Quantification of emissions from methane sources in Indianapolis using an aircraft-based platform

Maria Obiminda Cambaliza[1], Paul Shepson[1], Brian Stirm[1], Colm Sweeney[2,3], Jocelyn Turnbull[2,3], Anna Karion[2], Ken Davis[4], Thomas Lauvaux[4], Scott Richardson[4], Natasha Miles[4], Kevin Gurney[5], Dana Caulton[1], Kelly Mays[1], Rachel Svetanoff[1], James R. Whetstone[6], Antonio Possolo[6], Daniel Samarov[6], Eric Crosson[7]

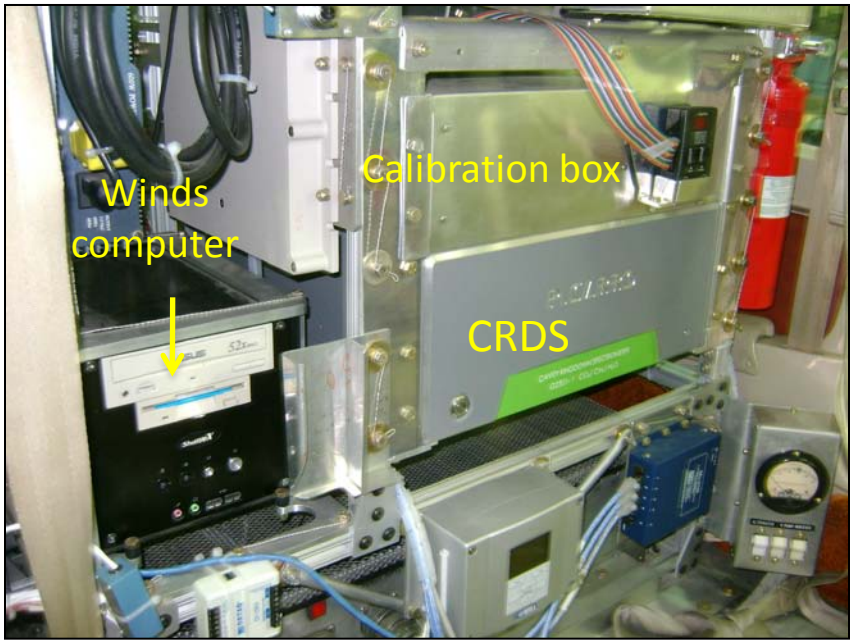
[1]Purdue University, [2]NOAA Earth System Research Laboratory, [3]CIRES, University of Colorado, [4]The Pennsylvania State University, [5]Arizona State University, [6]National Institute of Standards and Technology, [7]Picarro, Inc.

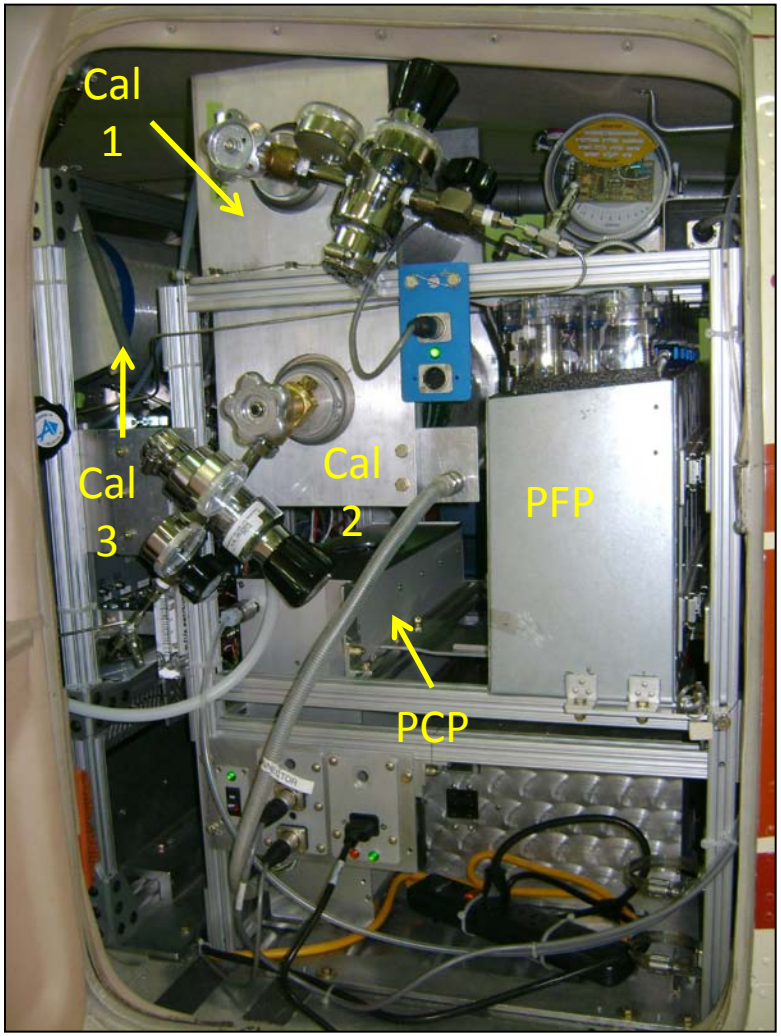
Background

- global warming potential of 25 over a period of 100 years
- Magnitude of individual sources of CH_4 is not well quantified
- Urban environments are significant sources of anthropogenic methane emissions
  - significantly larger than currently estimated (Mays et al., 2009, Wunch et al., 2009)
  - Does not correlate with combustion sources (Mays et al., 2009)
- Goals
  - Estimate the city-wide emission flux
  - Investigate and quantify source specific emissions
  - Carefully determine the magnitude of uncertainty

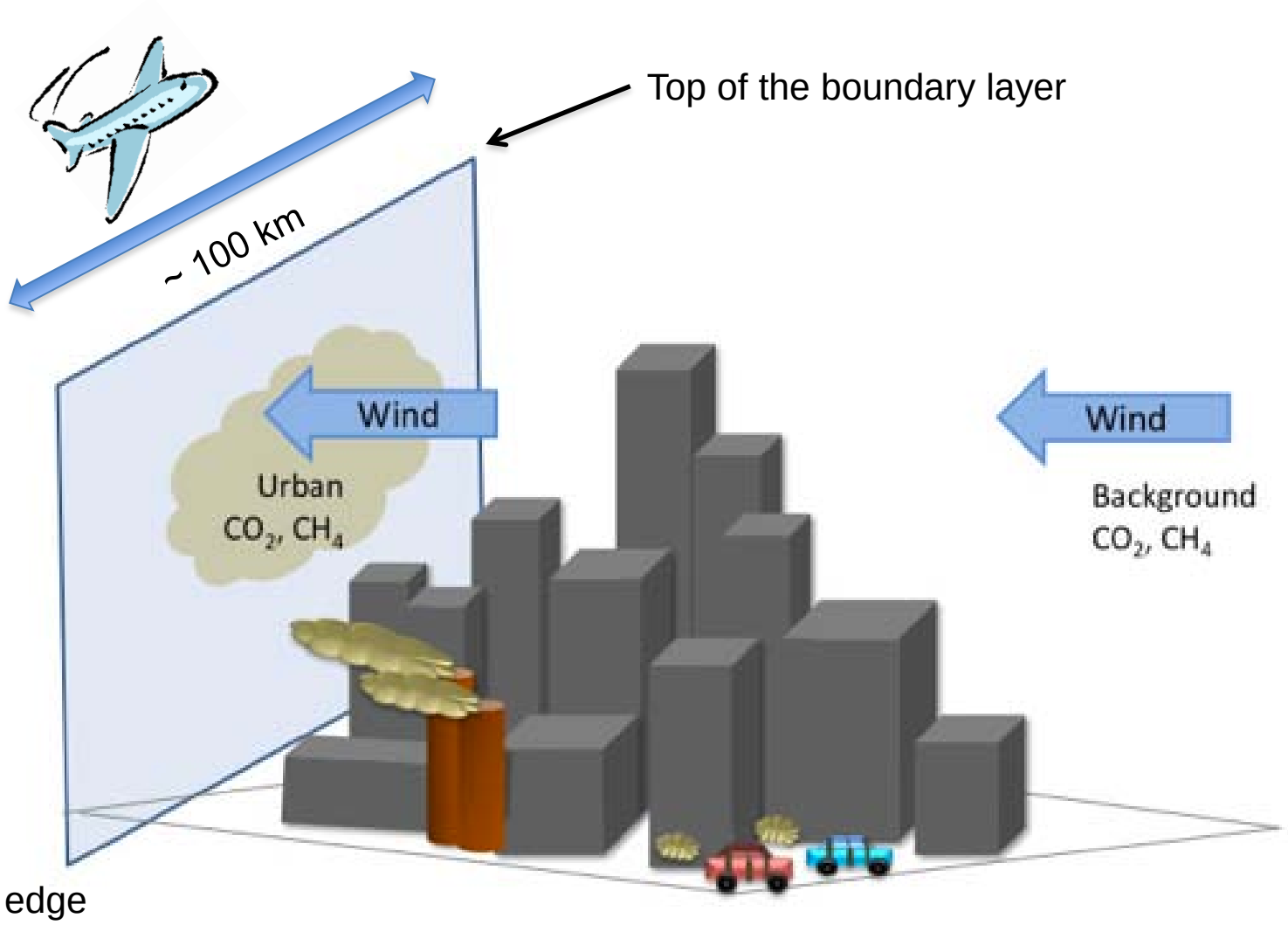
Experimental Set-up

Purdue Airborne Laboratory for Atmospheric Research

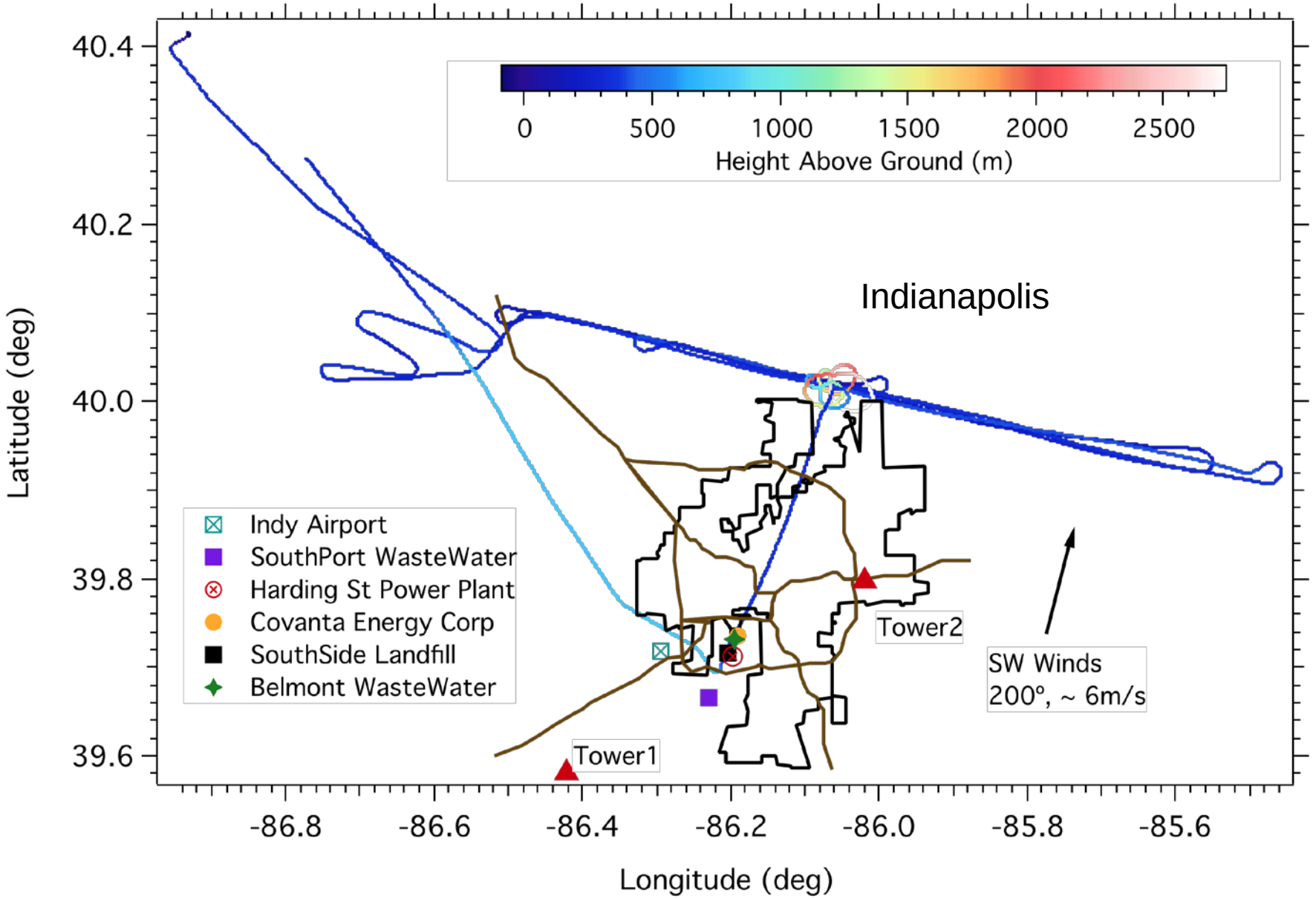




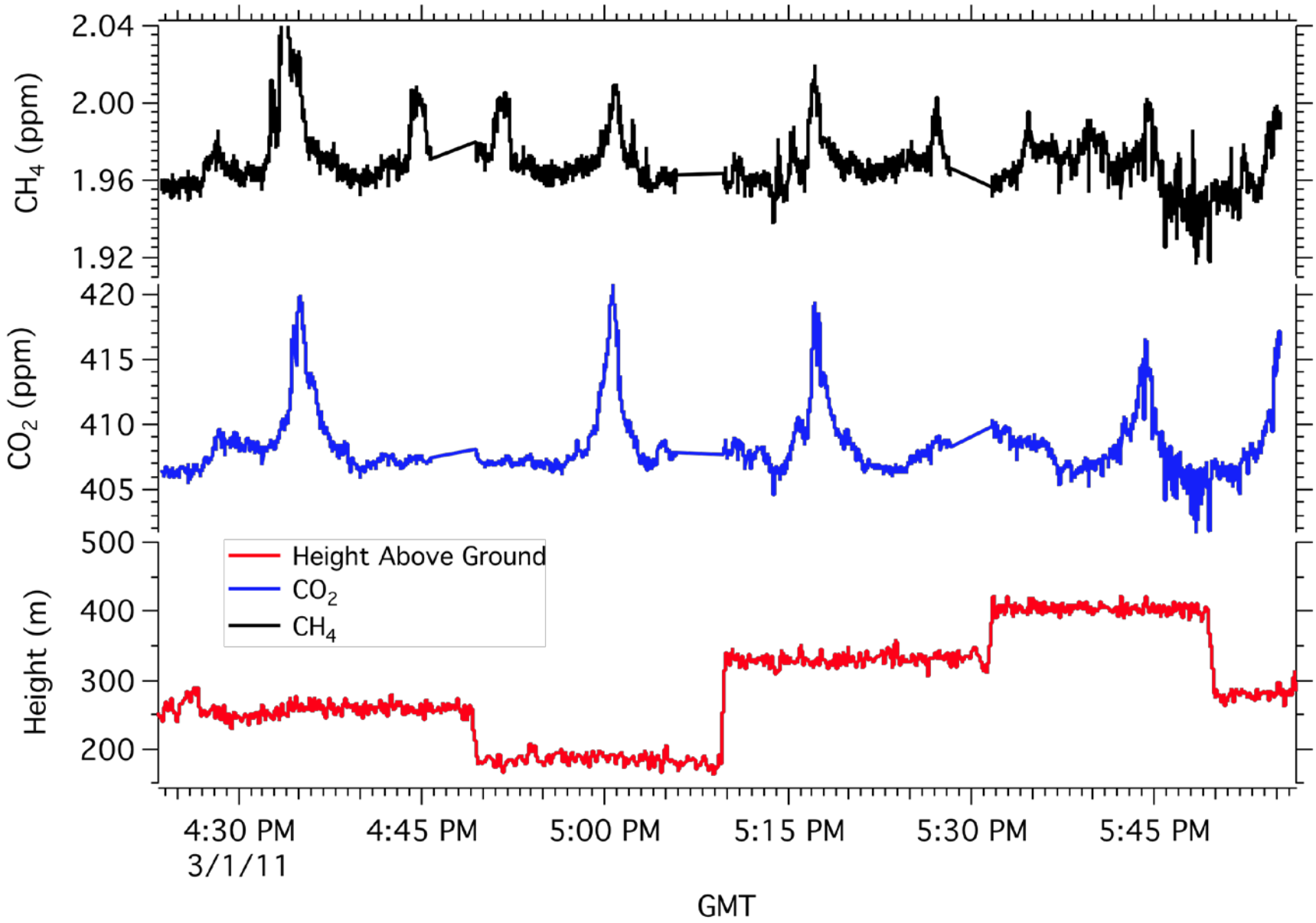
Experimental Sampling Design



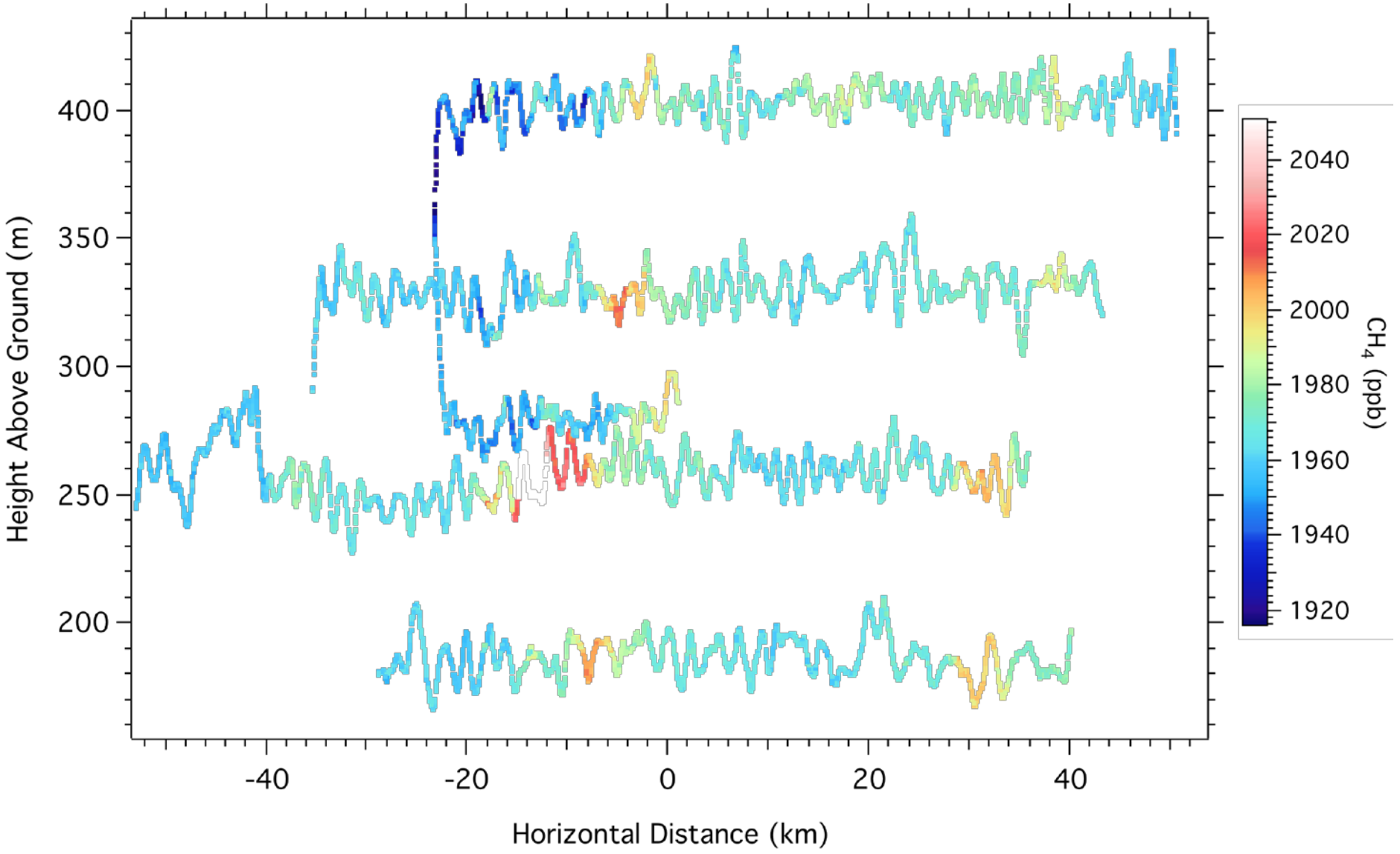
Flight Path: March 1, 2011



Time series distribution of CO_2 and CH_4

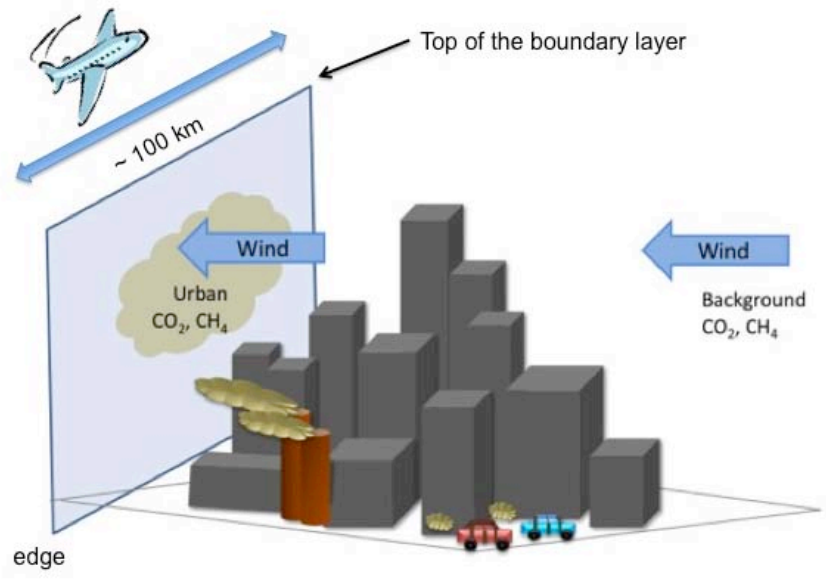


Downwind Observed CH_4 distribution



Estimating the Emission Flux

$$F_c = \int_0^{z_i} \int_{-x}^{+x} \left([C]_{ij} - \overline{[C]}_b \right) * U_{\perp ij} \, dx \, dz$$



F_c: area-averaged emission flux (mols/s)

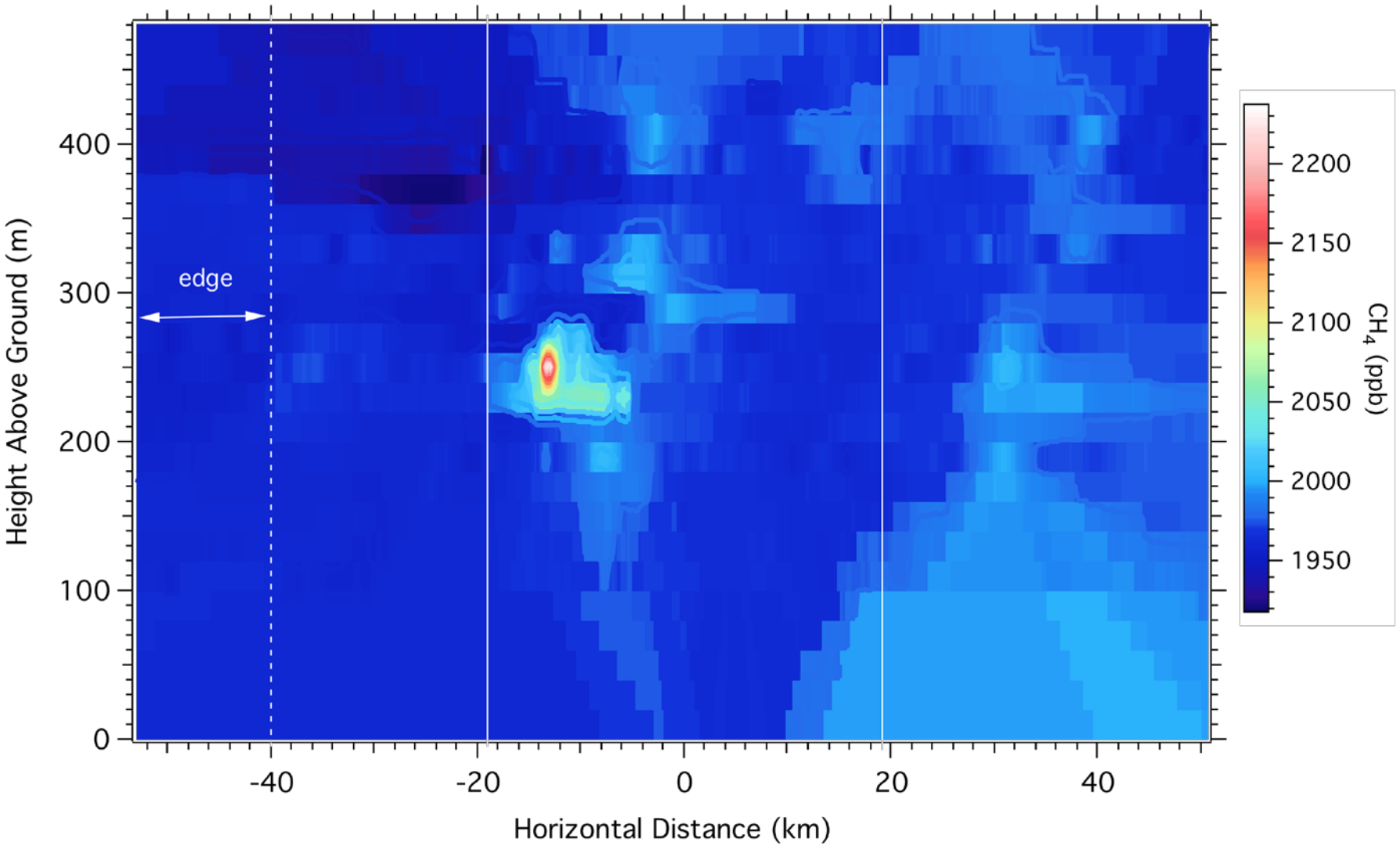
-x and +x: min and max horiz transect distance limits corresponding to the area bounded by the city

Uij: gridded wind vector perpendicular to the flight path

dx and dz: horizontal and vertical grid spacing

$[C]_b$: ave background estimated from the edge of the transect

Interpolated CH_4 distribution

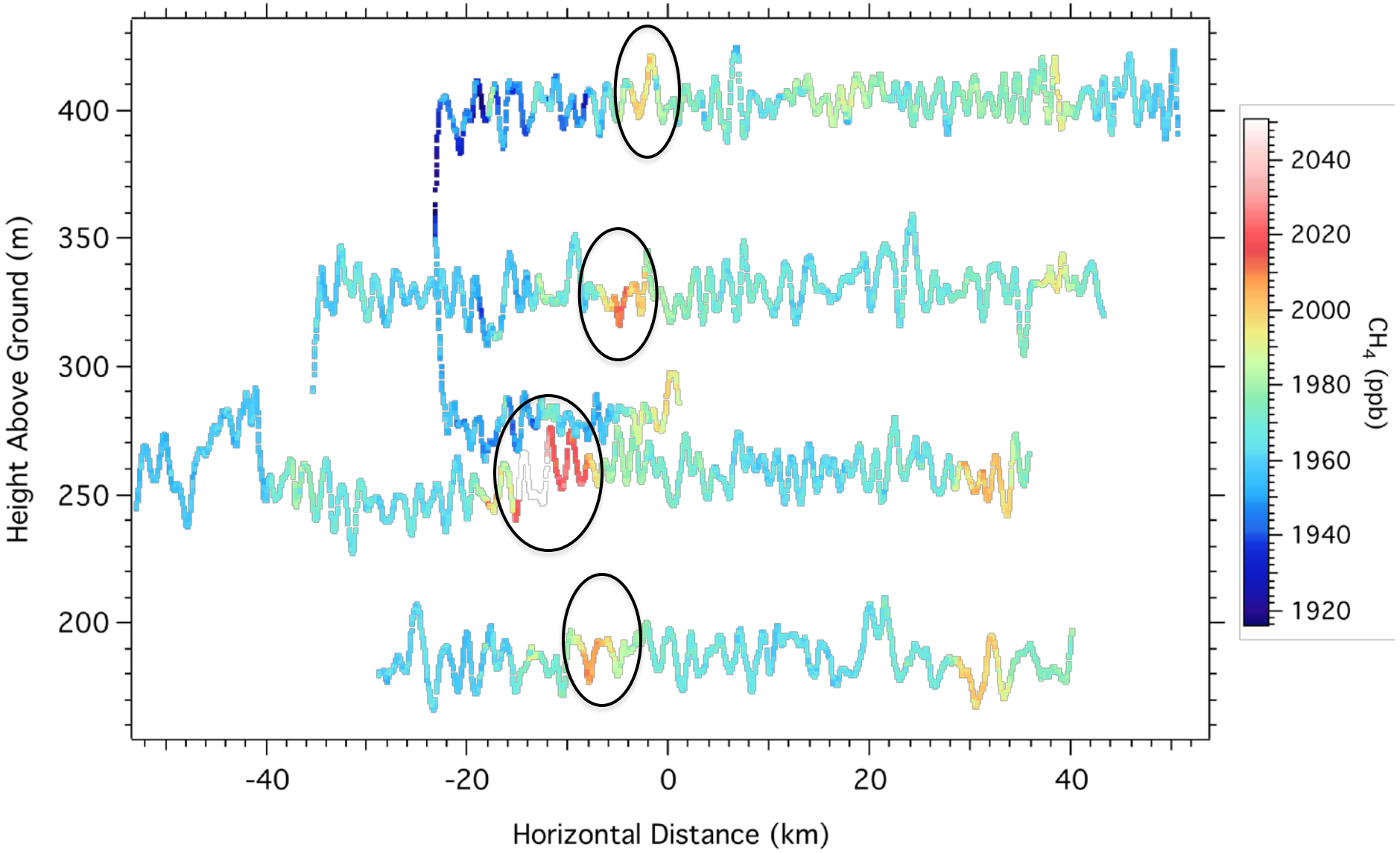


Chu, D. The GLOBEC kriging software package – EasyKrig3.0; The Woods Hole Oceanographic Institution: 2004. Available from http://globec.whoi.edu/software/kriging/easy_krig/easy_krig.html (accessed November 2010)

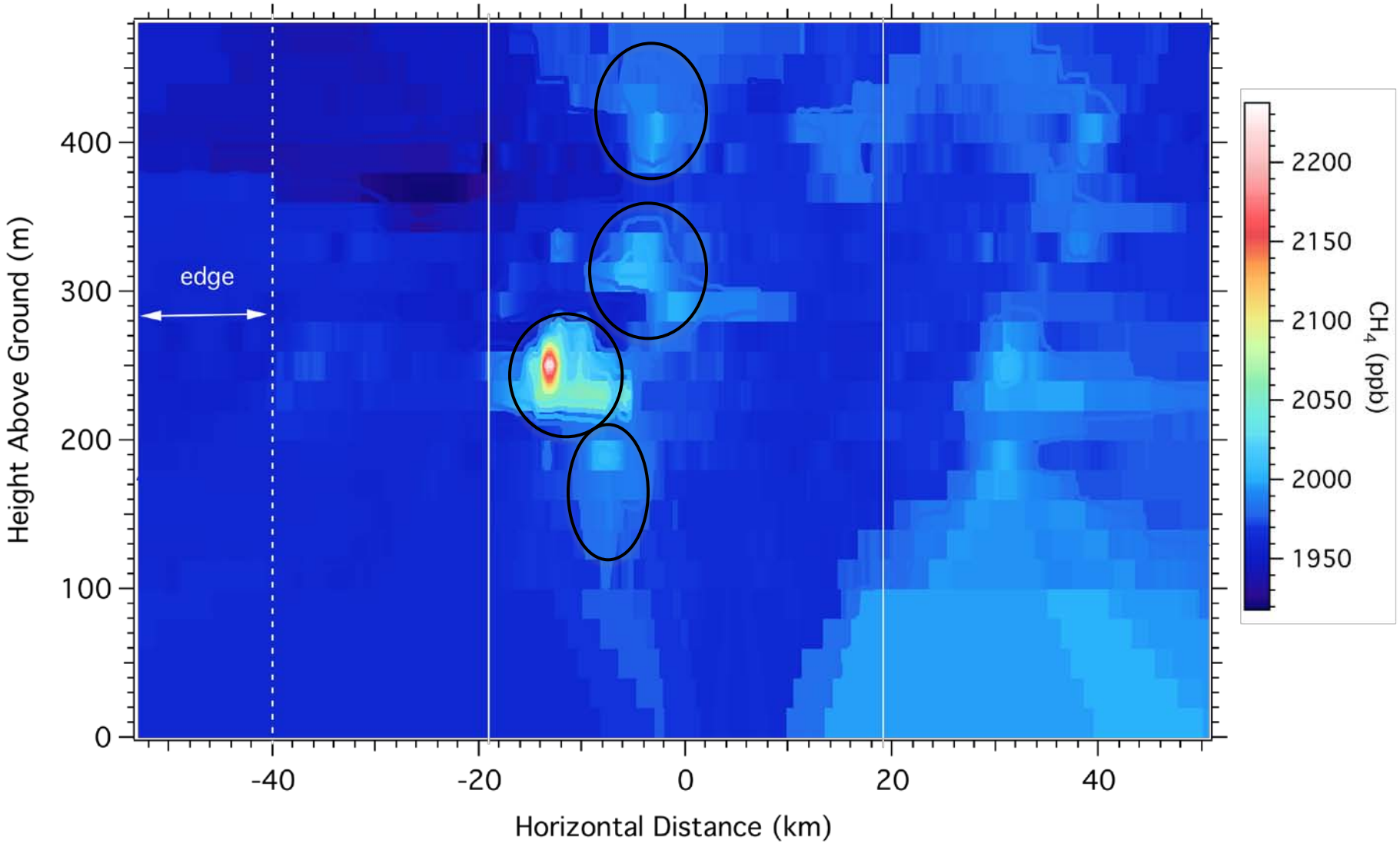
Result of Flux Calculation

	City	year	Analytical Technique	population density, per km^2	Emission, mols s^{-1}	Emission per capita, µmols s^{-1}/person
Mar 1 measurement	Indianapolis	2011	aircraft-based, CRDS	861	47 ± 14	57 ± 17
Mays et al., 2009	Indianapolis	2008	aircraft-based, CRDS	861	102 ± 73	123 ± 89
Wunch et al., 2009	South Coast air Basin, Southern CA	2007-2008	ground-based open path FTS	3168	1189 ± 198	121 ± 20
Lowry et al., 2001	London	1996 - 1997	ground-based GC and IRMS for [CH_4] and $\delta^{13}C$ measurement	4807	476 - 618	67 - 87

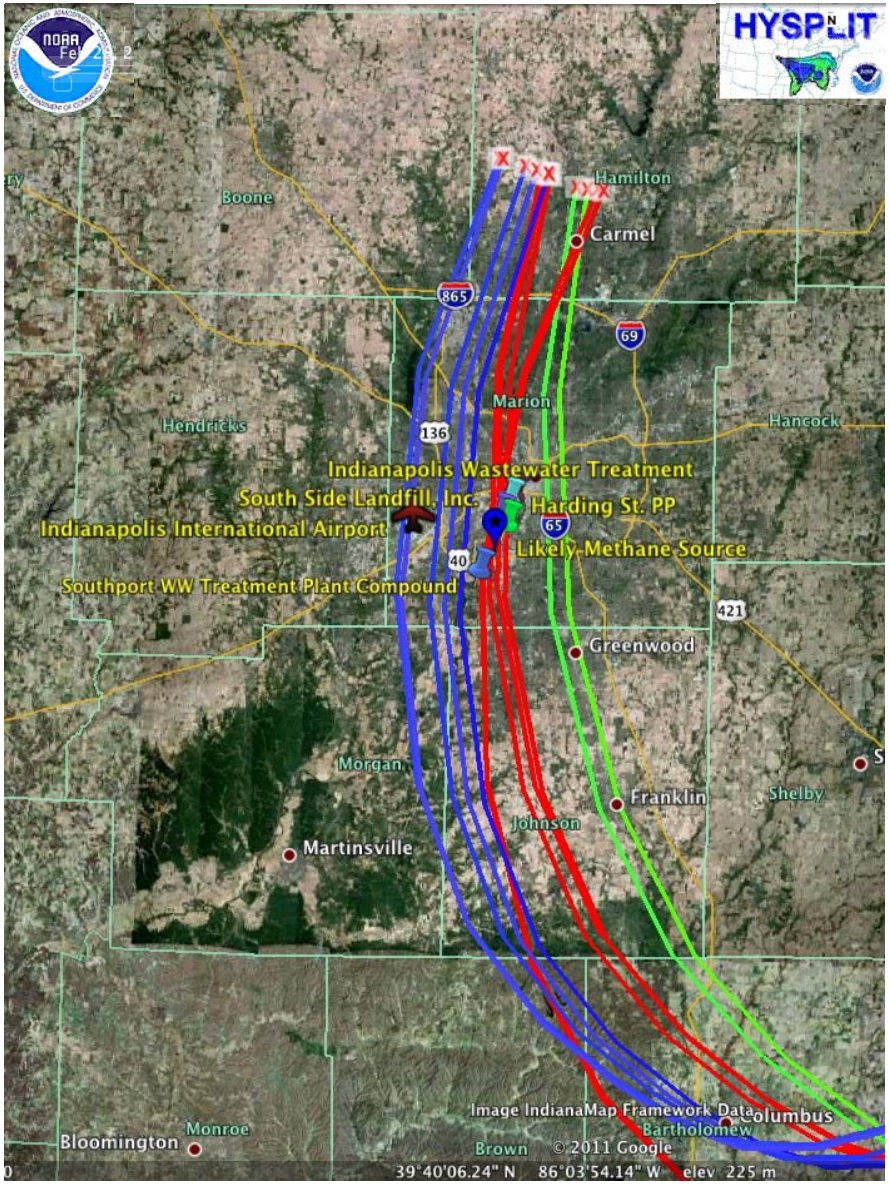
Revisiting the curtain transect CH_4 distribution



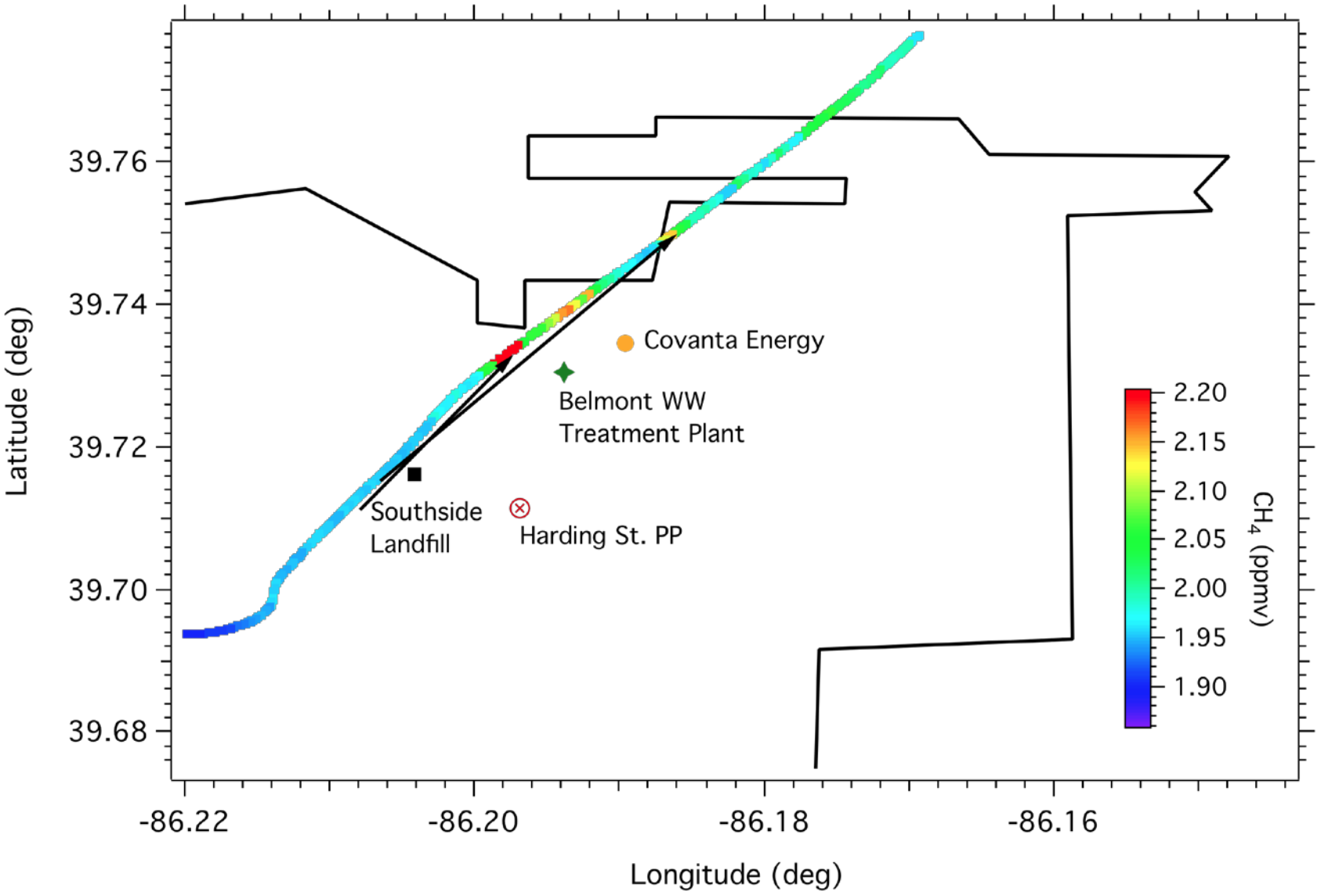
Interpolated CH_4 distribution



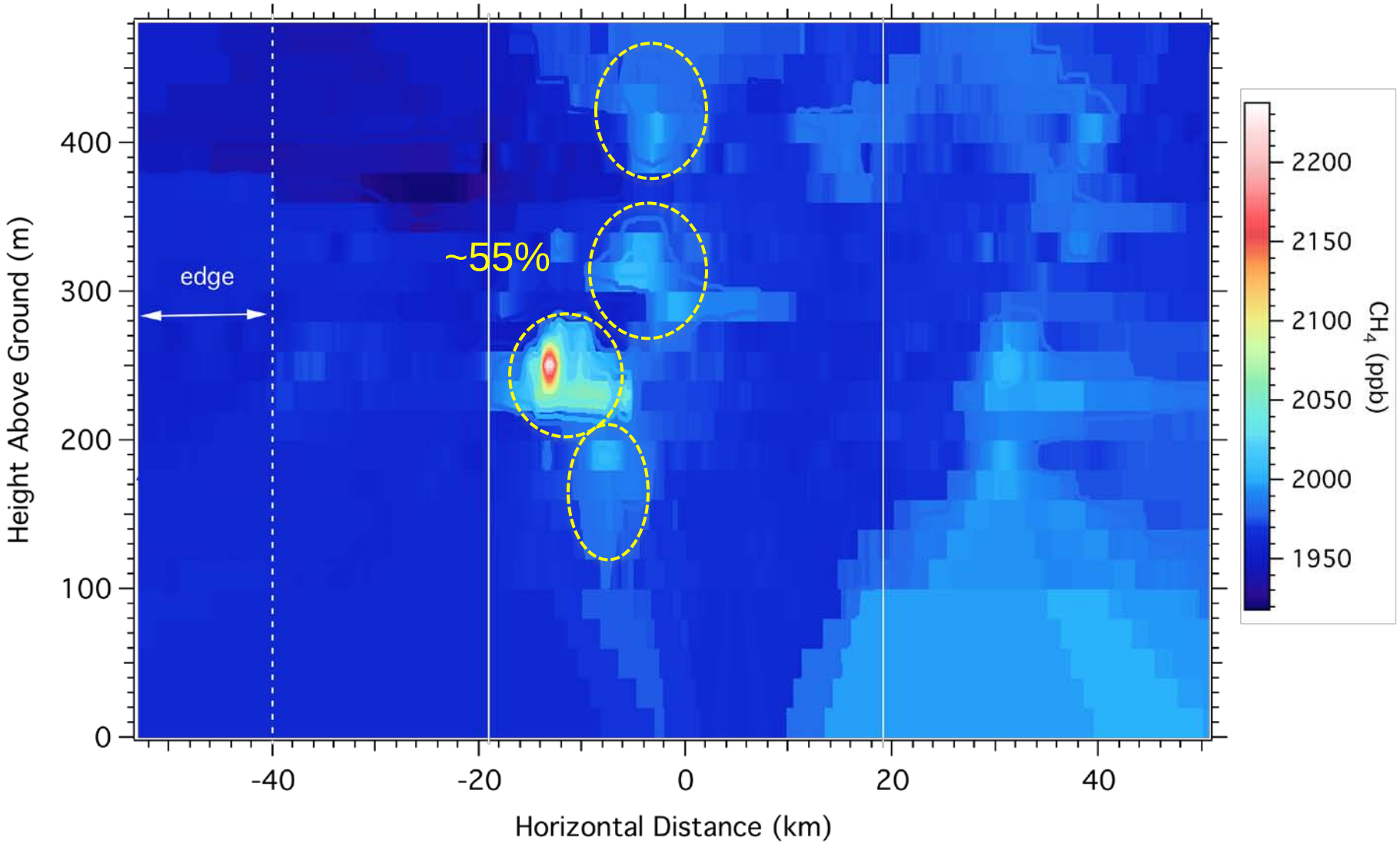
Back Trajectories



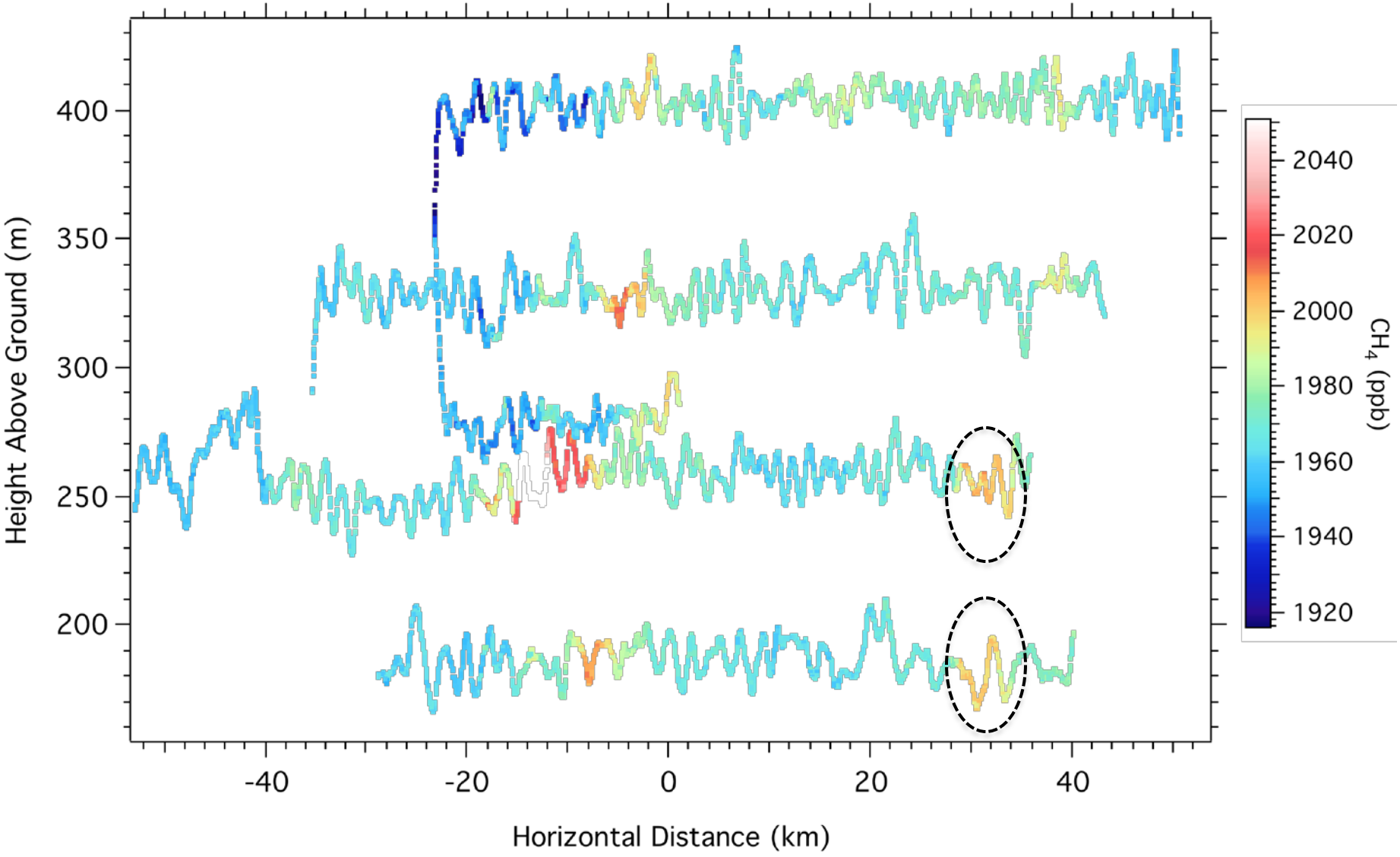
Following the plume upwind . . .



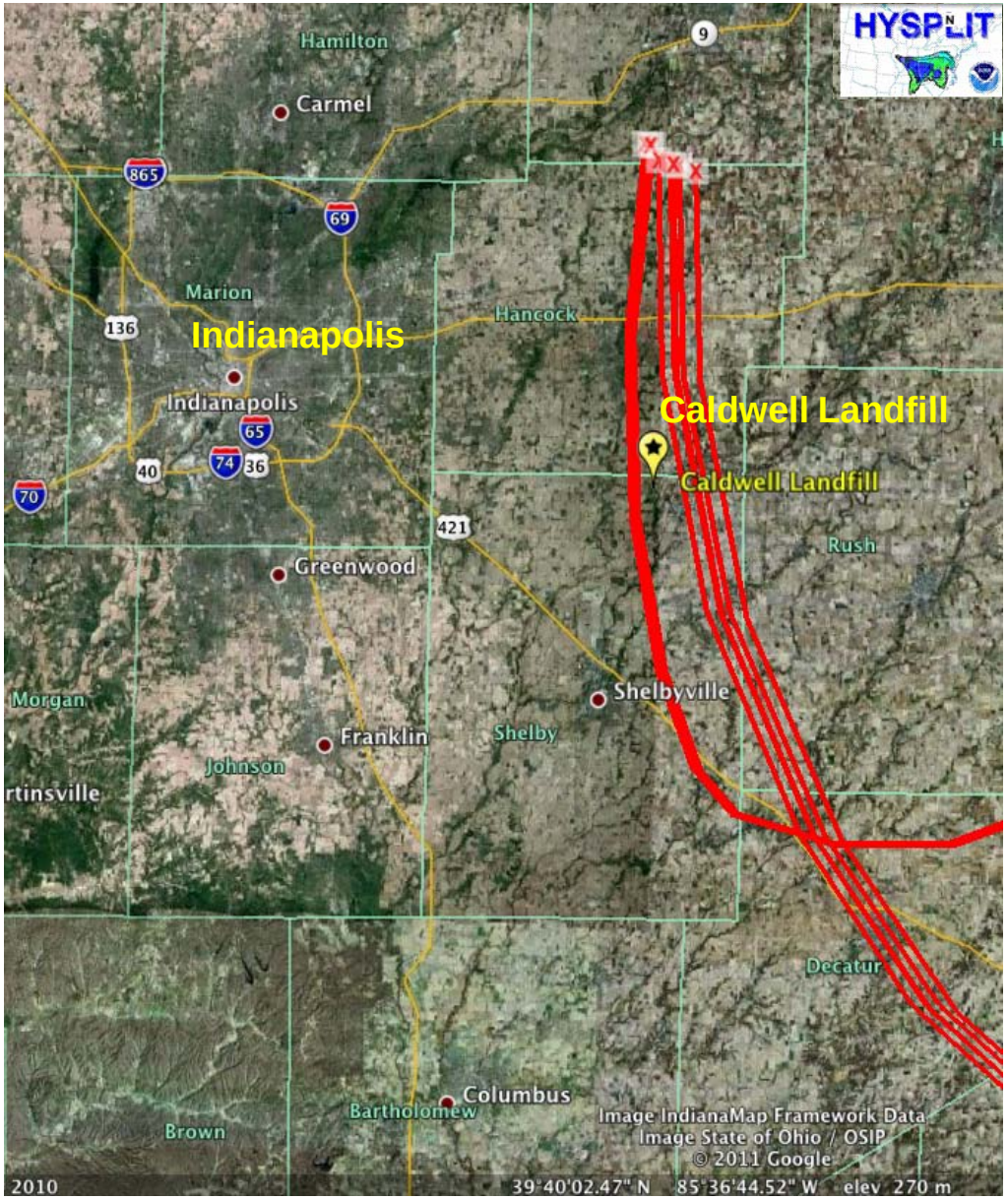
Interpolated CH_4 distribution



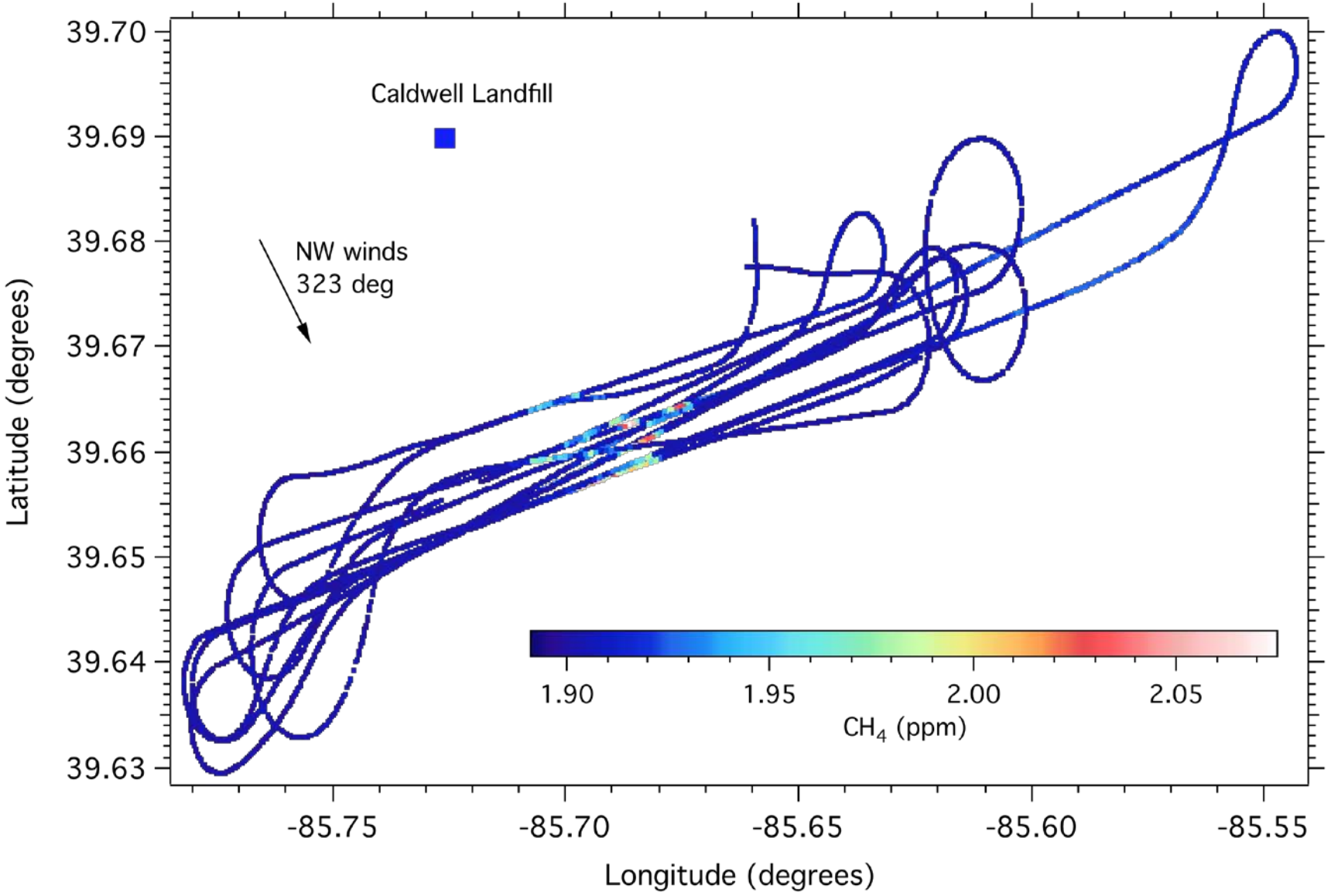
Revisiting the Downwind Observed CH_4 distribution



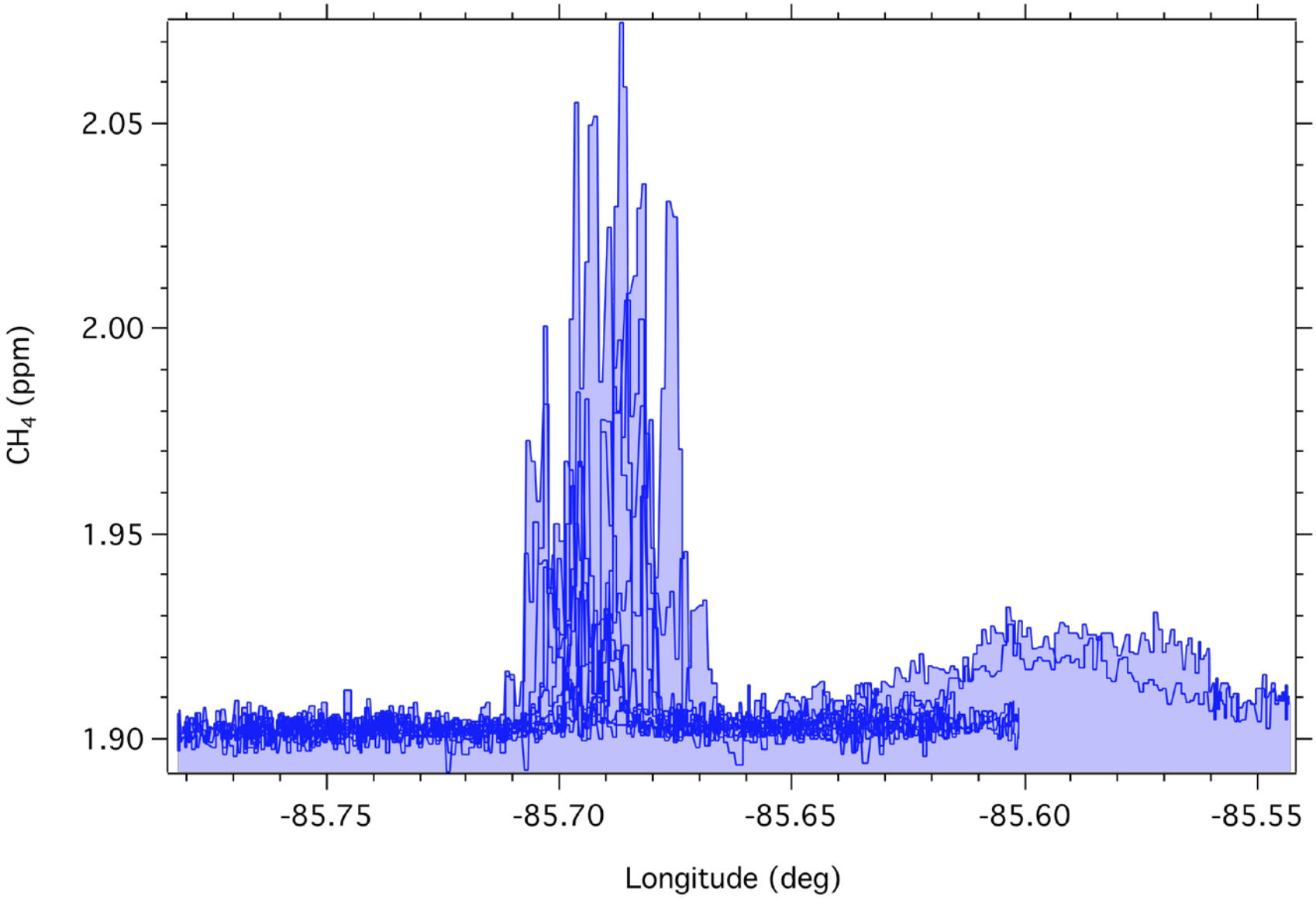
Back trajectories corresponding to hot spots from the East



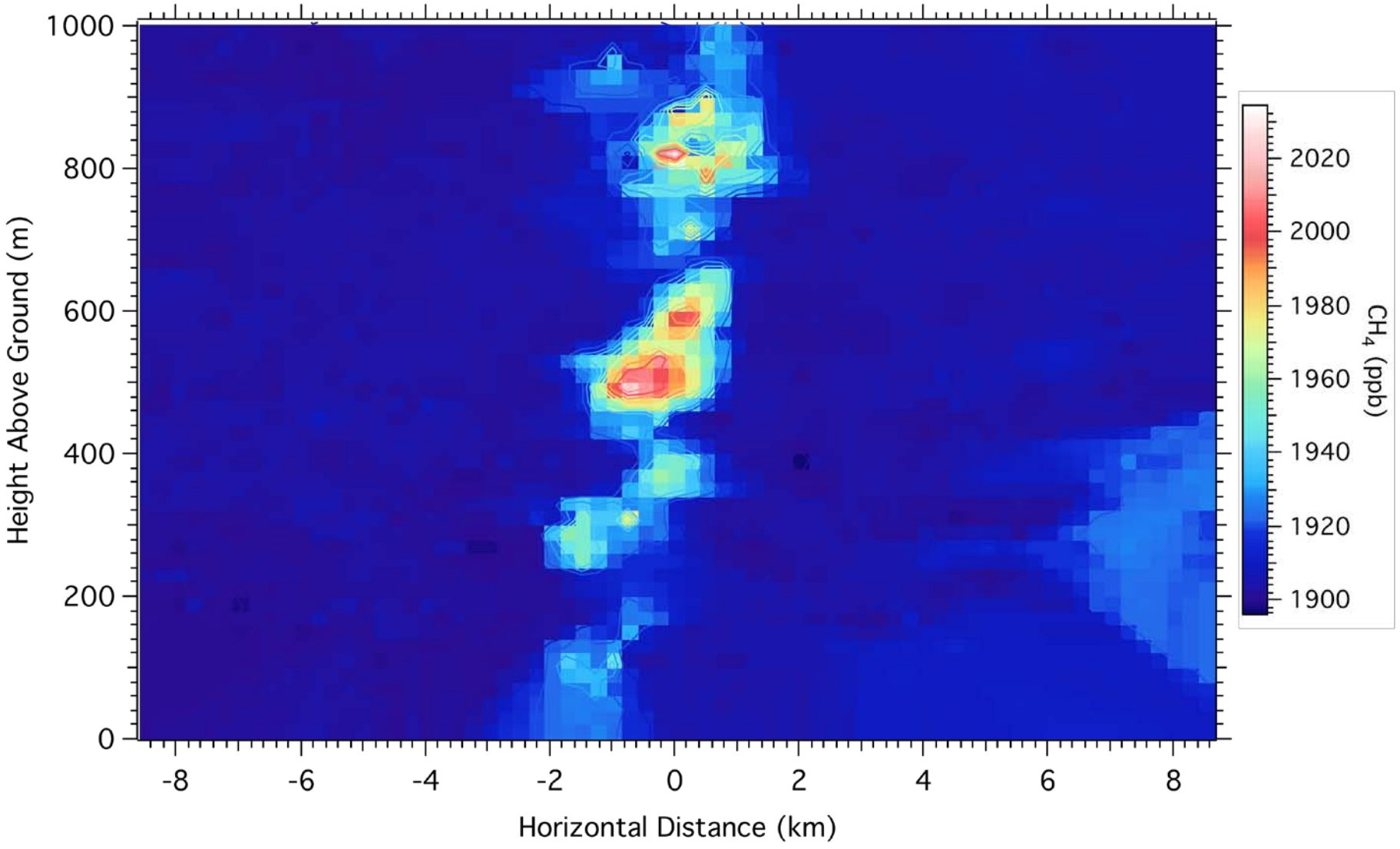
Horizontal flight segments on May 4, 2011



CH_4 Curtain Distribution vs Longitude



Interpolated CH_4 Curtain Flight Distribution



Calculating the Energy Equivalent from the Caldwell Landfill, Morristown, IN

- Estimated Flux = 9.1 mols s^{-1} = 821 m^3 hr^{-1}
- 1 m^3 CH_4 has an energy content of 2.9 kWhr at 30% efficiency
- 821 m^3/hr * (2.9 kWhr/m^3 CH_4) = 2381 kWhr/hr
- From US EIA: In 2008, the average hourly electricity consumption for a US residential utility customer was 1.26 kWhr
- Emissions from the Caldwell landfill can provide energy for approximately:
  - ~ 1890 households (at 30% efficiency)
- Can provide energy for the city of Morristown which has a population of ~1400
- We assume constant emission

Summary and Future Work

- Starting to gain better understanding of CH_4 sources and their magnitudes
- Combine aircraft flux measurements with mobile surface measurements of CH_4
- Combine aircraft measurements with a Lagrangian particle dispersion model to determine the surface footprint corresponding to elevated CH_4 concentrations
- Need flask measurements to further constrain the location of CH_4 sources

Acknowledgement: Funding from NIST

NIST PURDUE NOAA PENN STATE PICARRO