In this work, we quantified CH$_4$ emissions from the Marcellus Shale natural gas operation area during August/September 2015. The mass balance approach was used, which involves the following steps:

1. **Data Collection:** Aircraft observations of GHGs, other trace gases, and aerosols were conducted over the Marcellus Shale region.
2. **Background Concentration:** Background CH$_4$ concentrations were detected upwind.
3. **Concentration Change:** The change in CH$_4$ concentrations from upwind to downwind was measured.
4. **Determination of Flux:** The flux was calculated using the mass balance equation:

$$Flux = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left( \left[ C_{upwind} - C_{downwind} \right] x U_{\perp} \right) dx dz$$ \hspace{1cm} (1)

where:
- $C_{downwind}$: concentration at a downwind location $(x_i, z_i)$
- $C_{upwind}$: background concentration detected upwind
- $U_{\perp}$: perpendicular wind speed at a downwind location $(x_i, z_i)$

**Results:**

**8/25/2015**

**Fig. 3.** Left: [CH$_4$] along the flight track; Middle: Time series of altitude, [CH$_4$], wind speed and direction; Right: vertical profiles of [CH$_4$], [CO$_2$], potential temp and H$_2$O mixing ratio for the flight on 8/25/15.

**9/14/2015**

**Fig. 4.** Left: [CH$_4$] along the flight track; Middle: Time series of altitude, [CH$_4$], wind speed and direction; Right: vertical profiles of [CH$_4$], [CO$_2$], potential temp and H$_2$O mixing ratio for the flight on 9/14/15.

**Summary:**

- The averaged CH$_4$ flux from a 110x120 km area in the Marcellus Shale region in SW PA and Northern WV was estimated to be 4,160±1,600 moles s$^{-1}$.
- CH$_4$/NG$_{production}$ = 5.9±1.6%, consistent with the results (2.0-14 g CH$_4$ km$^{-2}$ s$^{-1}$) by Caution et al. (2014) in SW PA, but larger than the results (1.2±0.6 g CH$_4$ km$^{-2}$ s$^{-1}$ — measurements made in 2012) in SW PA by Swarthout et al. (2015) and an order of magnitude larger than the results (~0.4 g CH$_4$ km$^{-2}$ s$^{-1}$) by Peischl et al. (2015) in the Marcellus Shale region in NE PA.
- CH$_4$/NG$_{production}$ = 5.9±1.6%, much greater than the loss rate (0.18–0.41%) estimated for the Marcellus region in northern PA by Peischl et al. (2015).

**Future Work:**

- To obtain other CH$_4$ sources in the surveyed area to derive CH$_4$ leak rate.

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