A Global Calibration for the Total Carbon Column Observing Network (TCCON) using HIPPO Aircraft Profiles

Debra Wunch, Geoffrey C. Toon, Steven Wofsy, Britton Stephens, Eric Kort, Jean-Francois L. Blavier, Tomoaki Tanaka, Isamu Morino, Osamu Uchino, Gretchen Keppel-Aleks, Vanessa Sherlock, Brian Connor, Nicholas Deutscher, David Griffith, Ronald Macatangay, Paul O. Wennberg

Acknowledgments

TCCON Team: G. C. Toon, J.-F. L. Blavier, T. Tanaka, I. Morino, O. Uchino, G. Keppel-Aleks, V. Sherlock, B. Connor, N. Deutscher, D. Griffith, R. Macatangay, P. O. Wennberg
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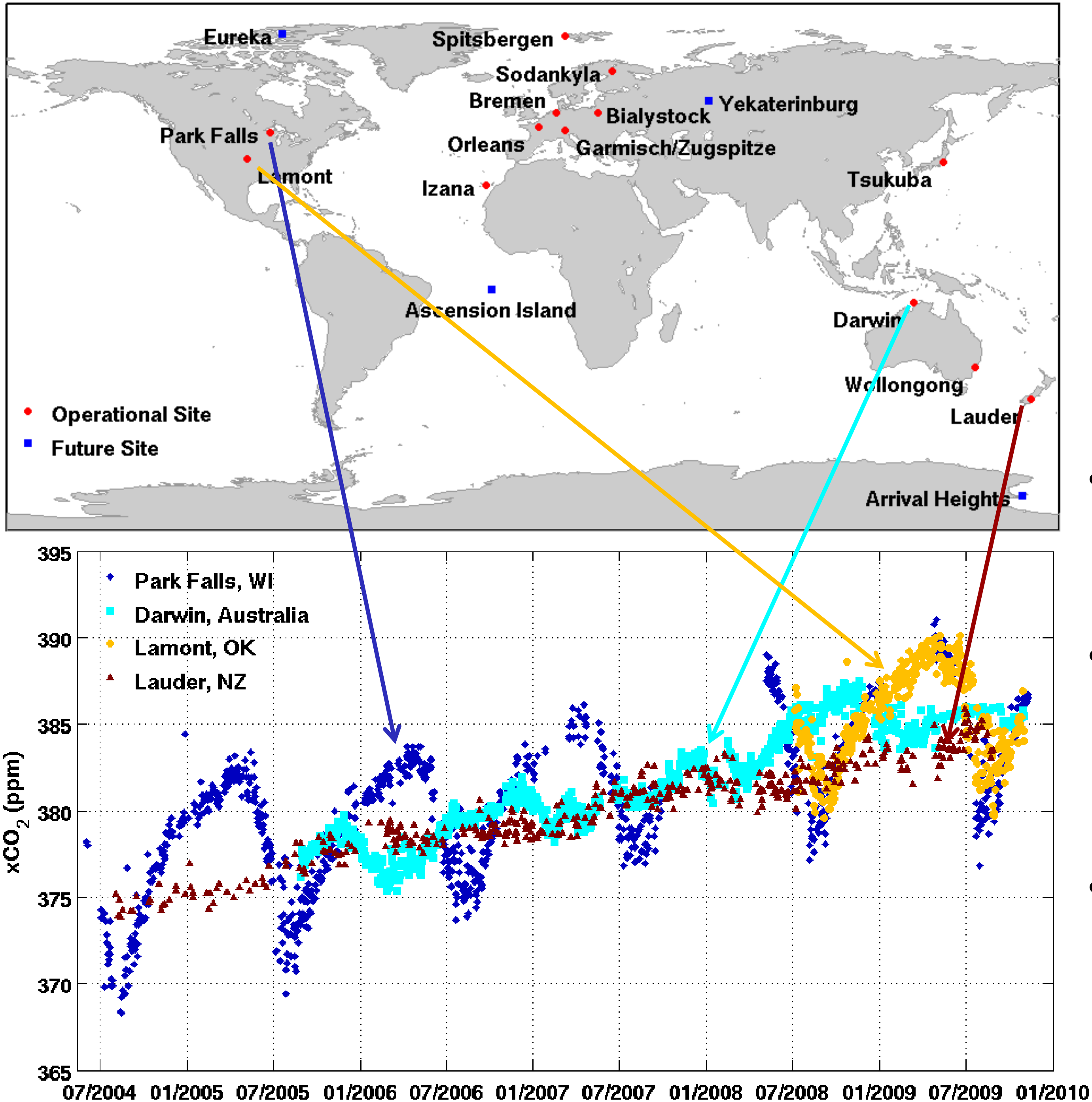
START08 and HIPPO1 Teams: S. Wofsy, B. Stephens, K. P. Bowman
CO_2 (OMS and QCLS): E. Kort, B. C. Daube, S. Park, R. Jimenez, E. Gottlieb, S. Wofsy; QCLS CH_4, N_2O and CO: E. Kort, B. C. Daube, S. Park, R. Jimenez, S. Wofsy; UCATS: D. Hurst; VECSEL H_2O: M. Zondlo
Funding: NSF with instrumentation support from NOAA

SGP/ARM Aircraft Team: M. Fischer, J. Abshire, E. Browell, S. Biraud

ACE Science Team: P. Bernath, S. McLeod, C. Boone, K. Walker

Total Carbon Column Observing Network (TCCON)



- Ground-based Fourier transform spectrometers
- Remote sensing of total columns of CO_2, CH_4, N_2O, CO, O_2 via solar absorption
- Divide trace gas columns by O_2 column to get dry-air mole fractions: xCO_2, xCH_4, xN_2O, xCO

TCCON as a Resource for Satellite Validation

- Means of calibration for measurements of greenhouse gases from satellites (GOSAT, SCIAMACHY, AIRS, TES), which measure column-averaged mixing ratios
- TCCON achieves high precision
- TCCON ***accuracy*** depends on spectroscopy and other external information about the atmosphere to retrieve total columns

Molecule	Precision
CO_2	~1 ppm
CH_4	~5 ppb
N_2O	~1.5 ppb
CO	~0.5 ppb

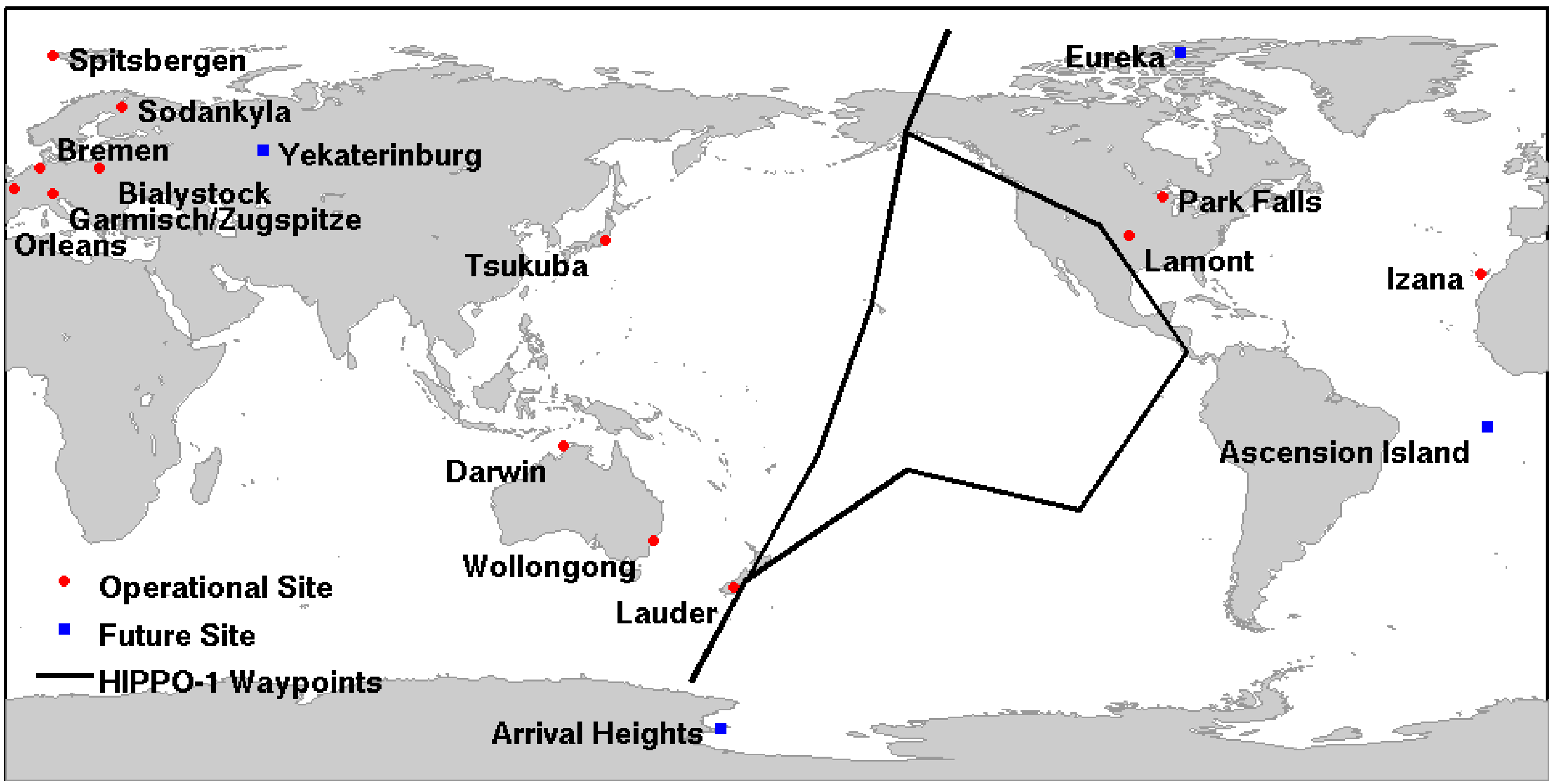
- Unfortunately, current accuracy requirements to determine sources/sinks/fluxes are more stringent than current spectroscopy allows
- TCCON must be calibrated to WMO-standards

TCCON Overpasses

Site	Aircraft Campaign	Gases Measured	Dates
Park Falls	INTEX-NA COBRA START-08	CO_2, CO, H_2O CO_2, CO, H_2O CO_2, CH_4, N_2O, CO, H_2O	July 2004 July/Aug 2004 May 2008
Darwin	TWP-ICE	CO_2	Feb 2006
Lamont	**HIPPO** Lear	CO_2, CH_4, N_2O, CO, H_2O CO_2, CH_4, N_2O, CO	Jan 2009 Aug 2009
Lauder	**HIPPO**	CO_2, CH_4, N_2O, CO, H_2O	Jan 2009
Tsukuba		CO_2, CH_4, N_2O	Jan 2009

The Hiaper Pole-to-Pole Observations (HIPPO)

- "Utilize observed distributions of major greenhouse gases to help determine their continental-scale sources and sinks"
- NCAR Gulfstream V
- HIPPO-1 performed 135 vertical profiles over various locations
  - During HIPPO-1 (January 2009), performed overpasses of Lamont, OK, USA and Lauder, New Zealand, measuring CO_2, CH_4, N_2O, CO, H_2O



Mathematical Approach Rodgers and Connor (2003)

Compare two instruments, one of which has much higher vertical resolution than the other, use equation (4) of Rodgers and Connor (2003)

$$\hat{\mathbf{x}} = \mathbf{x_a} + \mathbf{A}(\mathbf{x_t} - \mathbf{x_a})$$

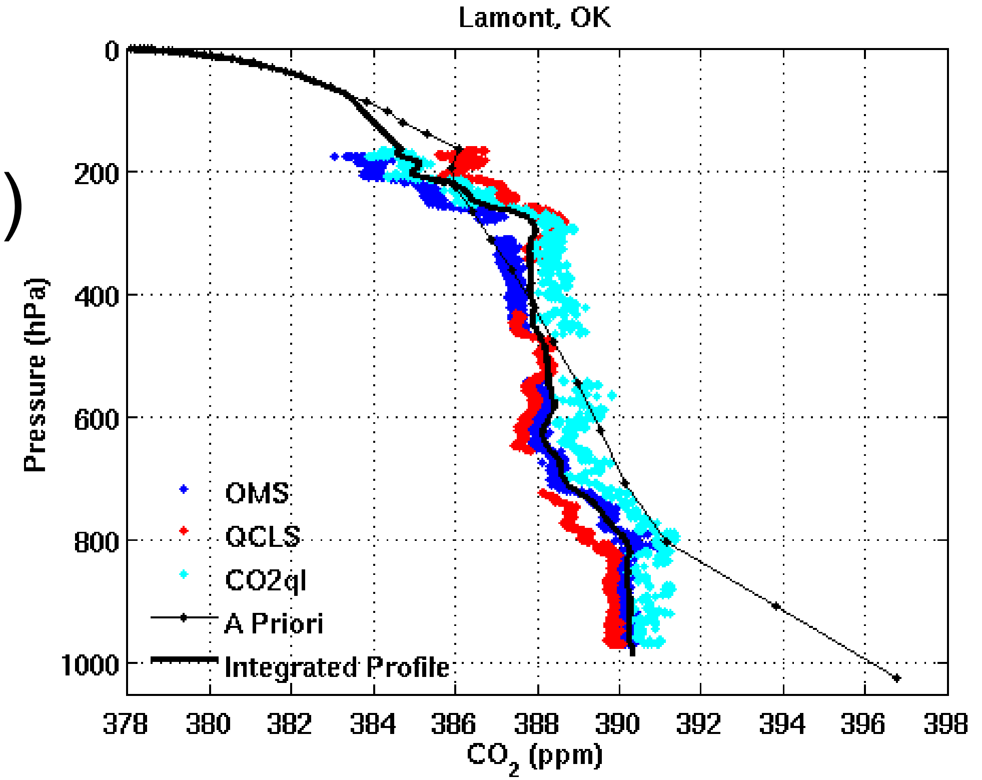
x_a is the *a priori* profile, x_t is the aircraft profile, A is the averaging kernel

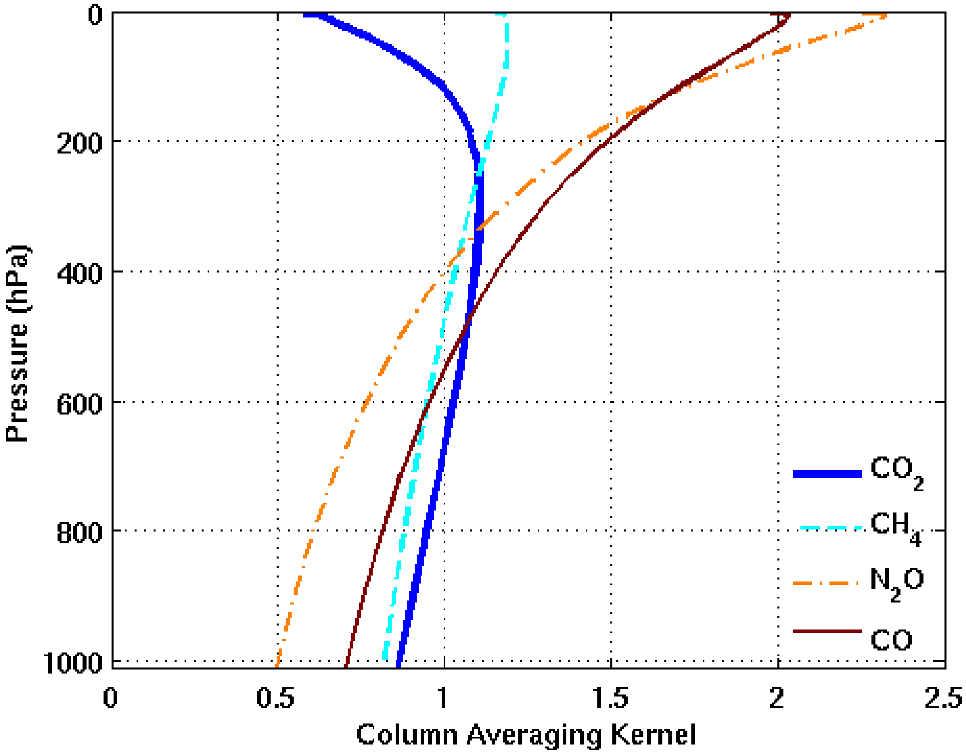
To compare the DMFs of each instrument, integrate the above equation

$$\hat{c} = \gamma c_a + \mathbf{a}^{\mathbf{T}}(\mathbf{x_t} - \gamma \mathbf{x_a})$$

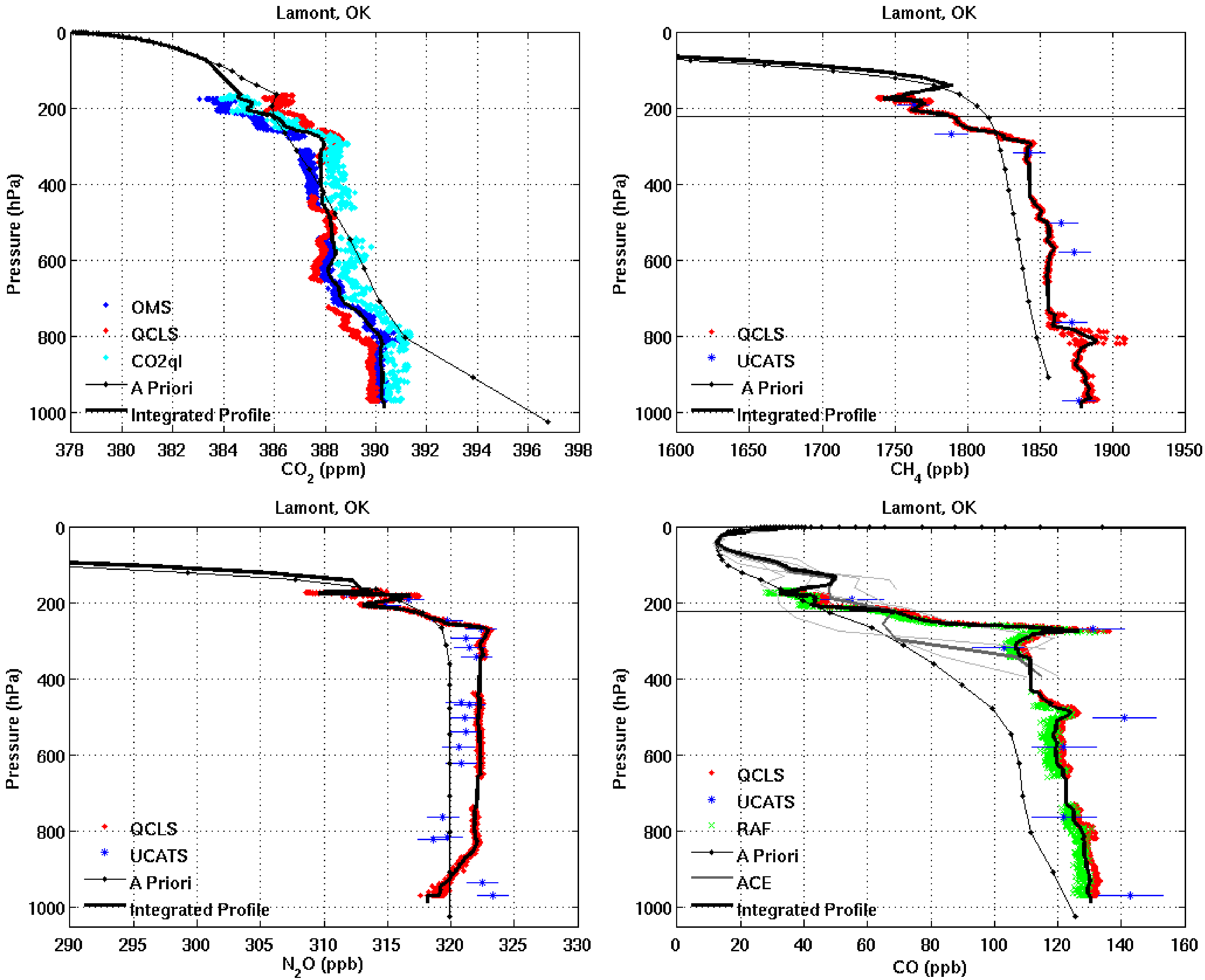
ĉ is the retrieved DMF of the aircraft, smoothed by the FTS column averaging kernel, a^T, gamma is the FTS retrieval scale factor

Lack of stratospheric in situ data is largest contributor to uncertainty in the calibration

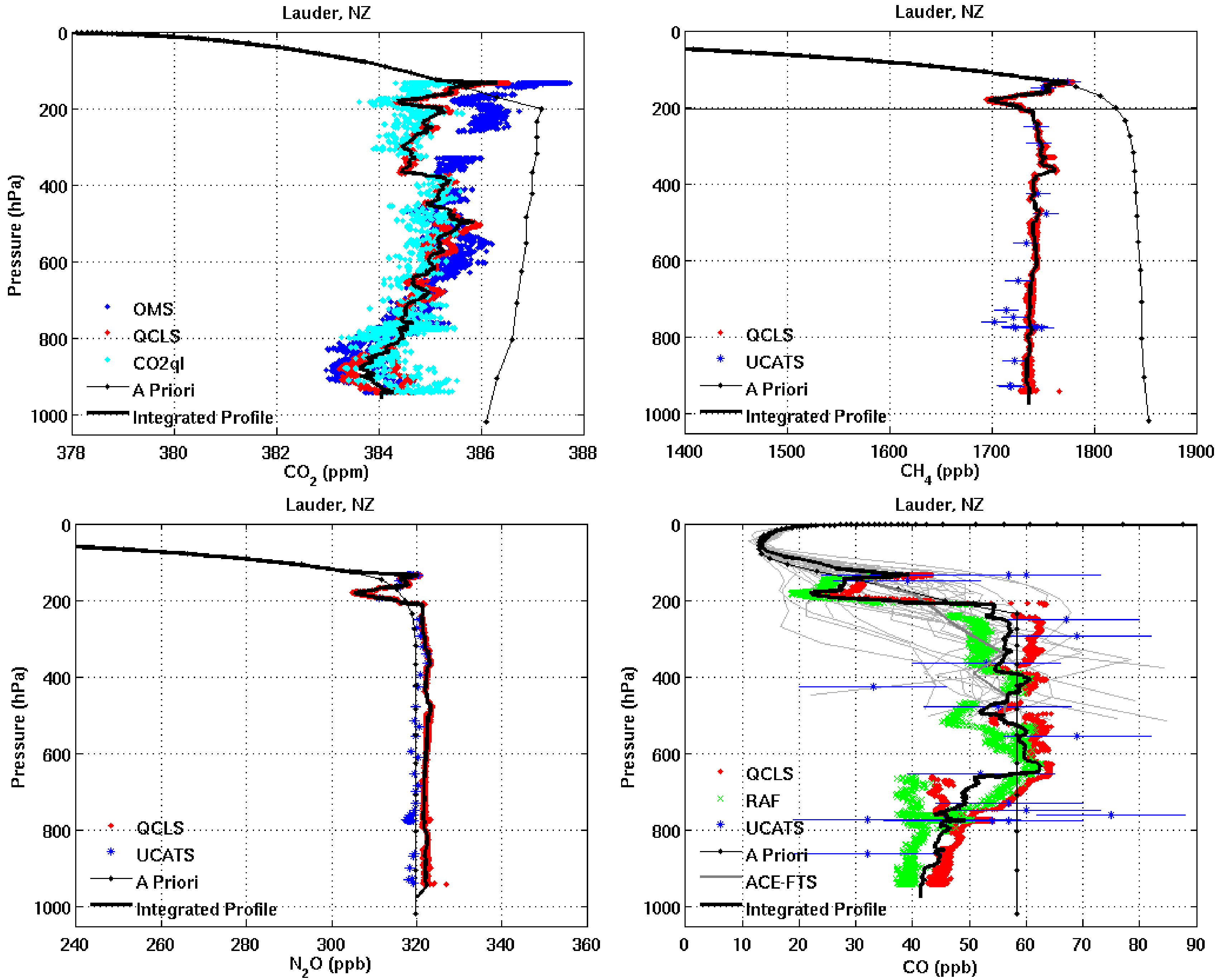




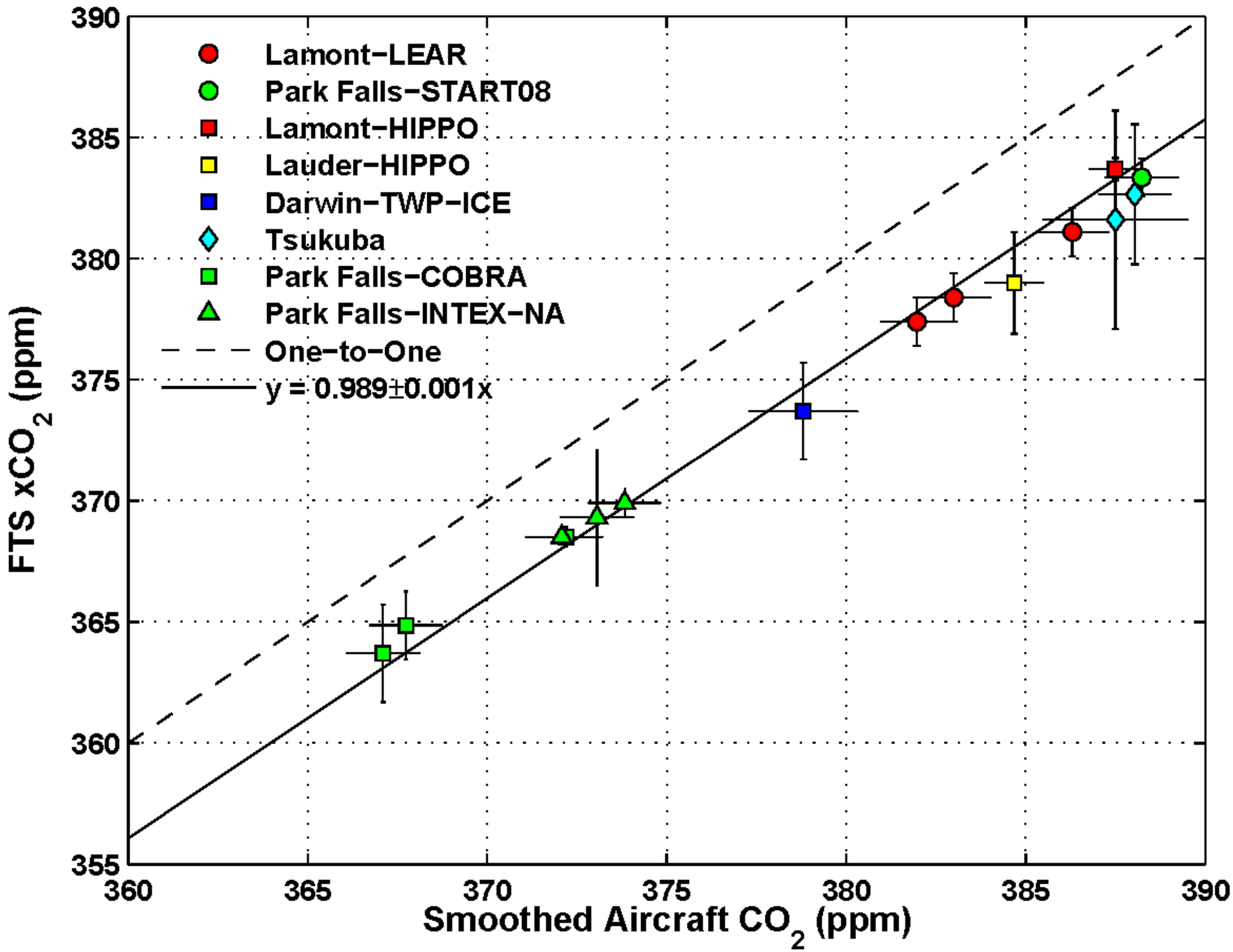
HIPPO Overpass of Lamont, OK



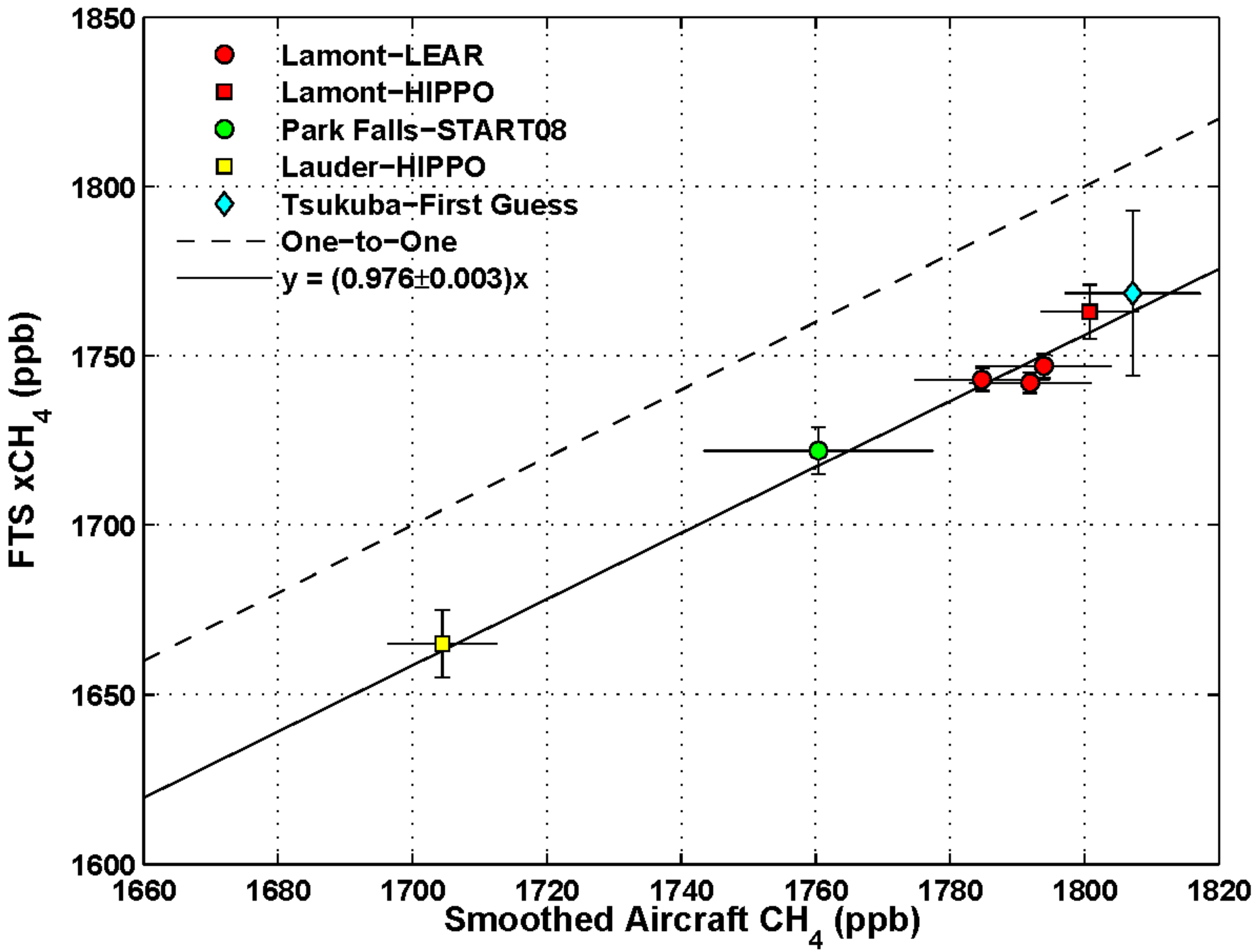
HIPPO Overpass of Lauder, NZ



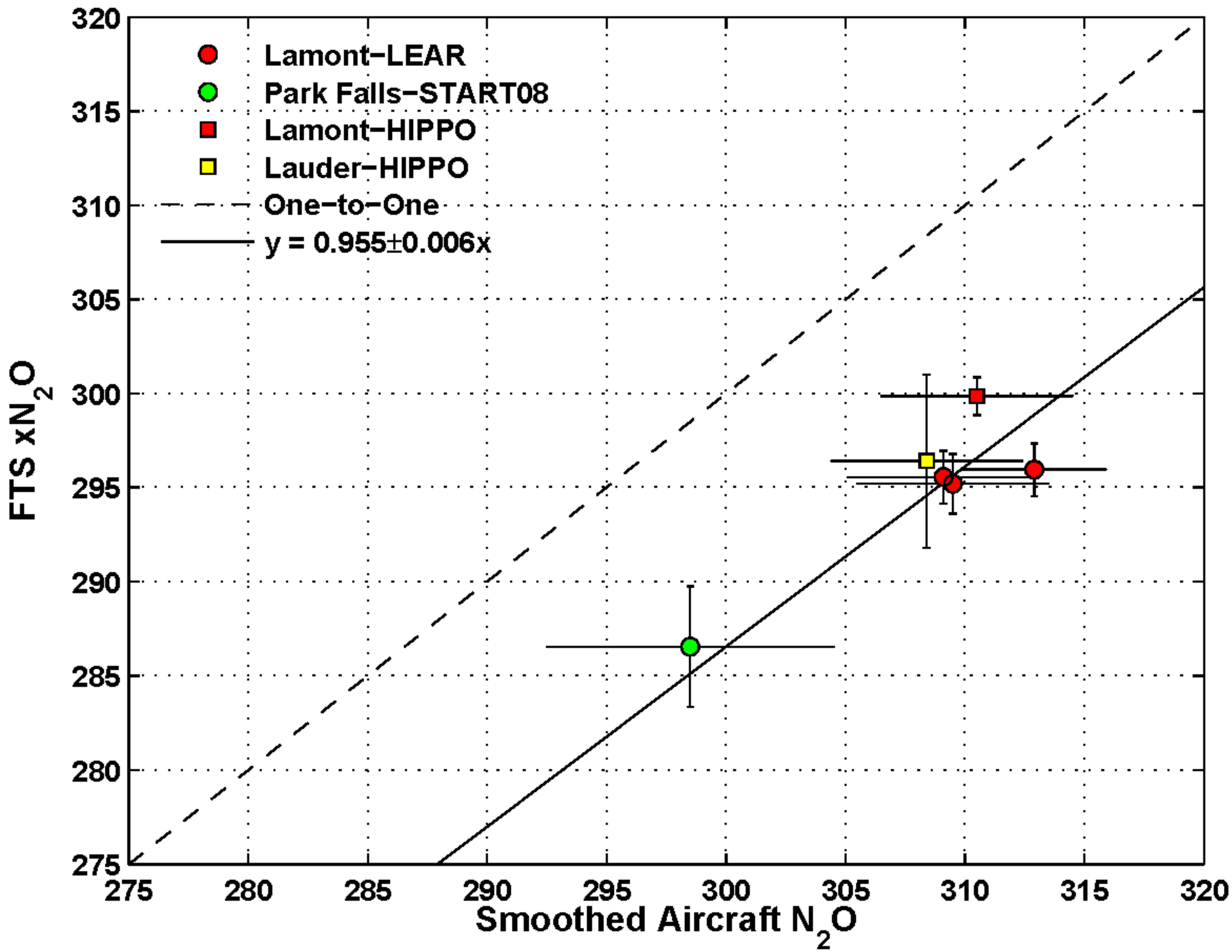
Preliminary Calibration of xCO_2



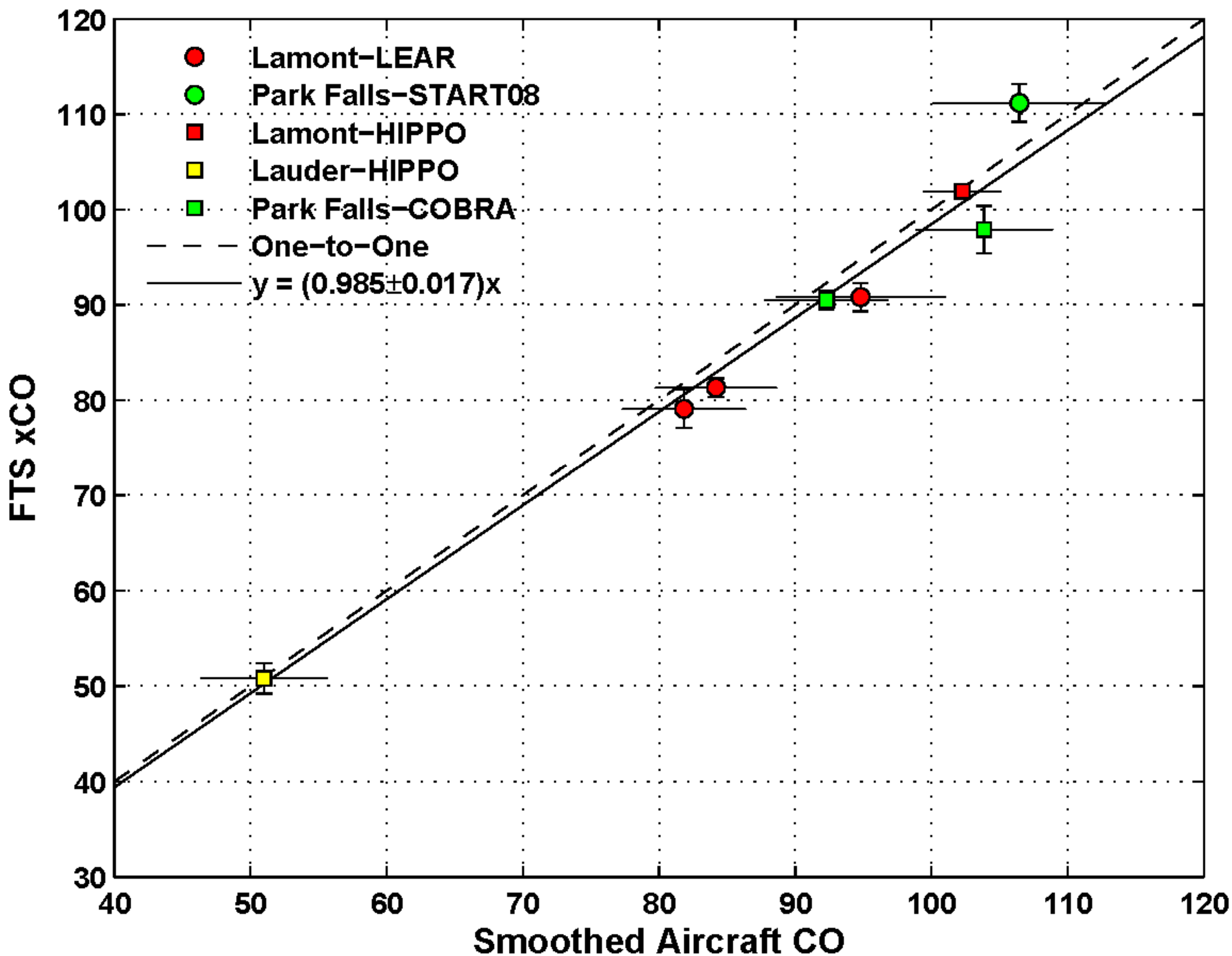
Preliminary Calibration of xCH_4



Preliminary Calibration of xN_2O



Preliminary Calibration of xCO



Summary

- TCCON provides the ideal data for satellite validation
  - Measures column abundances, the same quantities as satellites
  - Measures same molecules in the same spectral regions
- HIPPO and other WMO-standard aircraft profiles over TCCON stations are *crucial* for proper calibration
  - Need to extend as high as possible into the stratosphere
- After applying the HIPPO calibrations, TCCON data is currently *precise* and *accurate* to

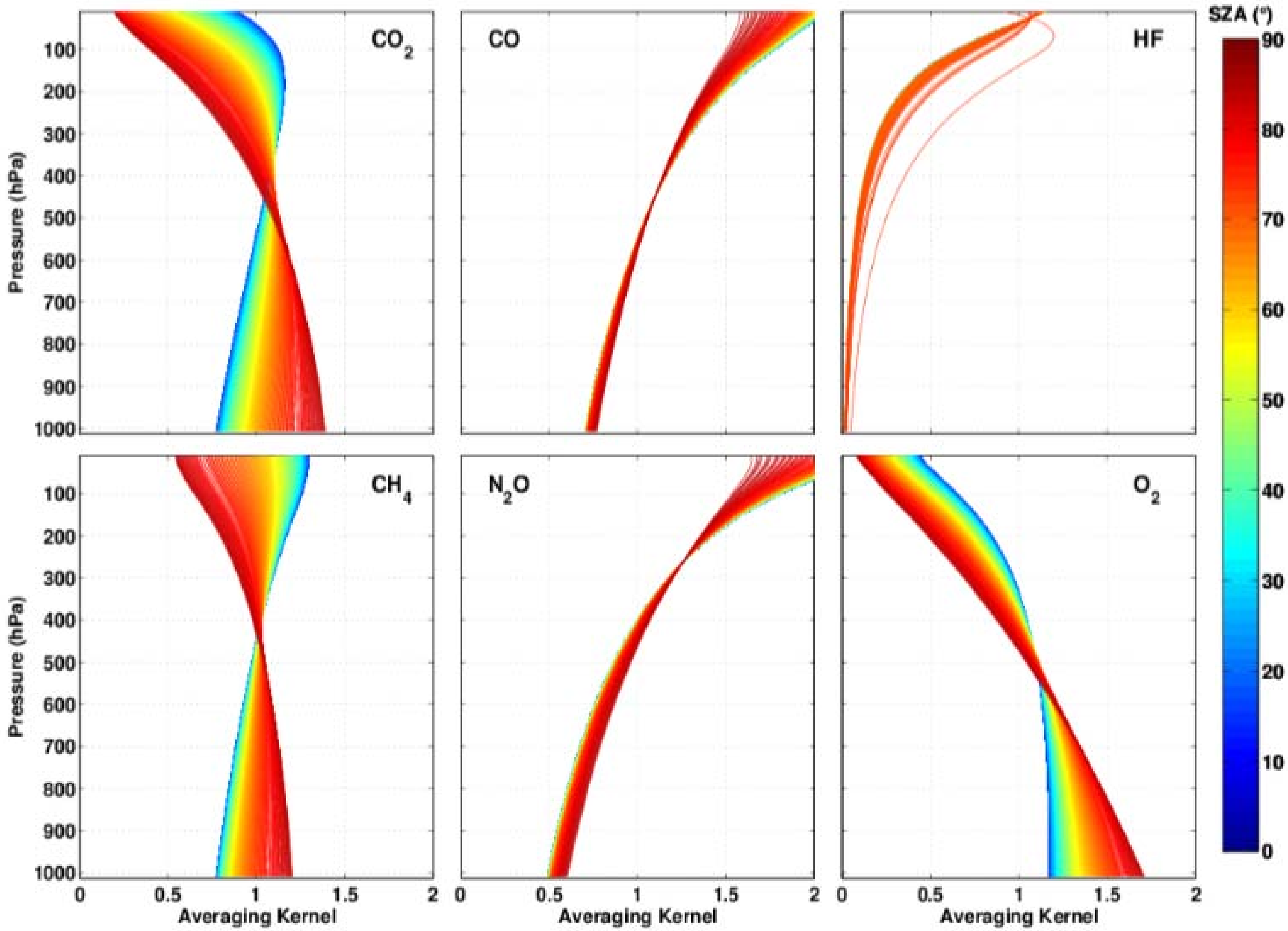
Molecule	Precision	Accuracy
CO_2	~1 ppm	~1 ppm
CH_4	~5 ppb	~5 ppb
N_2O	~1.5 ppb	<3 ppb
CO	~0.5 ppb	~3 ppb

- Prospects are good for future improvements
- More info can be found at http://www.tccon.caltech.edu

Other TCCON-Related Posters

- **A51A.** Atmospheric Carbon Dioxide: Observation, Validation, Modeling, and Assimilation III Posters. **Fri, Dec 18 - 8:00 AM**
- **A51A-0080**. Side by side Measurements of Greenhouse Gases by Ground-Based Fourier Transform Infrared (FTIR) Spectrometery. *J. Messerschmidt; C. Weinzierl; R. Macatangay; T. Warneke; J. Notholt*
- **A51A-0107**. Determination of Tropospheric Volume Mixing Ratios of CH_4 and N_2O from TCCON Column Measurements. *C. M. Roehl; V. Sherlock; B. J. Connor; D. Wunch; G. C. Toon; D. W. Griffith; N. M. Deutscher; P. O. Wennberg*
- **A51A-0097**. Coincident retrievals of CO and CO2 from high resolution solar absorption spectrometry. *G. Keppel-Aleks; P. O. Wennberg; D. Wunch; G. C. Toon; C. M. Roehl; N. M. Deutscher; D. W. Griffith*
- **A51A-0092**. Ground-based Total Column and in situ measurements of CO_2 and CH_4 in the Southern Hemisphere, and an update to GOSAT/ground-based FTS comparisons.. *N. M. Deutscher; D. W. Griffith; N. B. Jones; V. Sherlock; D. Smale; I. Morino; O. Uchino; B. J. Connor; P. O. Wennberg; D. Wunch; G. C. Toon; G. Keppel-Aleks; R. Macatangay; J. Robinson*

TCCON Column-Averaging Kernels



Mathematical Approach

The vertical column (*VC*) of gas *G* is computed by integrating the dry-air mole fraction (f^{dry}) profile:

$$VC_{G,ak} = \frac{1}{\{g_G\} \cdot m_{air}^{dry}} \int_0^{Ps} \frac{f_G^{dry}(p) \cdot a(p)}{\left[1 + f_{H_2O}^{dry}(p) \cdot (m_{H_2O} / m_{air}^{dry})\right]} dp$$

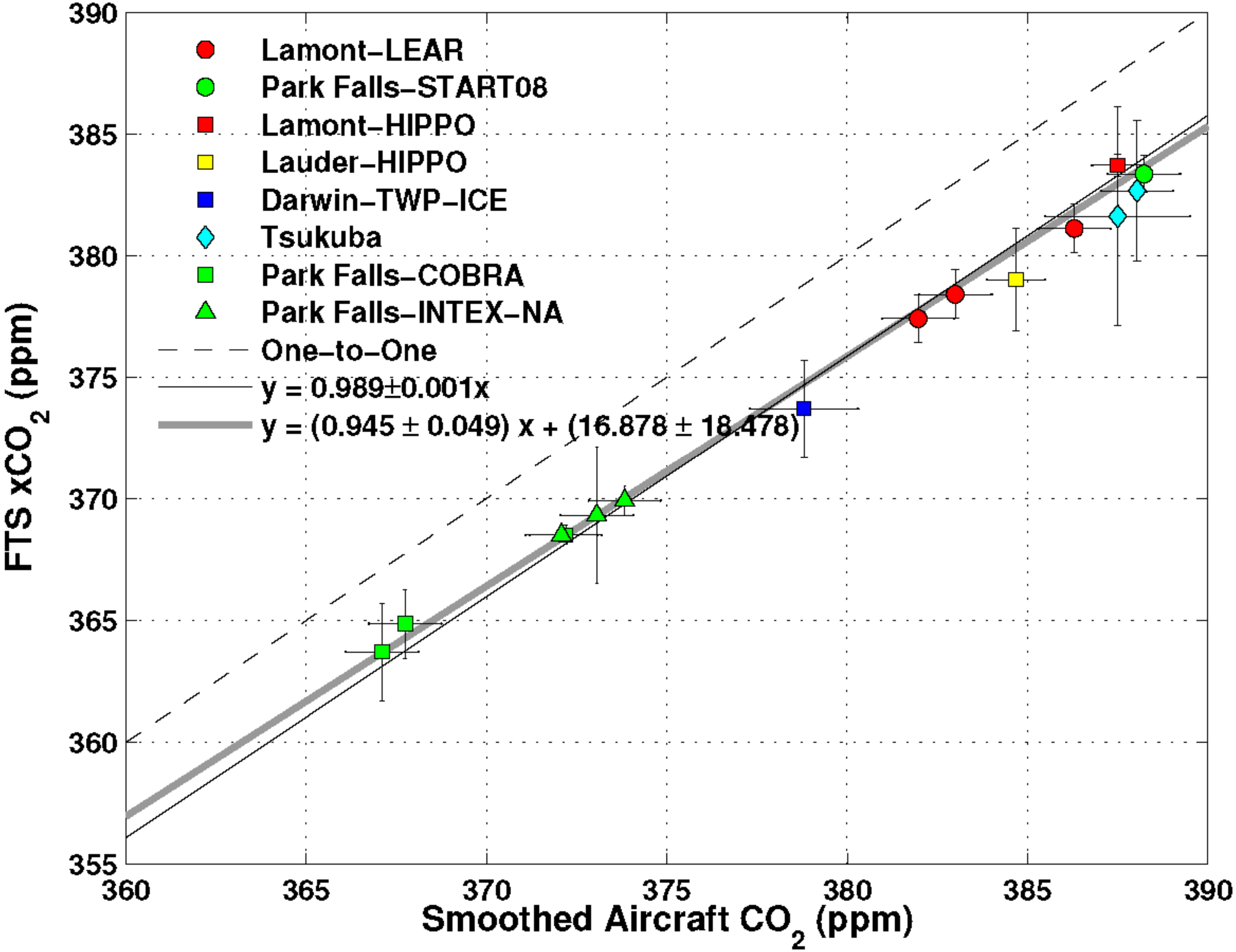
This is divided by the total column of air

$$VC_{air} = \frac{1}{\{g_G\} \cdot m_{air}^{dry}} \int_0^{Ps} \frac{1}{\left[1 + f_{H_2O}^{dry}(p) \cdot (m_{H_2O} / m_{air}^{dry})\right]} dp$$

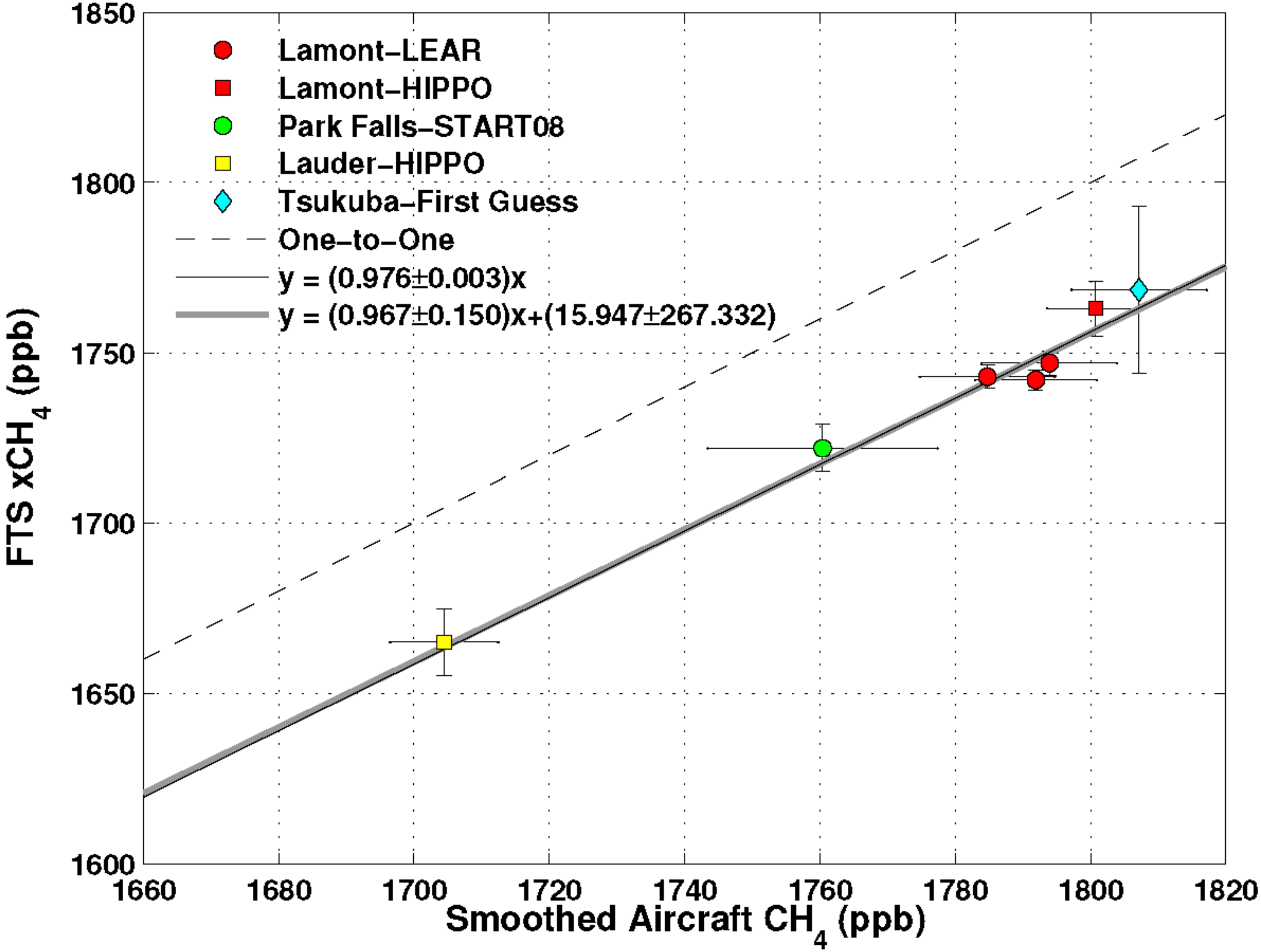
to get the DMF:

$$\hat{c} = \gamma \frac{VC_G^{a\ priori}}{VC_{air}} + \left(\frac{VC_{G,ak}^{aircraft} - \gamma VC_{G,ak}^{a\ priori}}{VC_{air}} \right)$$

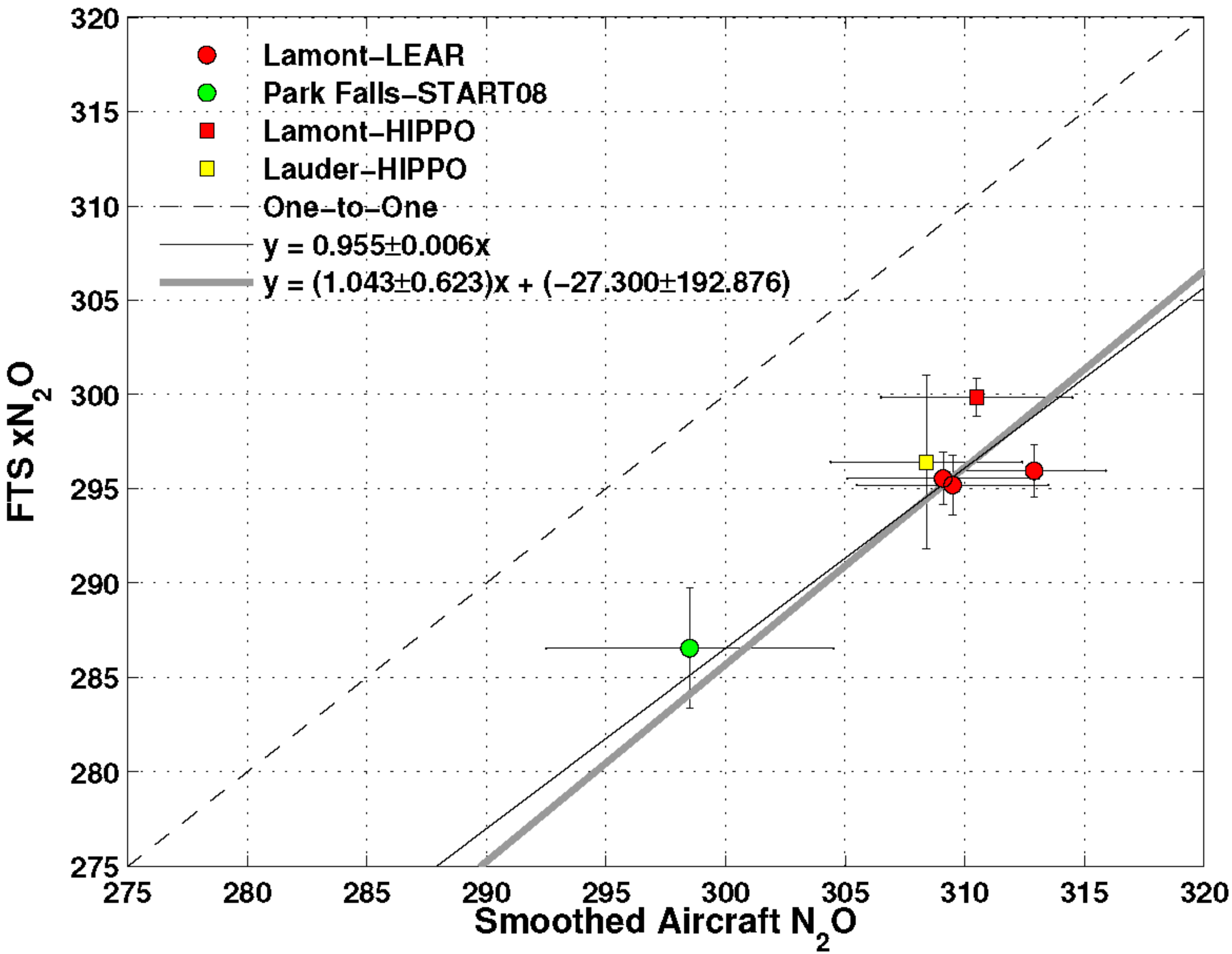
Preliminary Calibration of xCO_2



Preliminary Calibration of xCH_4



Preliminary Calibration of xN_2O



Preliminary Calibration of xCO