Separation of methane emissions from agricultural and natural gas sources in the Colorado Front Range

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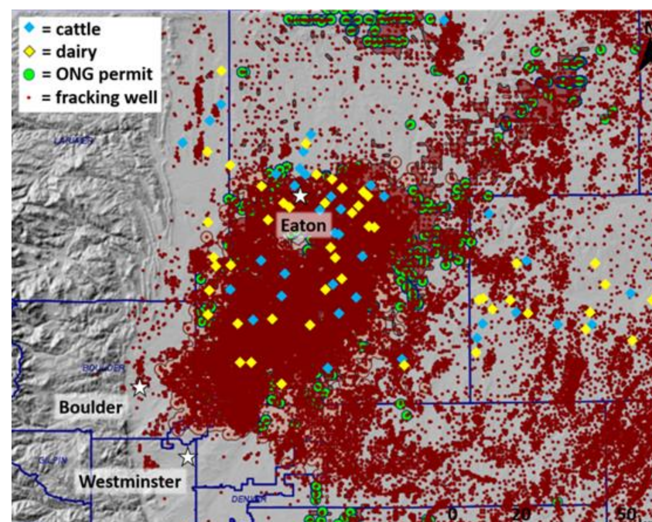
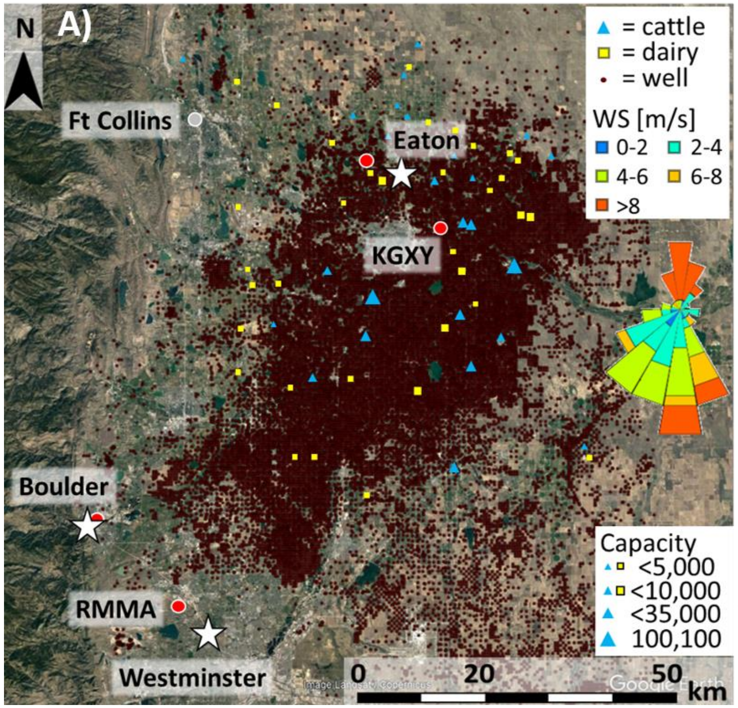


Outline

- Campaign overview
- Instrumentation
- Data analysis
- Campaign results
- Summary and outlook

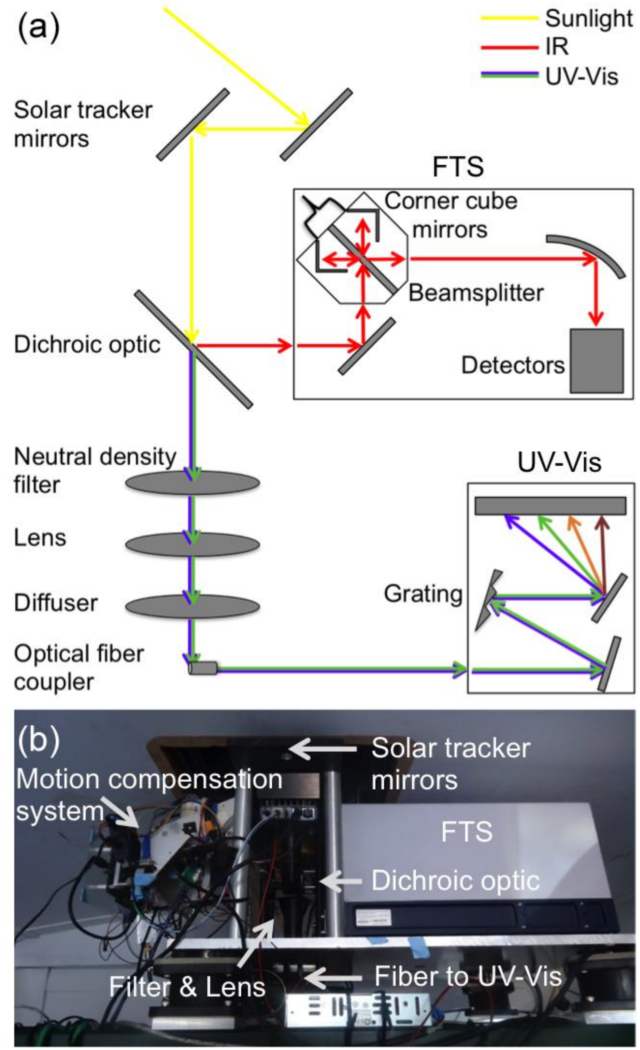
Campaign Overview

- Three COCCON EM27/SUN spectrometer (CH_4 detection, no CO channel)
- One CU mobile solar occultation flux (SOF) instrument (C_2H_6 and NH_3 detection)
- Measurements from 14 to 23 March 2015 in the Colorado Front Range
- Five days with clear sky conditions
- Temperatures from 8 to 28 °C
- Surface wind speeds from 1.5 to 13.9 m/s



CU mobile SOF instrument

- Digital mobile solar tracker
- UV-Vis grating spectrometer
- EM27 spectrometer
- Resolution: 0.5 cm^{-1}
- MCT detector
  - Spectral range: 700 – 1850 cm^{-1}
- InSb detector
  - Spectral range: 1850 – 5000 cm^{-1}
- SFIT4 retrieval code



Kille et al, AMT (2017)

CU mobile SOF instrument + EM27/SUN

- Digital mobile solar tracker
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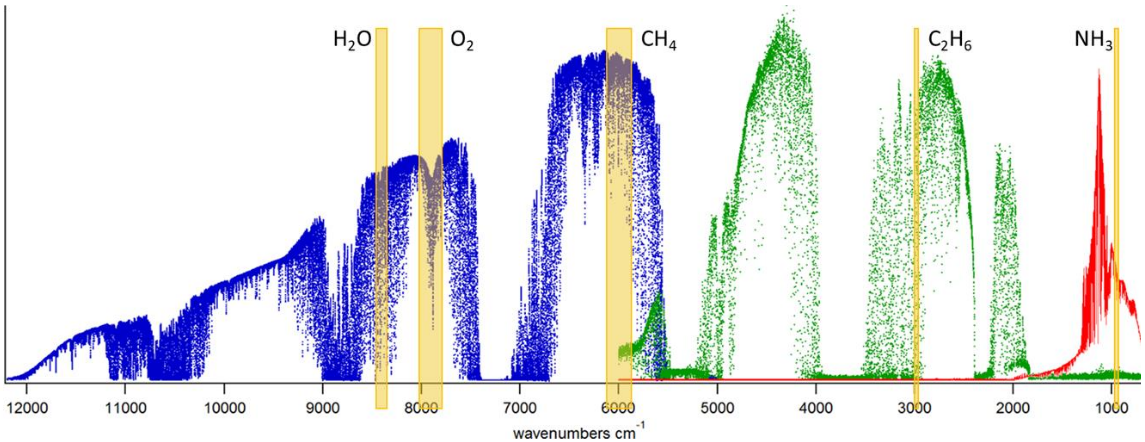
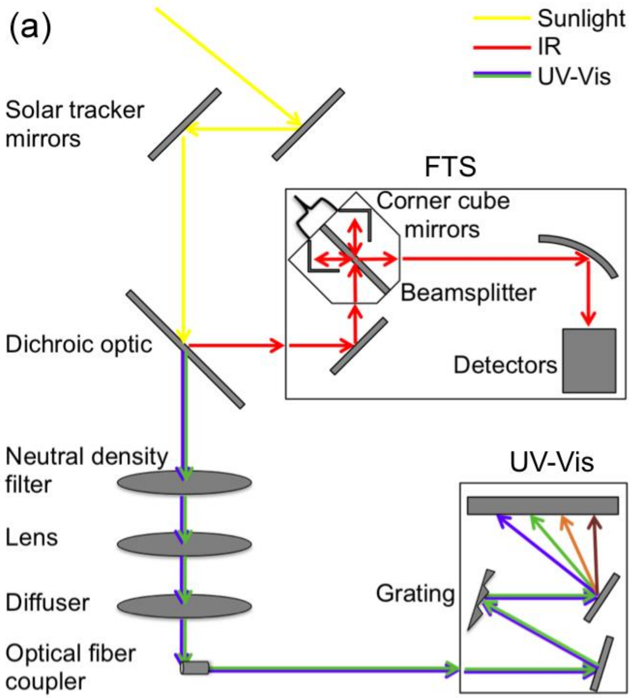
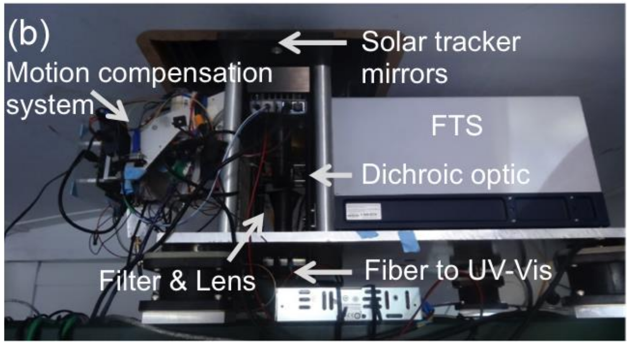






Kille et al, AMT (2017)

Data analysis

- Dry air mole fractions (XGas) are derived from total columns (VC) as

$$XGas = 0.2095\,\frac{VC\ (Gas)}{VC\ (O2)}$$

- Enhancement over the background

$$\Delta XGas = XGas\ - XGasBKG$$

- $XGas_{BKG}$ is determined as the second percentile of pooled time series data, for XCH_4 on a daily basis from the three measurement sites, for the other gases as a constant value over the whole time series

Data analysis

- Linear regression analysis on ΔXCH_4 timeseries

$$\Delta XCH_4 = \beta_0 + \beta_1 \cdot \Delta XC_2H_6 + \beta_2 \cdot \Delta XNH_3$$

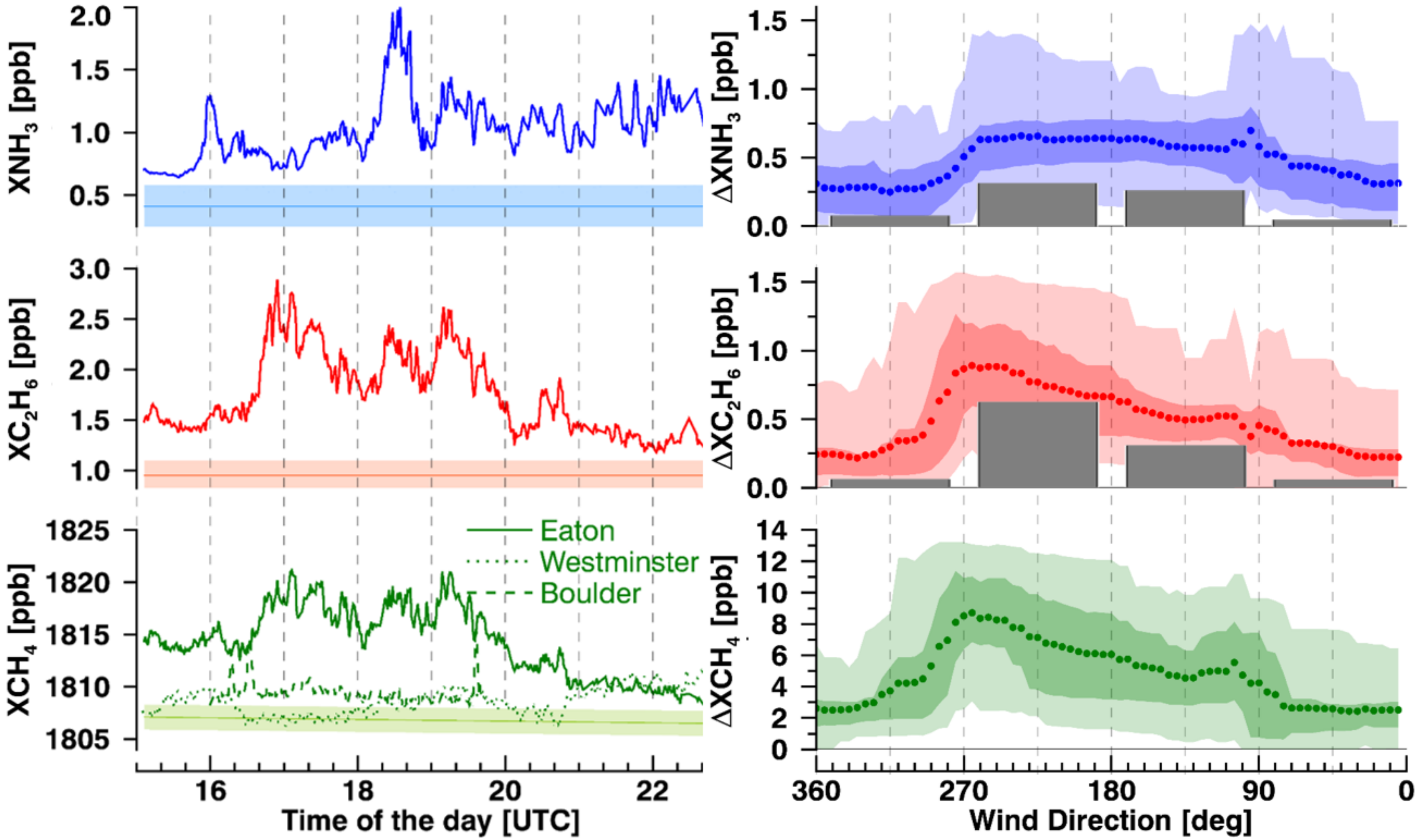
- Regression parameters β_1, β_2 represent $\Delta XCH_4/\Delta XC_2H_6$, $\Delta XCH_4/\Delta XNH_3$ ratio at the source
- β_0 is excess ΔXCH_4 not attributable to tracers
- Several sensitivity studies with different constraints for β_i performed
- β_i used to calculate contributions of natural gas (NG), agriculture (AG) and other sources

$$\%NG = \frac{\beta_1 \cdot \Delta XC_2H_6}{\beta_0 + \beta_1 \cdot \Delta XC_2H_6 + \beta_2 \cdot \Delta XNH_3}$$

$$\%AG = \frac{\beta_2 \cdot \Delta \mathrm{XNH_3}}{\beta_0 + \beta_1 \cdot \Delta XC_2H_6 + \beta_2 \cdot \Delta XNH_3}$$

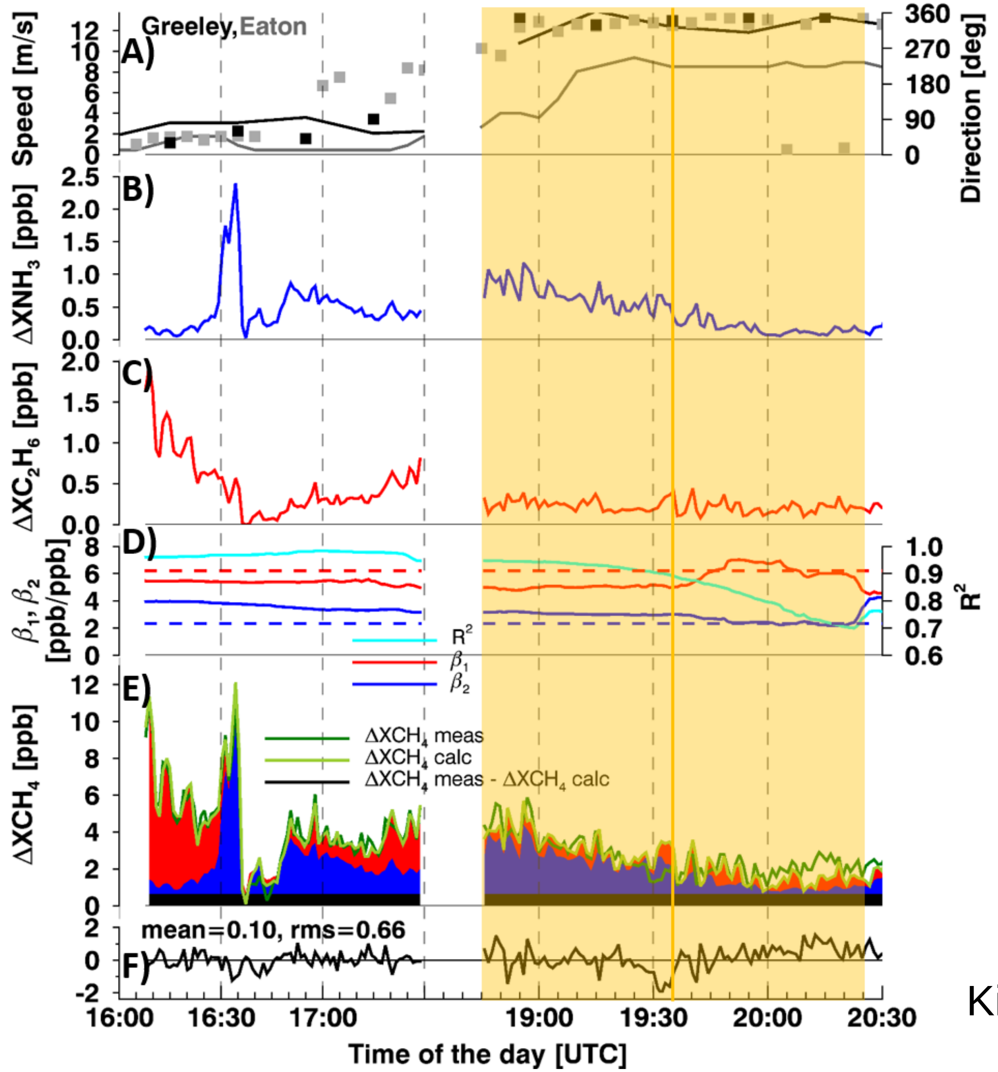
$$\%Other = \frac{\beta_0}{\beta_0 + \beta_1 \cdot \Delta XC_2H_6 + \beta_2 \cdot \Delta XNH_3}$$

XGas and ΔXGas timeseries



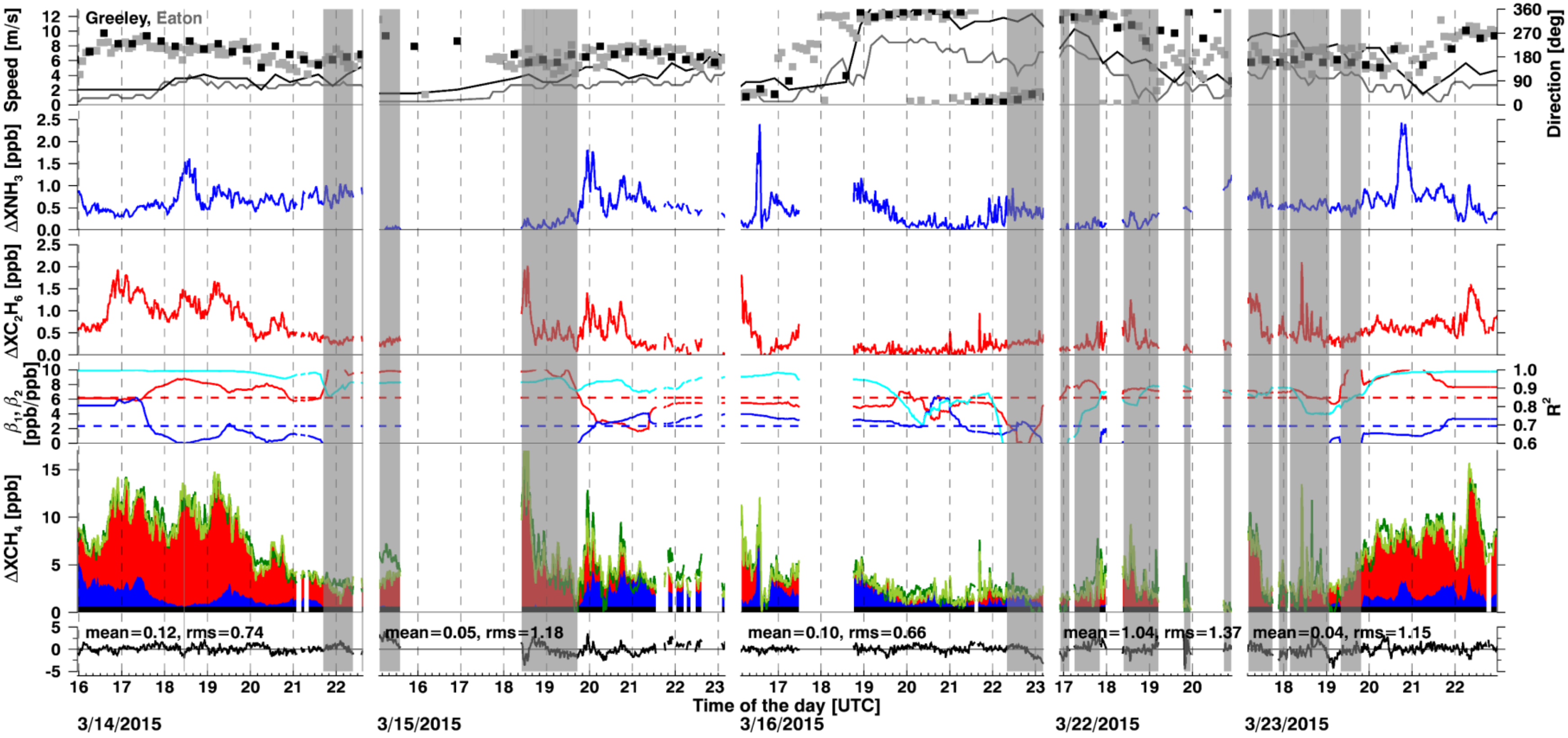
14 March **Full timeseries**

Time series data for 16 March 2015



Kille et al, GRL (2019)

Time series data full campaign



Source attribution

- Inferred regression parameters
  - $\beta_0 = 0.64 \pm 0.64$ ppb
  - $\beta_1 = 6.20 \pm 0.81$ ppb/ppb
  - $\beta_2 = 2.34 \pm 0.65$ ppb/ppb
- Percent-contributions of sources and comparison with in situ studies

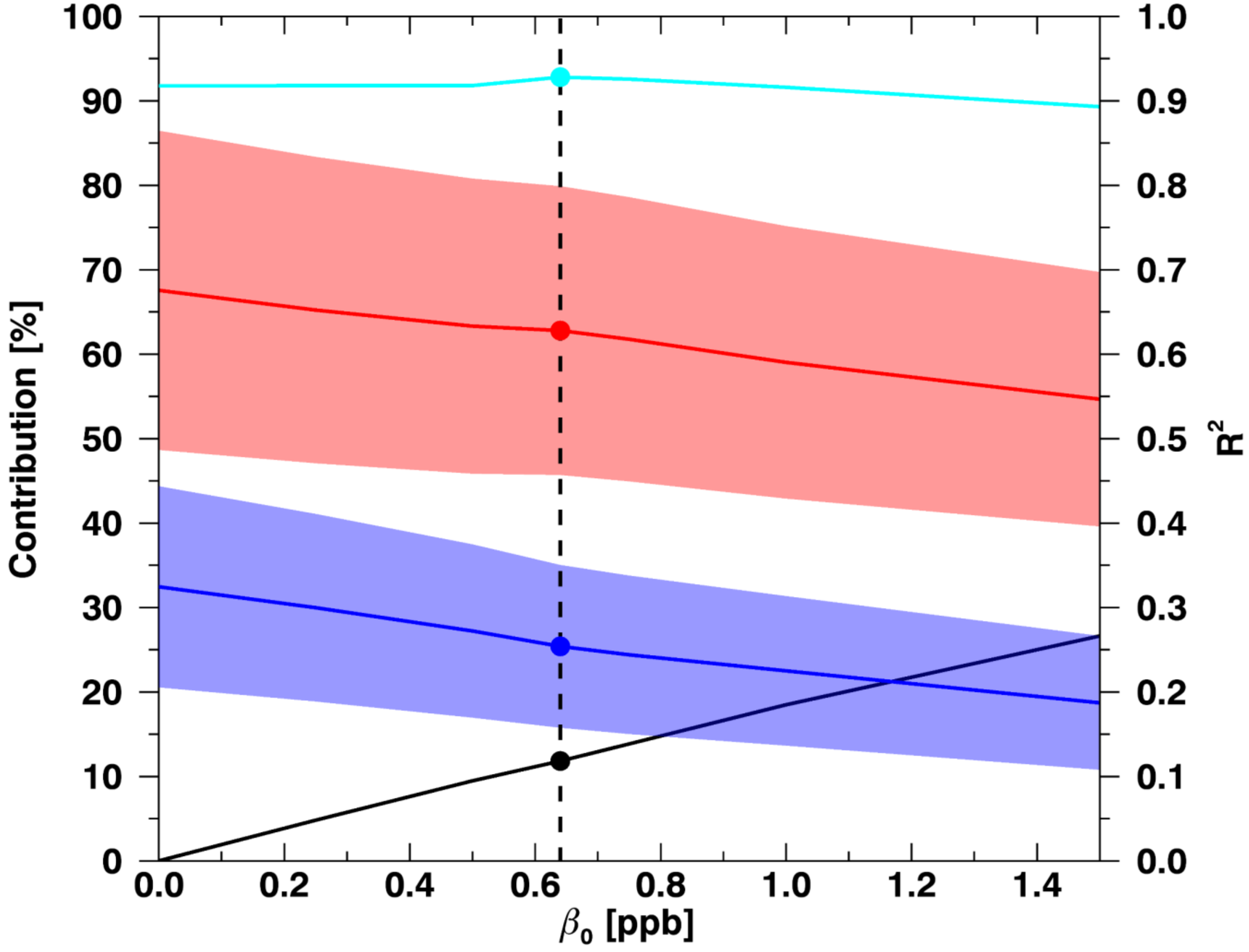
NG	AG	Other	Study period	Reference
62.8 ± 17.1	25.4 ± 9.6	11.8 ± 11.8	March 2015	This work
74	15	11	May 2012	Petron et al. (2014)
31 - 61	39 - 69		July/August 2014	Townsend-Small et al. (2016)
75 ± 37	-	-	March/April 2015	Peischl et al. (2018)

Summary and Outlook

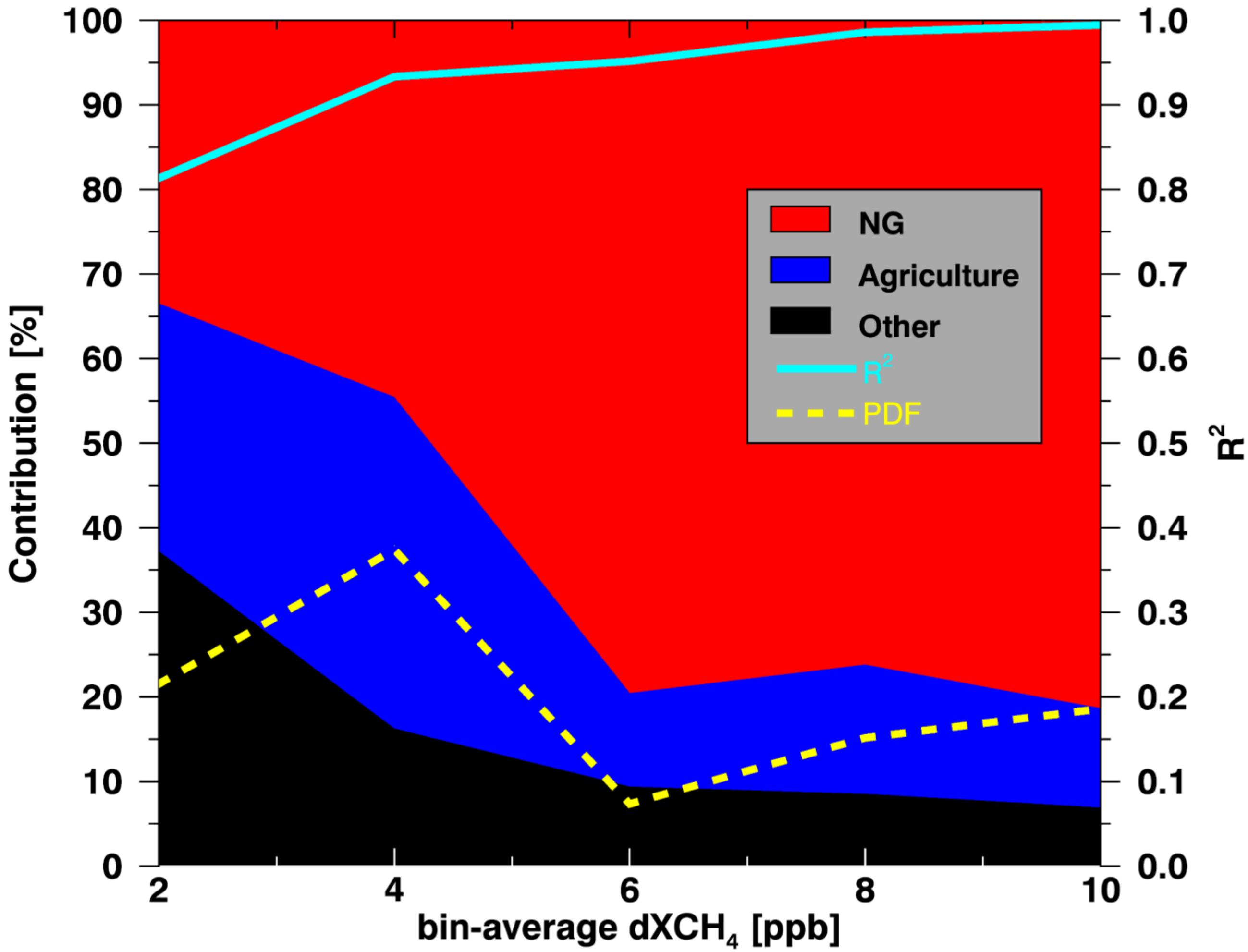
- Measurement campaign in Colorado Front Range March 2015
- Methane enhancements up to ΔXCH_4 = 17 ppb
- ΔXCH_4 variance explained by variations in C_2H_6 – NH_3 tracer pair using a linear regression analysis
  - 63 ± 17 % natural gas
  - 25 ± 10 % agriculture
  - 12 ± 12 % other sources
- Good agreement with in situ studies
- $\Delta XC_2H_6/\Delta XCH_4$ ratio of 16 ± 2 % indicates wet natural gas

Extra slides

Percent contributions from different sources as function of β_0



Percent contributions as function of ΔXCH_4



Averaging kernels