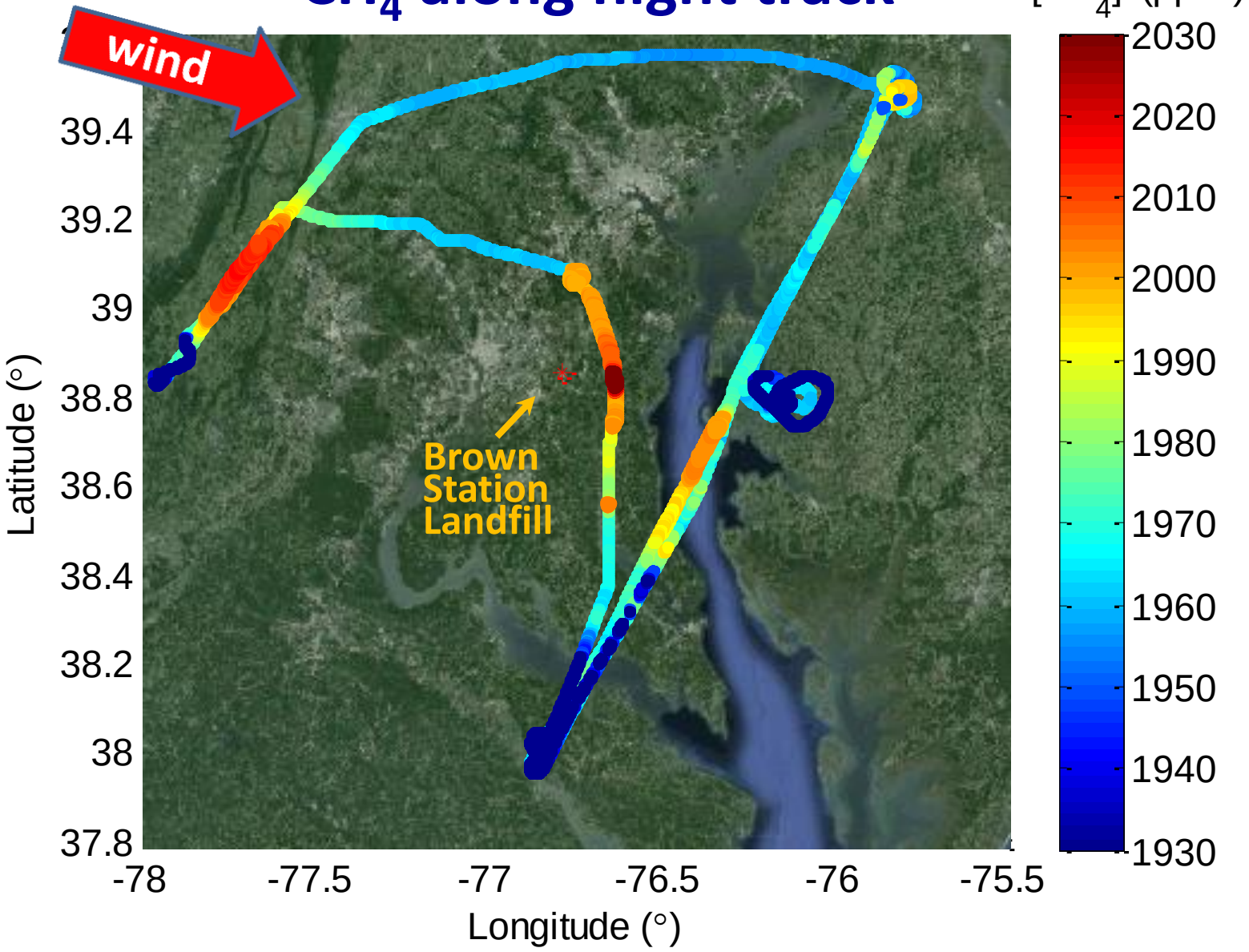


Power plant plumes clearly observed along the downwind transects.

CO_2 on 2 downwind transects along the latitude

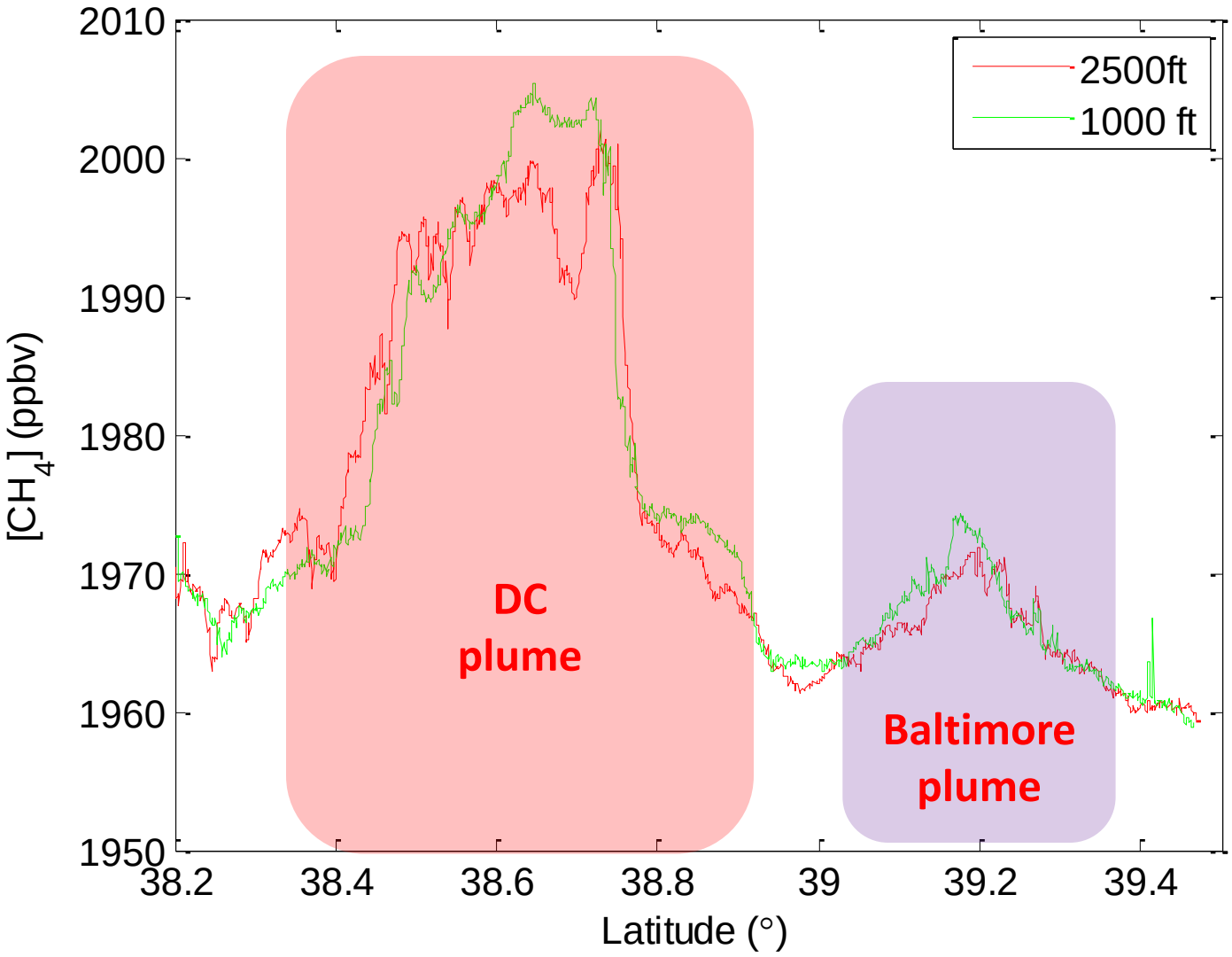


CH_4 along flight track



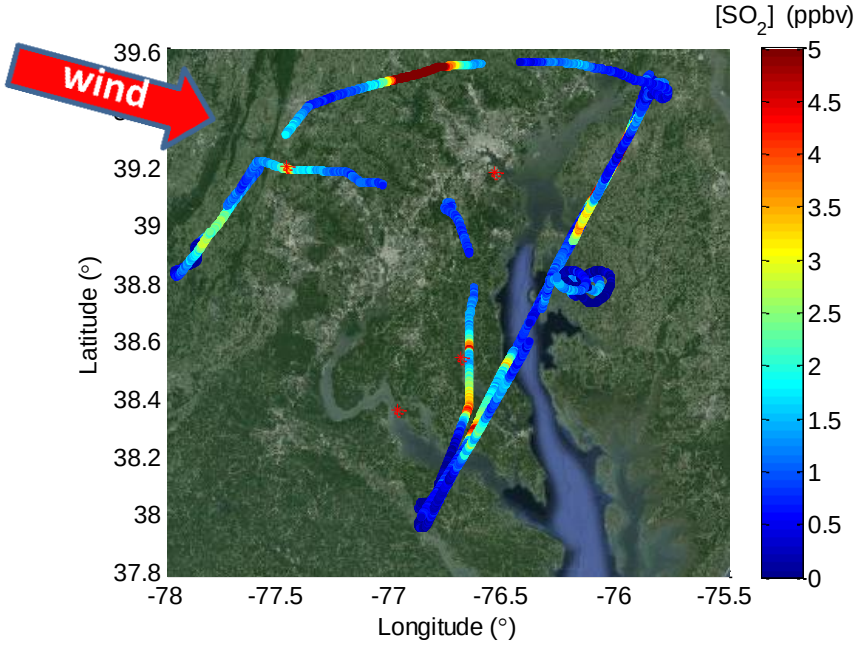
- **Significant CH4 emissions from Brown Station Landfill.**
- **High CH_4 levels aloft along SW of the upwind leg: CH_4 emissions from fracking?**

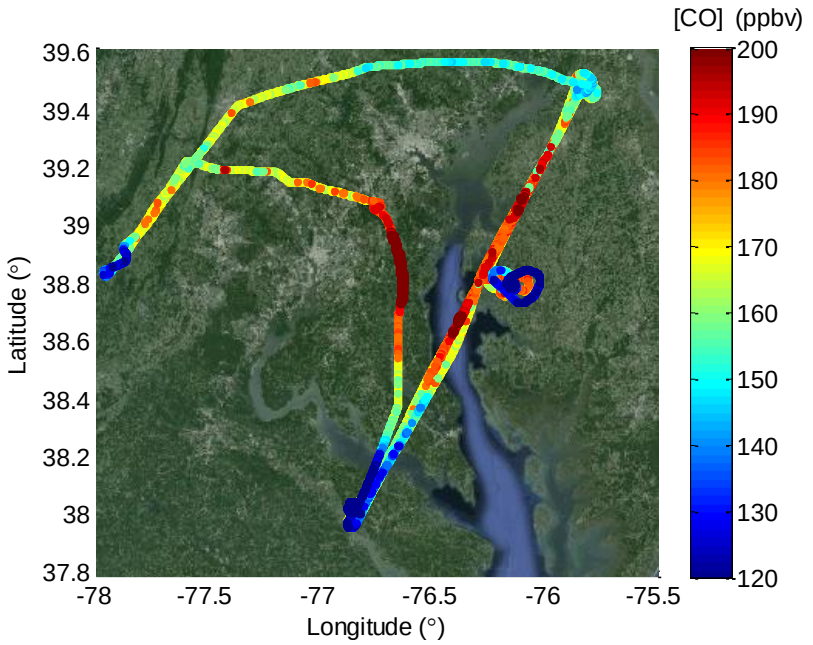
CH_4 on 2 downwind transects along the latitude



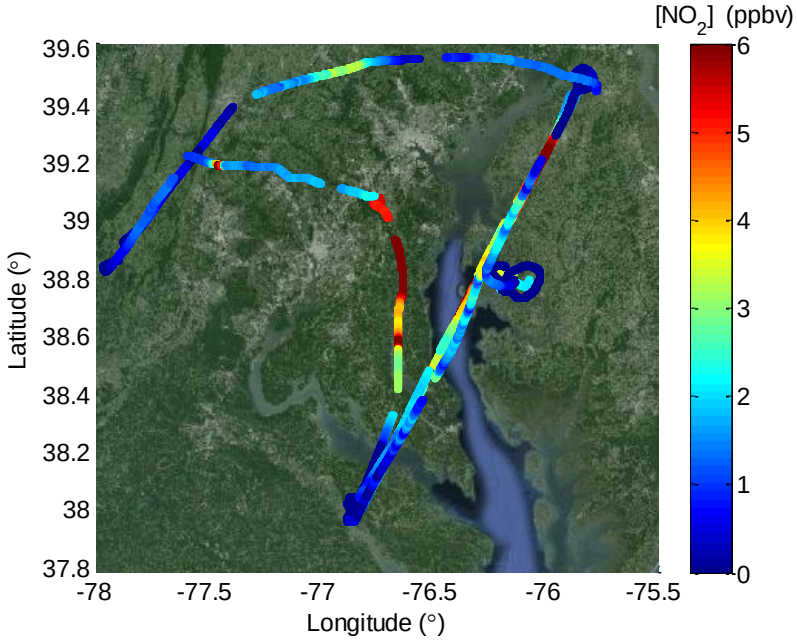
Much larger CH_4 enhancement in the DC plume than in the Baltimore plume.

SO_2, CO, & NO_2 along the Flight Track

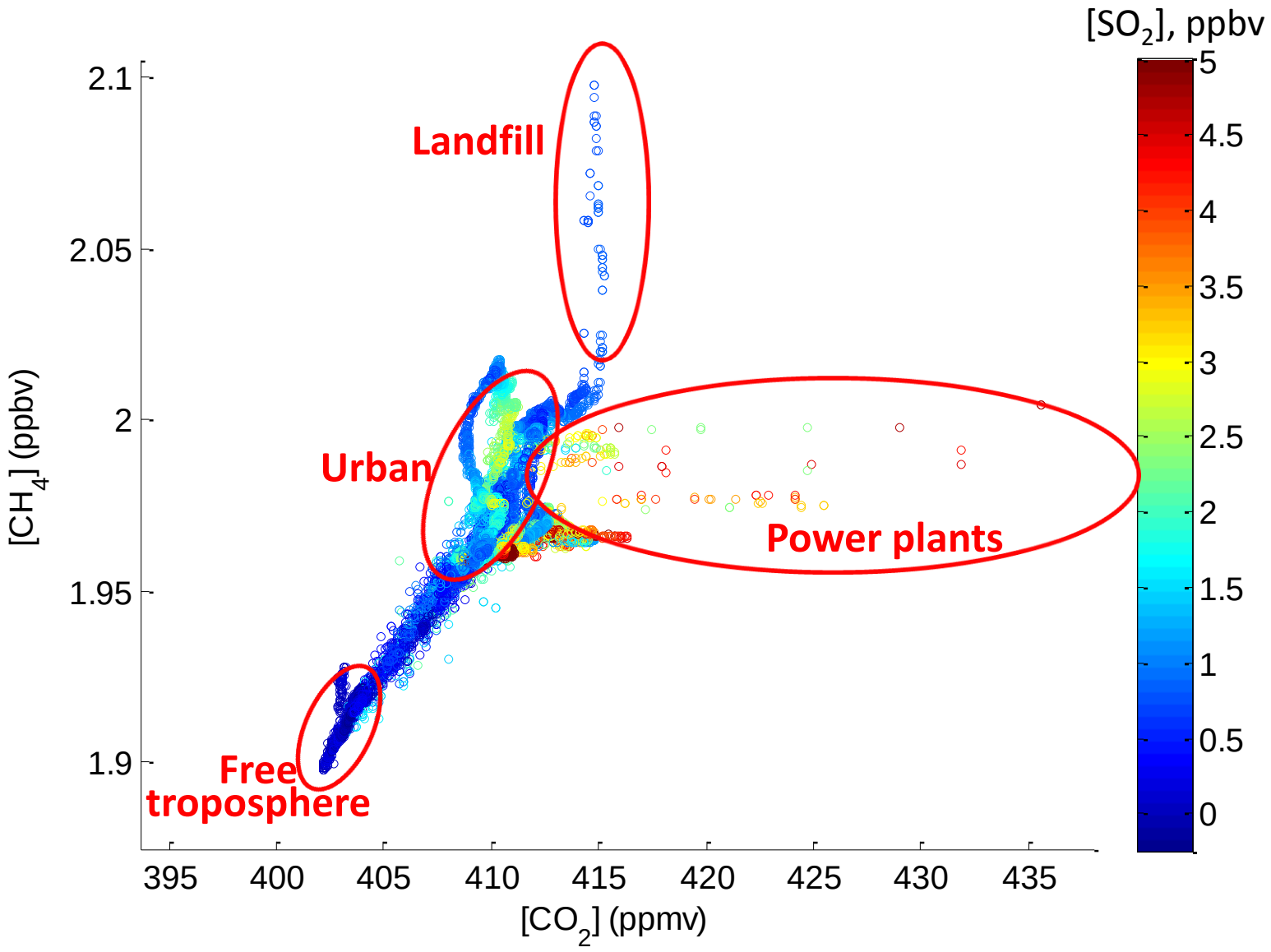




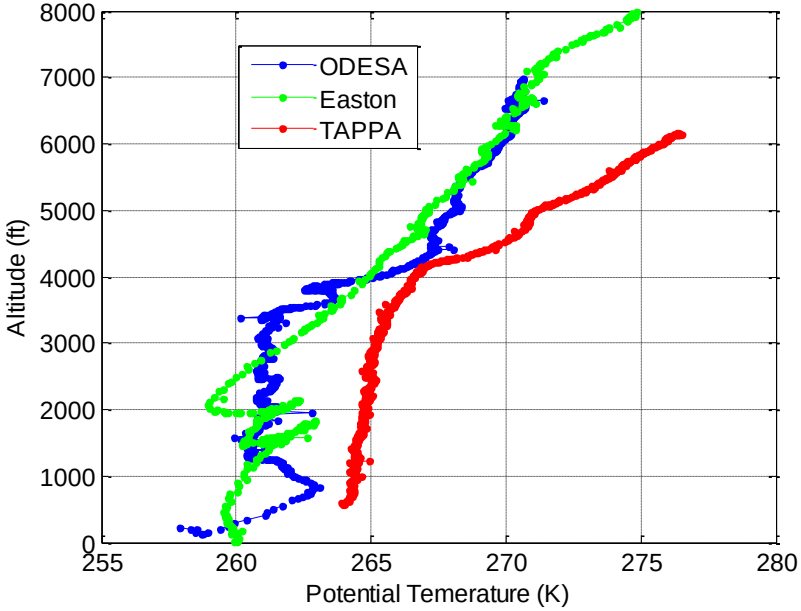
- Elevated SO_2, CO, NO_2 levels were observed along the downwind transects.
- Elevated SO_2 and NO_2 levels along the northern leg are associated with the emissions from the Lehigh Cement Company to the northwest upwind.

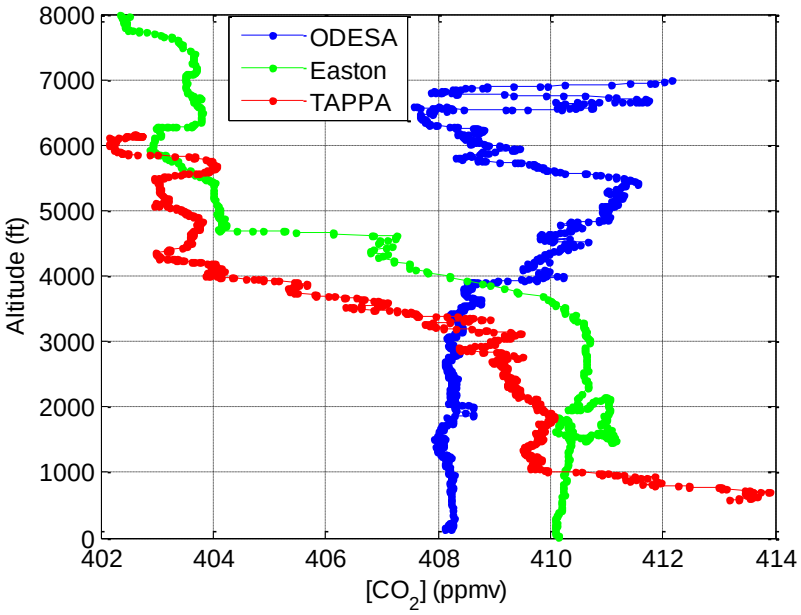


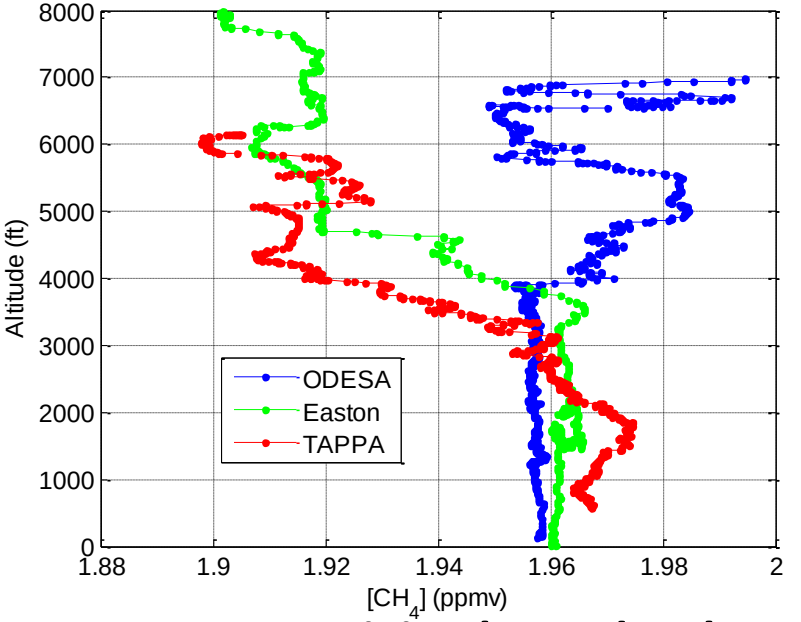
CH_4, CO_2 and SO_2 in Various Plumes

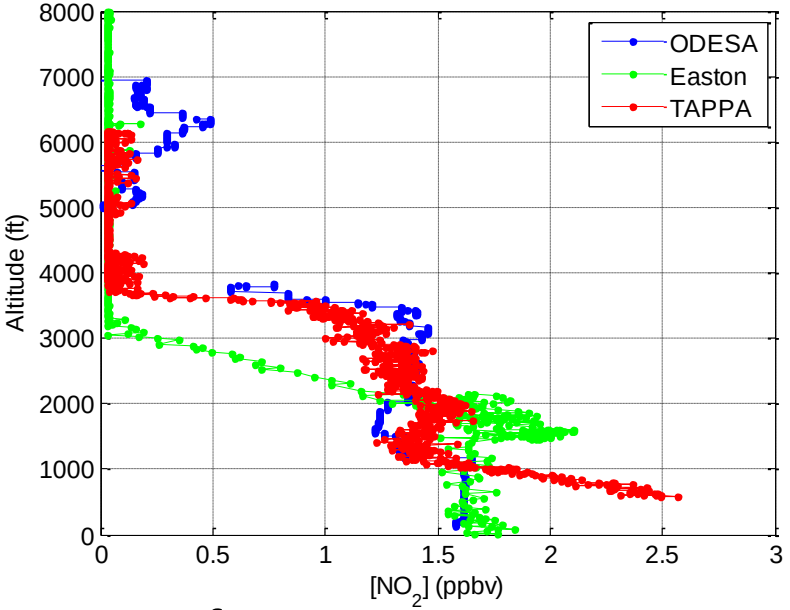


Downwind Vertical Profiles at 3 Locations









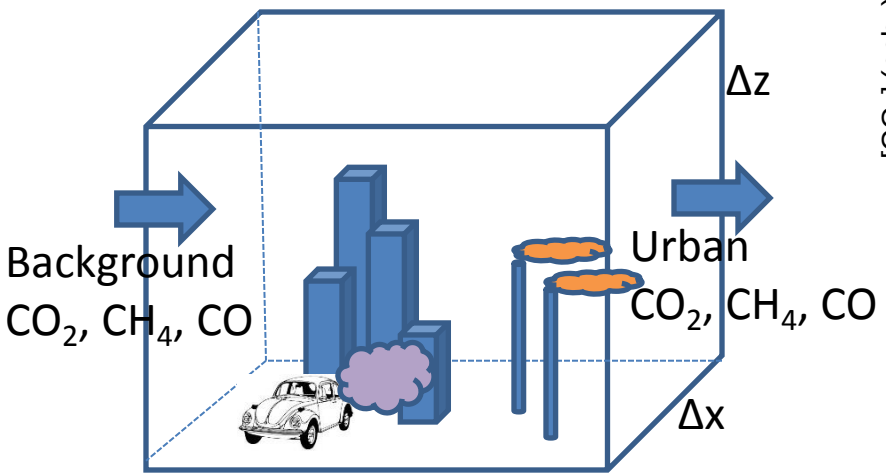
Mixing layer depth ~3500 - 4000 ft

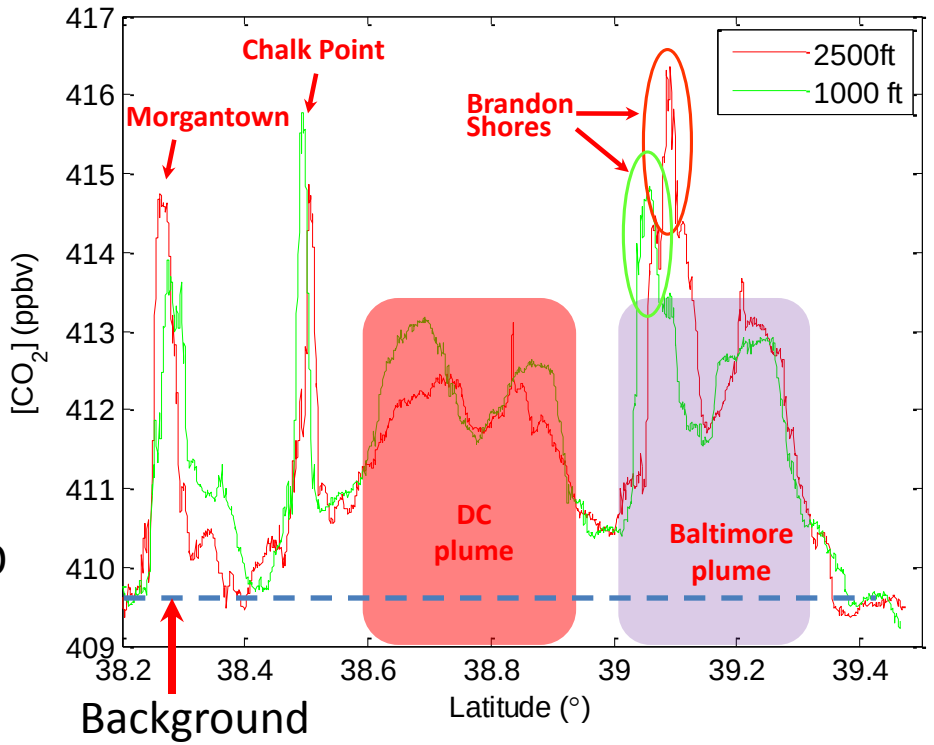
Estimation of CO_2, CH_4 and CO Fluxes

Mass Balance Experiment (MBE) approach:

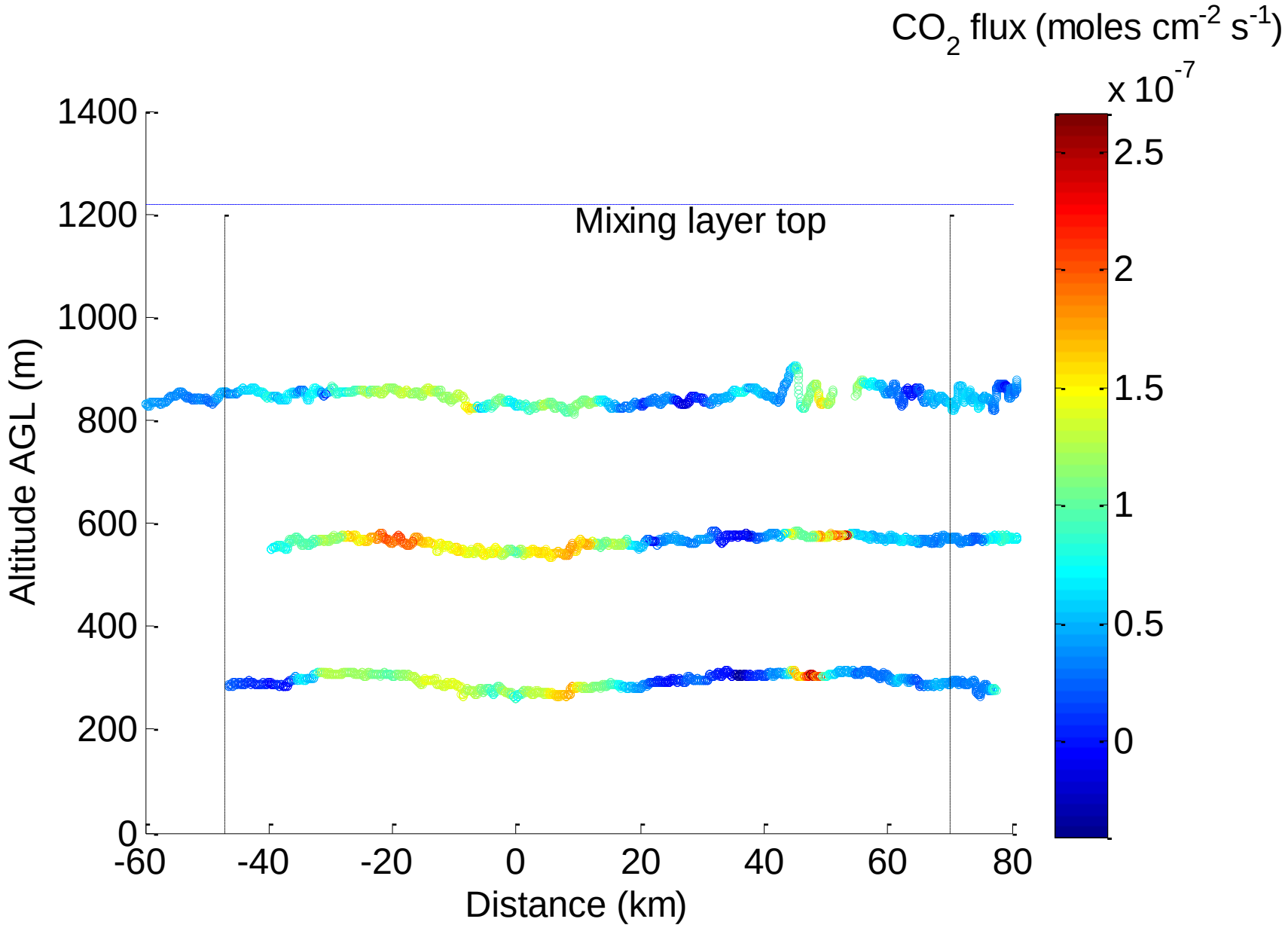
$$\text{Flux} = \int_0^{z_i} \int_{-x}^{+x} ([C] - [C]_b) \times U_\perp \, dx dz$$

E. R. : emission rate (flux)
[C] : concentrations (downwind)
$[C]_b$: concentration in background
$U_\perp$: perpendicular wind speed

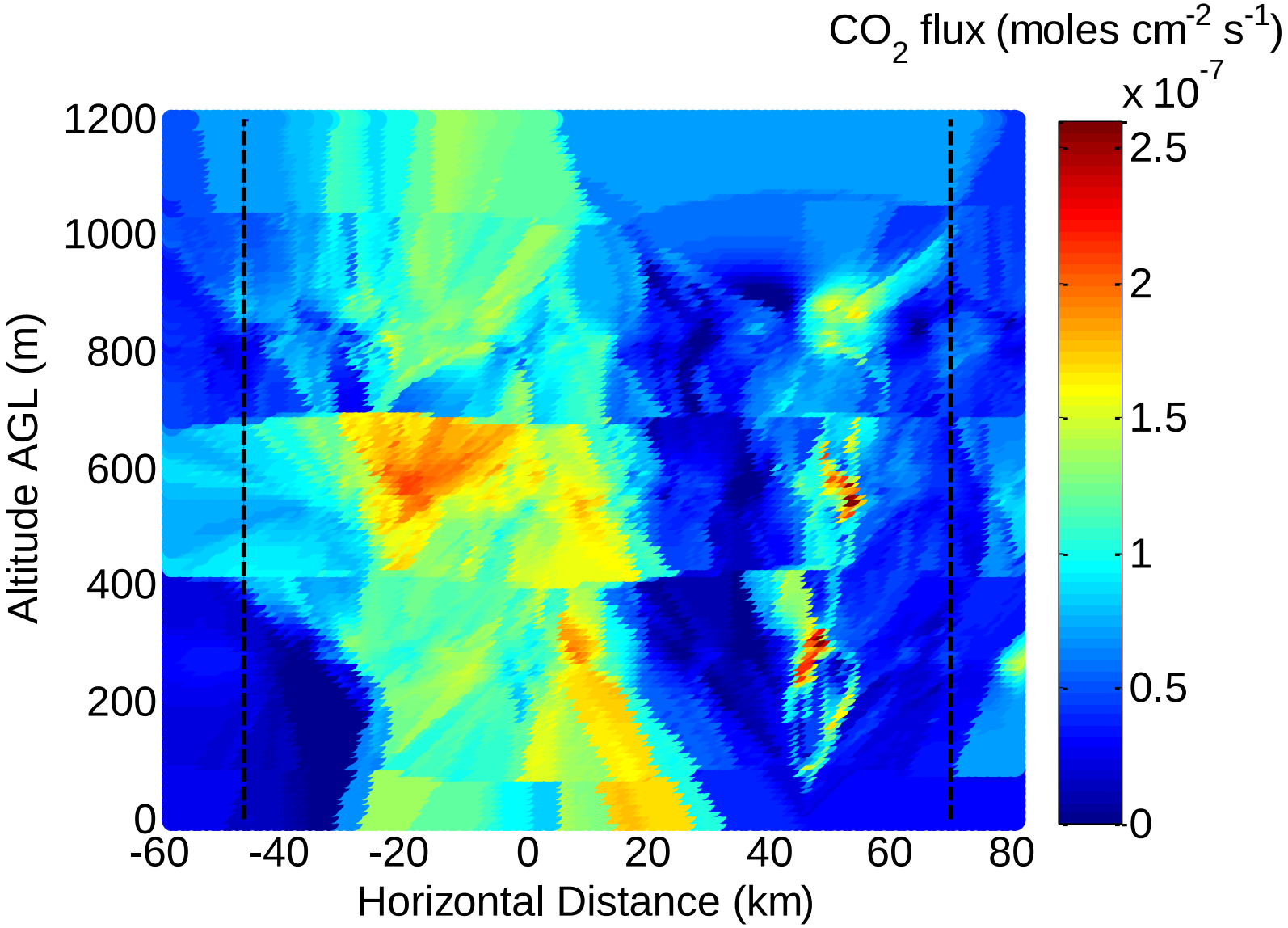




Fluxes of CO_2 along the downwind transects



Kriged Fluxes of CO_2 along the Downwind Curtain



Emissions of CO_2, CH_4 and CO from Baltimore-DC

Flight Date	Flux(CO_2) (moles s^{-1})		Flux(CH_4) (moles s^{-1})		Flux(CO) (moles s^{-1})	
	Transect mean	Kriging mean	Transect mean	Kriging mean	Transect mean	Kriging mean
2/13/15	84,000	80,000	331	395	315	429
2/19/15	122,000	110,000	1054	1202	466	490
2/20/15	102,000	116,000	558	586	697	809
2/23/15	139,000	144,000	987	1015	226	262
2/24/15	130,000	106,000	529	480	749	646
2/25/15	104,000	109,000	557	515	562	572
Mean	114,000 ±20,000	110,000 ±20,000	669±286	699±328	502±207	535±188

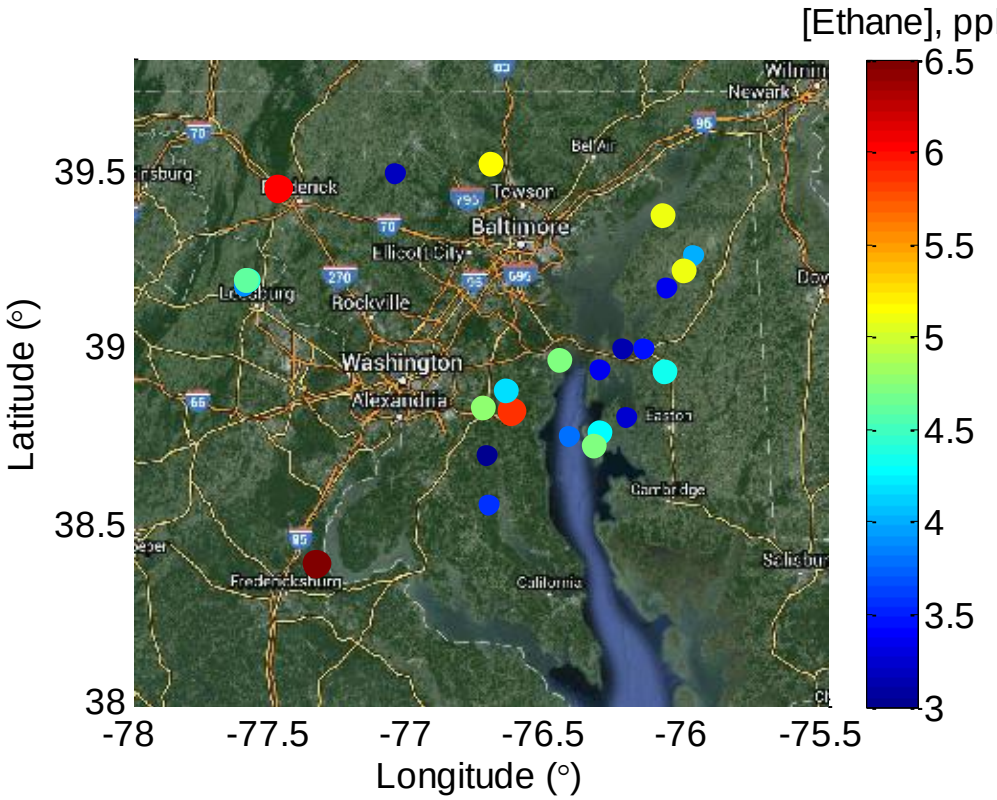
CO_2: ~150 million tons/yr

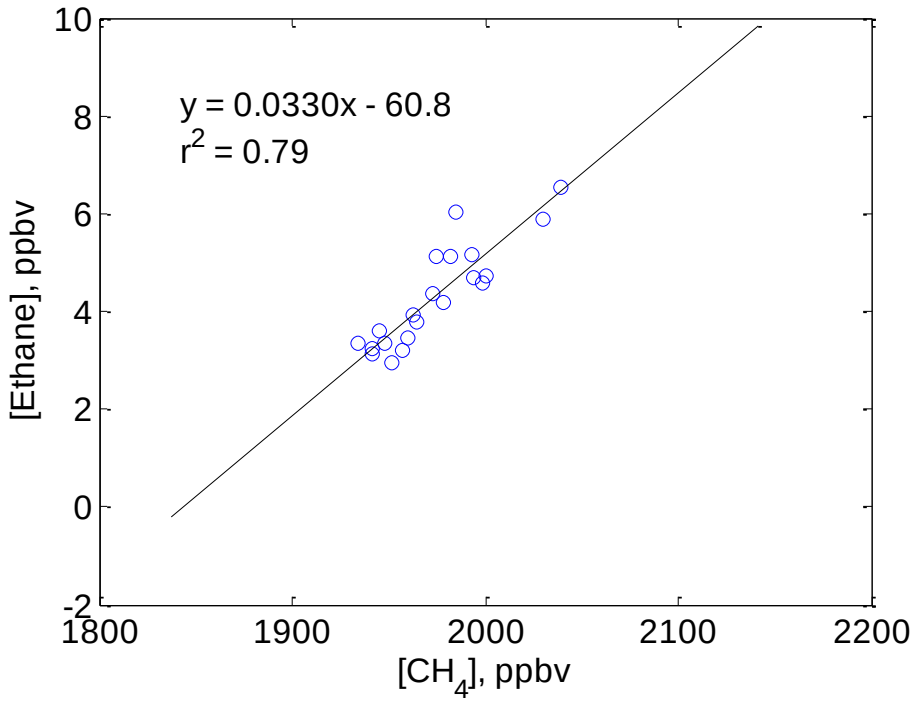
Note: (1) Estimated mean CH_4 emission from Brown Station: 73 ± 19 moles s^{-1}

(2) The population in the Balt–DC area is close to 10 million.

(3) In 2011, CO_2 emission per capita in MD is ~11 tons/yr.

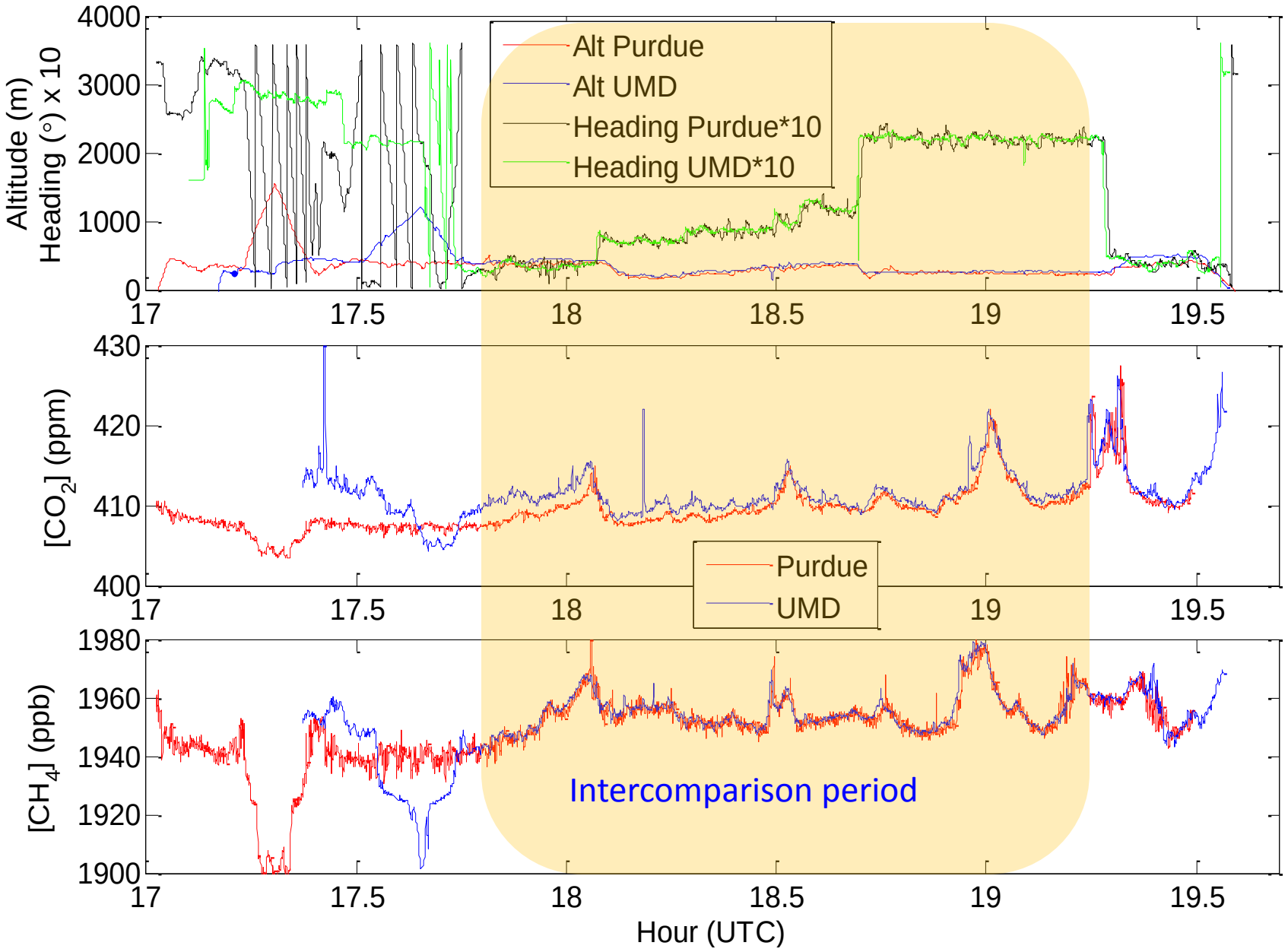
VOC Canister Sample of Ethane



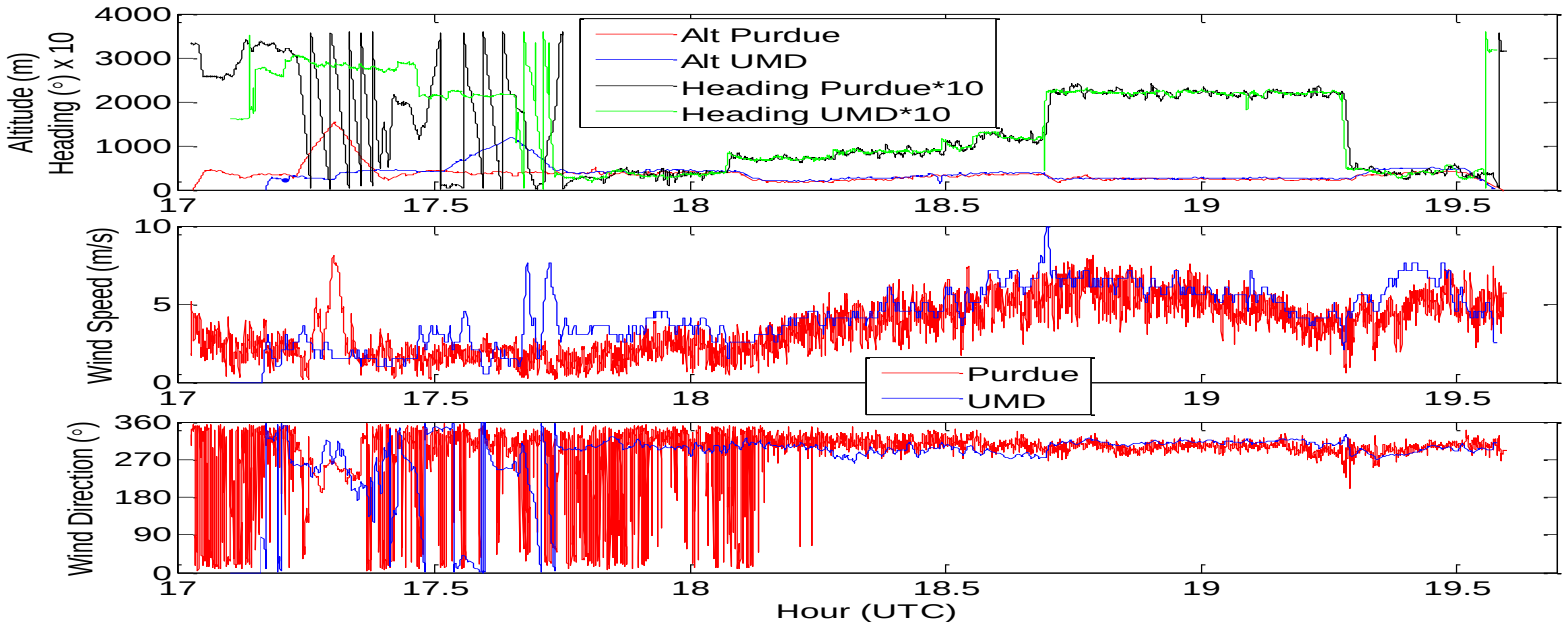


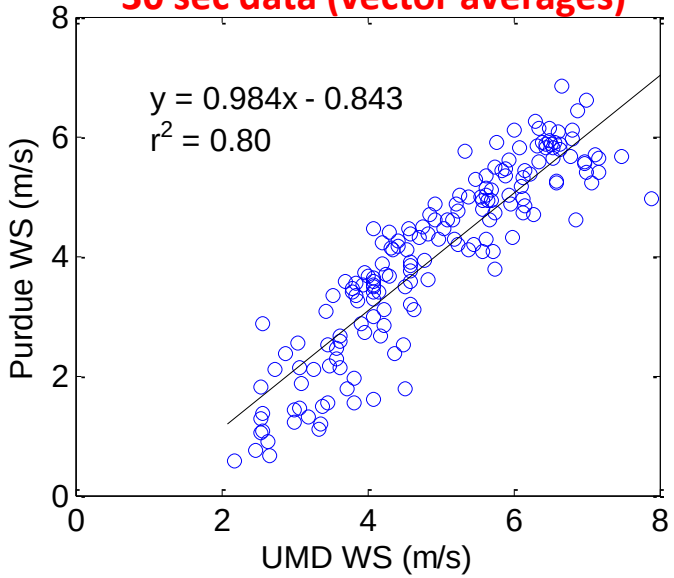
- Ethane versus methane: the ethane-to-methane ratio (slope) could potentially be used for identification and quantification of methane sources.
- Limited canister samples show an ethane-to-methane ratio (i.e., slope) of 3.3%.

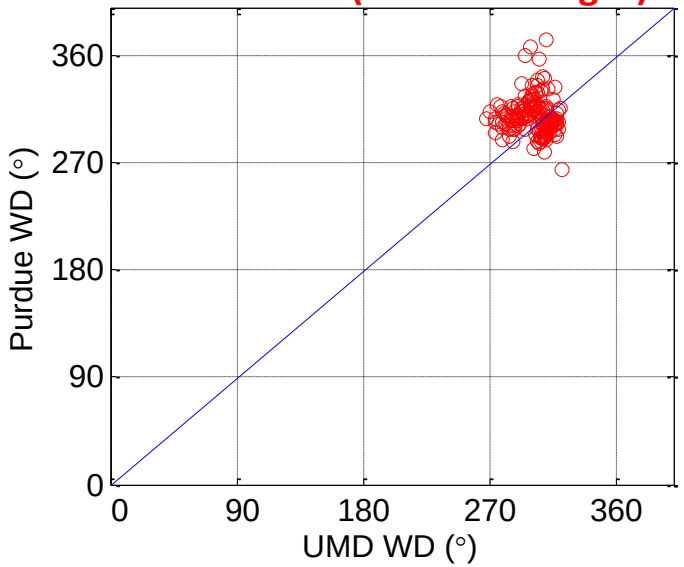
Cessna & Duchess Intercomparison



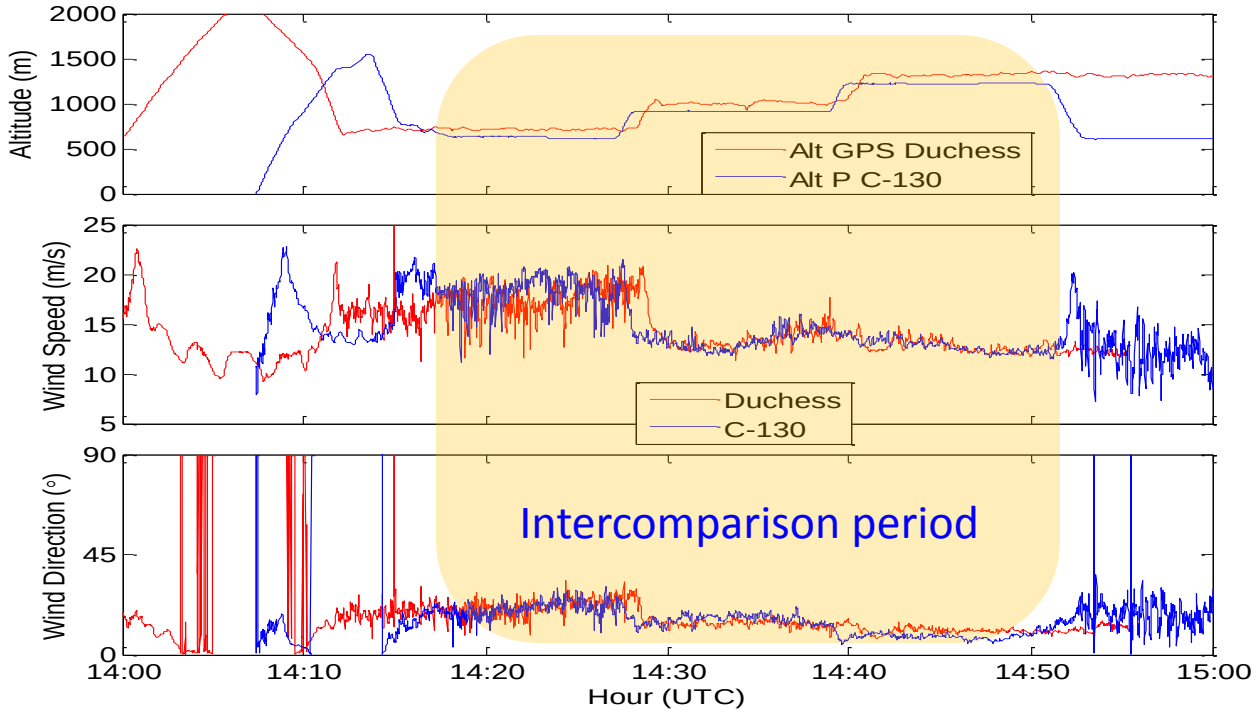
Duchess & Cessna Wind Intercomparison

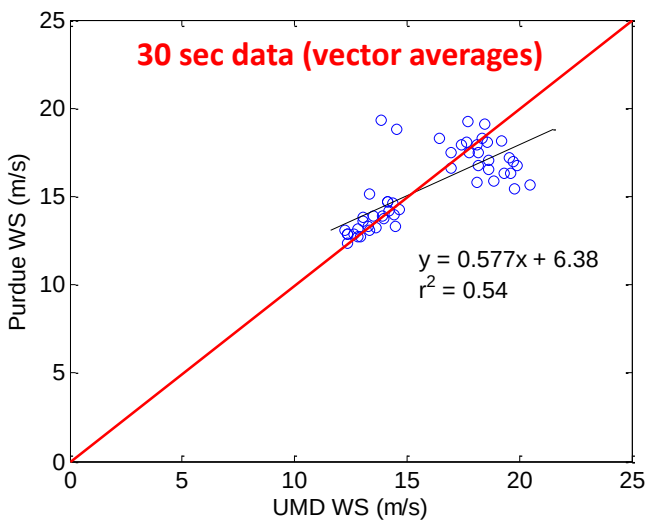


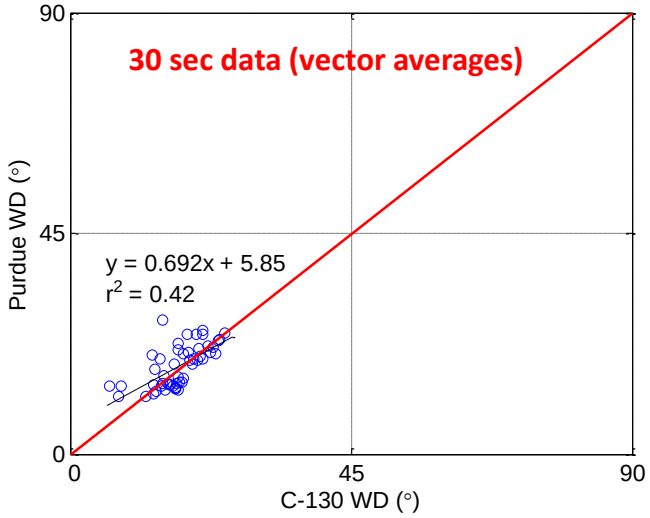




Duchess & C-130 Intercomparison







Summary

- Estimated emissions from the Baltimore-Washington area:
  $F(CO_2)$: 110,000±20,000 moles s^{-1} (or ~150 M tons/yr)
  $F(CH_4)$: 700±330 moles s^{-1}
  F(CO): 540±188 moles s^{-1}

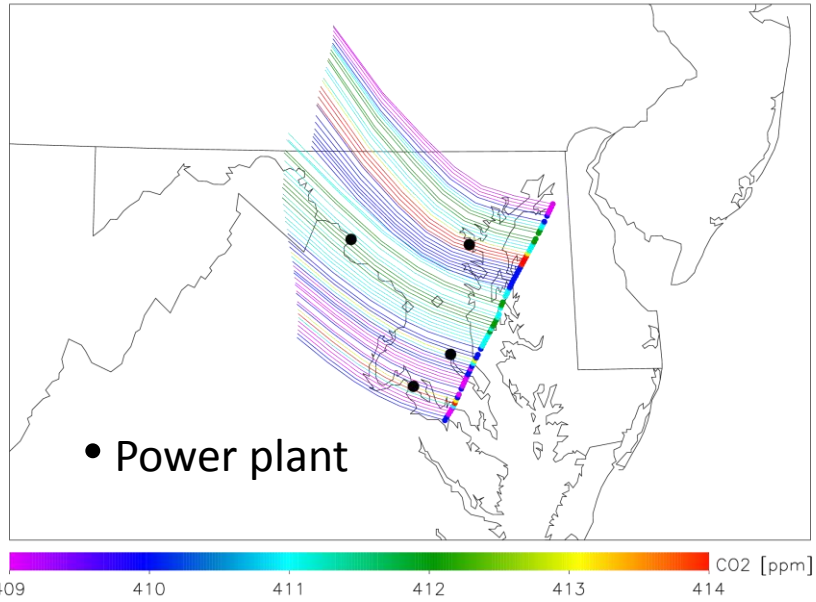
- CH_4 emissions from Brown Station Landfill account for ~10% of total CH_4 emissions from the entire Baltimore-Washington area.

- Limited VOC data show an ethane to methane ratio of 3.3%.

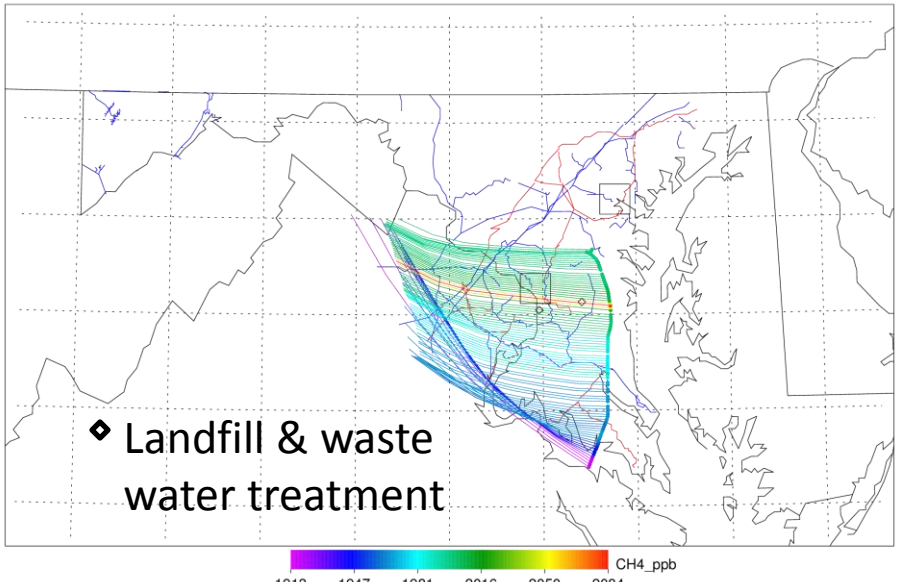
- Intercomparison flights: good agreement for some parameters but needs to investigate discrepancies for other parameters.

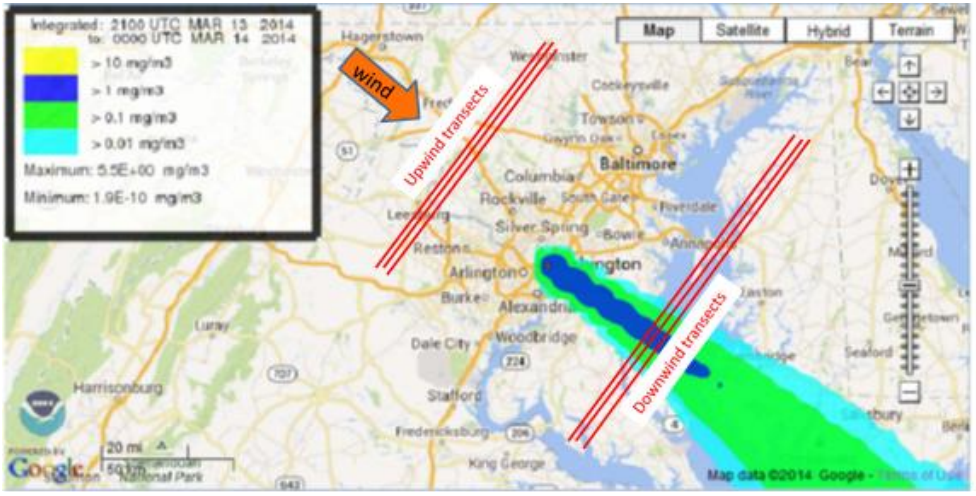
Ongoing Work: HYSPLIT Trajectory/Dispersion Model

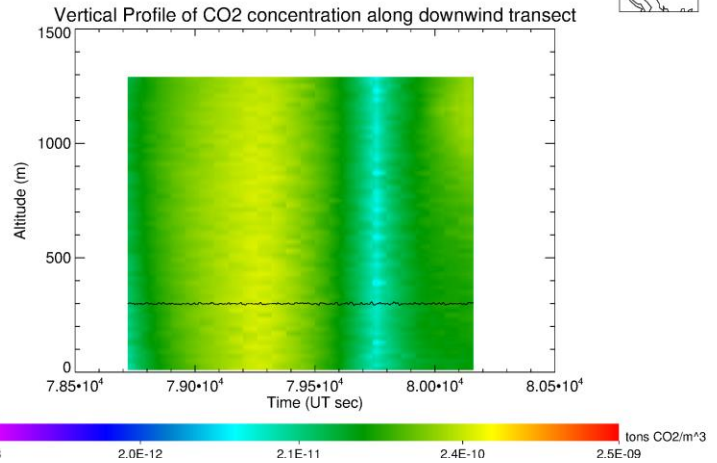
2/20/2015



6-hr HYSPLIT back trajectories off of FLAGG-MD flight, from 15 2 20 22 to 15 2 20 22 UTC.







Acknowledgements

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- Students who were involved in the flights
- Winston Luke and Paul Kelley at NOAA/ARL