Airborne In Situ CO_2 Measurements Used in Validation of Remote Sensing Measurements

[1]Stephanie Vay, [2]Yonghoon Choi, [1]Edward Browell, [1]Wallace Harrison, [3]Susan Kooi

[1]NASA Langley Research Center, Chemistry and Dynamics Branch, Hampton, VA 23681
[2]National Institute of Aerospace, Hampton, VA 23666
[3]SSAI, Hampton, VA 23666

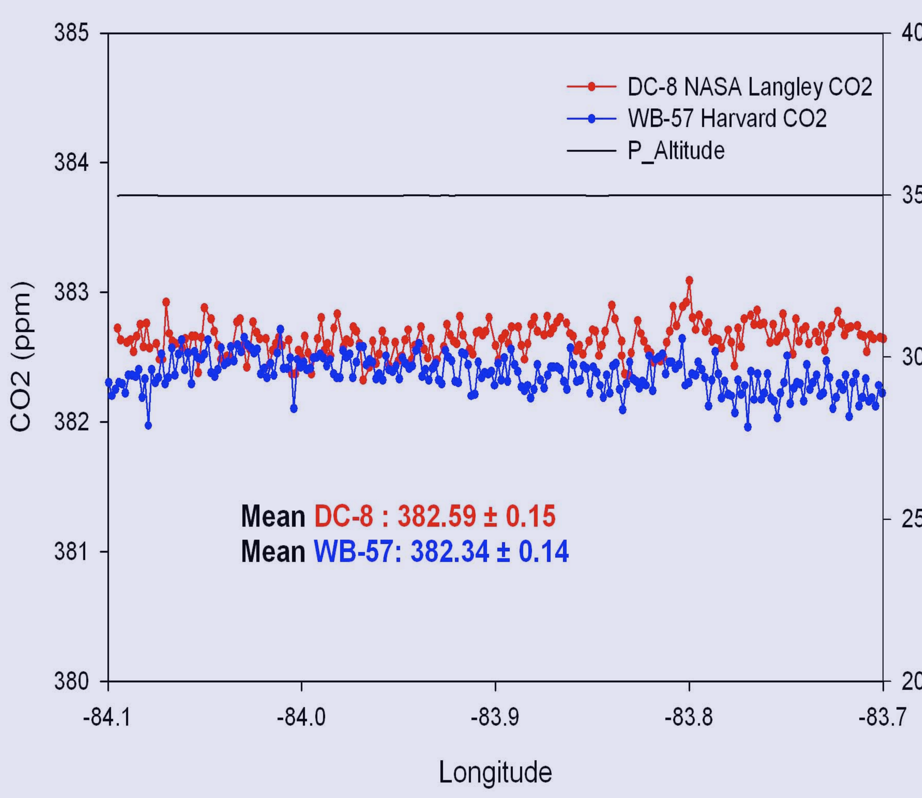
Contact Information: Stephanie.A.Vay@nasa.gov 757-864-1574

Atmospheric Vertical Observations of AVOCET CO2 in the Earth's Troposphere

INTRODUCTION: The validation of observations from remote sensors is an important objective of airborne field campaigns conducted under NASA's Tropospheric Chemistry Program. Through the quantitative comparison of retrievals and in-situ measurements from aircraft, the validation of remotely-sensed observations is feasible. As remote CO_2 sensors are evolving, airborne in-situ CO_2 measurements gain importance for evaluation of retrieved products. Since 1991, NASA LaRC has been funded to conduct airborne observations of atmospheric CO2 during numerous international field campaigns (e.g. PEM-WEST, TRACE, PEM-Tropics, INTEX, ARCTAS). Carbon dioxide measurements are made with an infrared gas analyzer (LI-COR) based sampling system. This instrument offers many high performance capabilities including high accuracy (± 0.25 ppm) and precision (0.1 ppm); fast-response; continuous; and real-time measurements. CO2 concentrations are established relative to the WMO primary calibration standards maintained by NOAA GMD.

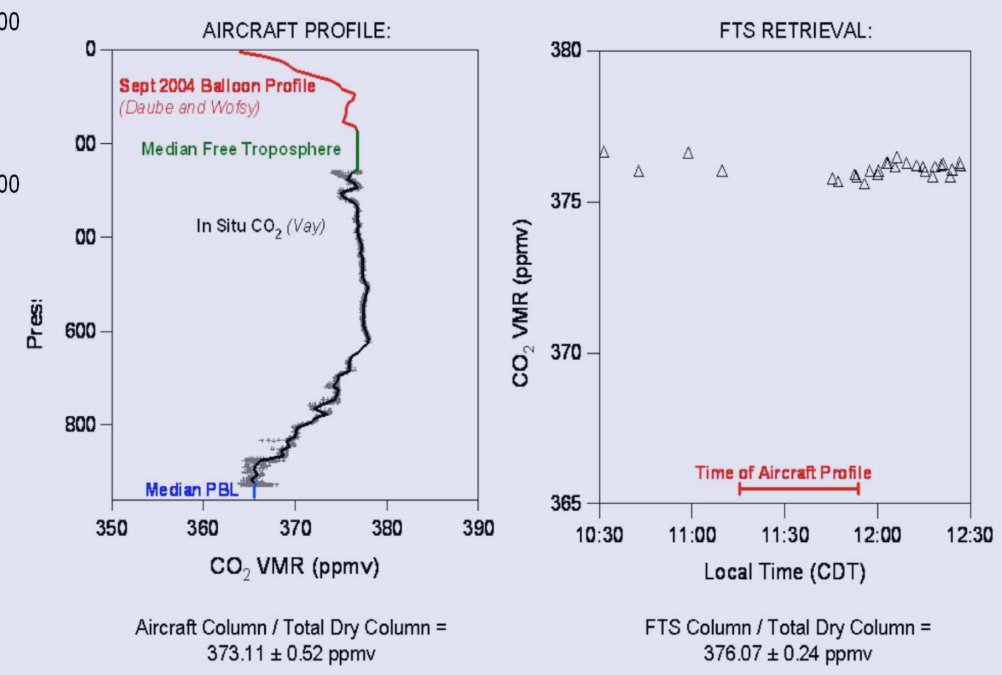
Intercomparison:
Two in-flight intercomparisons with the Harvard instrument (S. Wofsy) during SOLVE-I (DC-8, ER2) and TC4 (DC-8, WB-57) show good agreement (≤ 0.25 ppm). Intercomparison (left) between the DC-8 (NASA LaRC) and WB-57 (Harvard) during TC4 on 20080807 at 35 kft [382.59 ± 0.15 (LaRC) and 382.34 ± 0.14 (Harvard)]. Comparison was made with a 1:1 match of 1s data along the same longitude.

20070808 Intercomparison

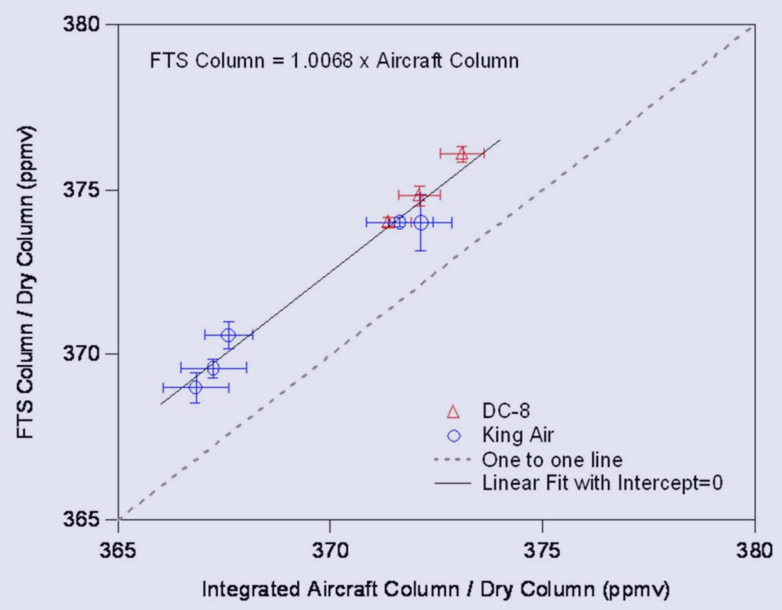


In-situ measurement for validation: Since in-situ measurements are done frequently and at high accuracy on the global calibration scale, linking this scale with total column retrievals ultimately provides a calibration scale for remote sensing. During the summer of 2004, vertical profiles by the DC-8 (LaRC) and King Air (Harvard) at the WLEF Tall Tower site provided validation of column measurements by a solar-based observatory within the Total Carbon Column Observing Network envisioned for OCO validation [Washenfelder et al., 2006]. (Right)

FTS Column and Aircraft In Situ Data – 12 July 04



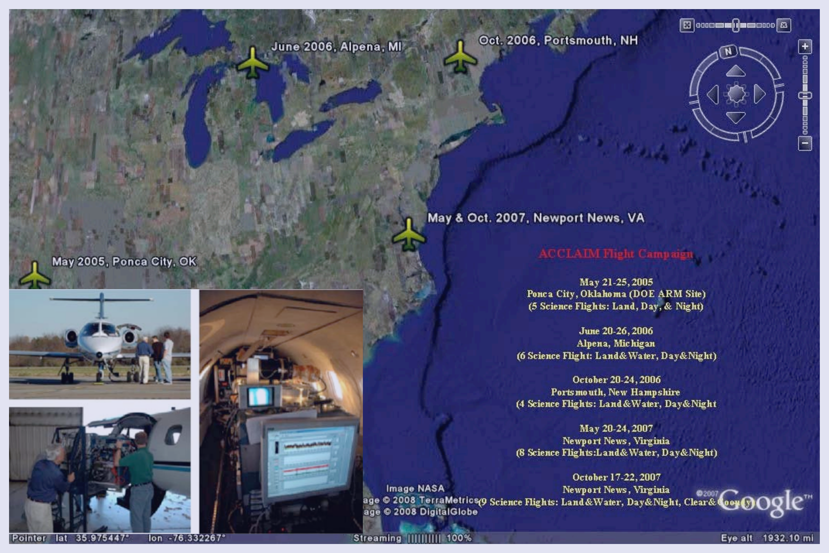
Comparison of FTS Column and Integrated Aircraft CO_2

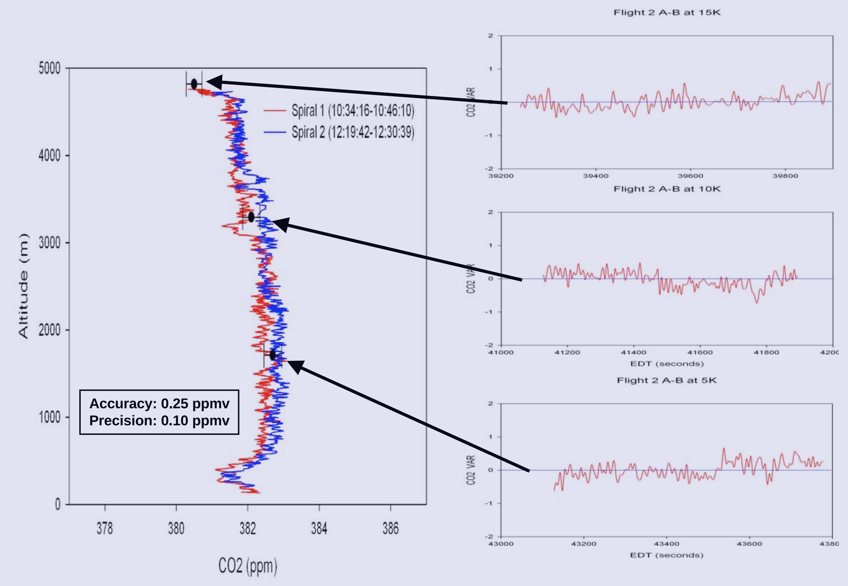


	LMDz_integr		TM3_integr		TOVS	
	Bias	RMS	Bias	RMS	Bias	RMS
PEMTROPICSA	-0.08	0.49	-0.3	0.64	-1.4	1.98
PEMTROPICSB	0.25	0.92	0.18	0.97	0.61	1.41
PEMWESTA	0.77	1.26	0.84	1.32	0.83	1.32
PEMWESTB	-0.23	0.61	-0.55	0.75	0.61	1.31
TRACEA	-0.27	1.78	-0.7	1.85	1.62	2.4
TRACEP	-0.02	0.96	-0.54	1.07	-0.1	2.05
BIBLE-A	-0.71	0.95	-0.74	1.01	-0.38	1.02
BIBLE-B	-0.96	1.12	-1.05	1.21	-1.7	1.77
BIBLE-C	-0.66	0.81	-0.59	0.74	3.15	3.73
MATSUEDA	-0.08	0.83	0.01	0.88	0.3	1.88
CARIBIC	0.77	1.42	0.61	1.34	1.61	2.64
All campaigns	-0.1	0.96	-0.27	1.04	0.3	2.03

LaRC high resolution in-situ CO_2 measurements contribute to evaluating model simulations, TOVS-CO_2 and AIRS retrievals [Peylin et al., 2007; Chahine et al., 2008]. (Left)

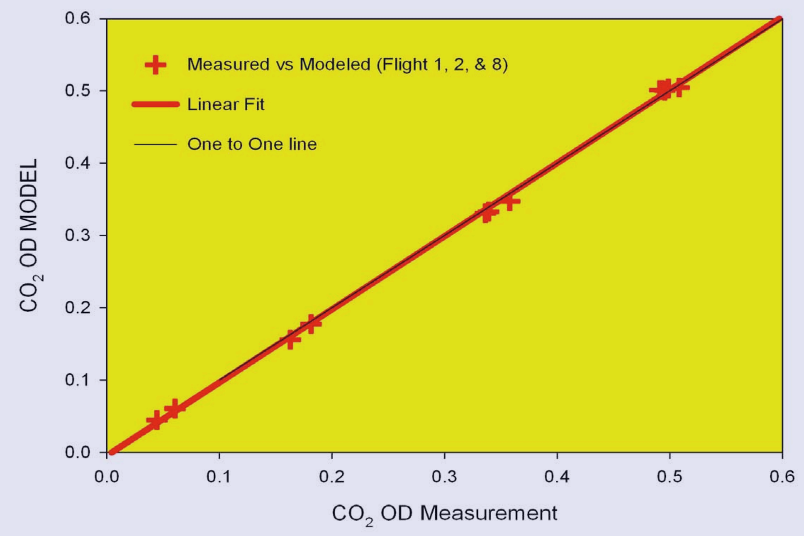
In-situ Validation for Advance Carbon and Climate Laser International Mission (ACCLAIM)





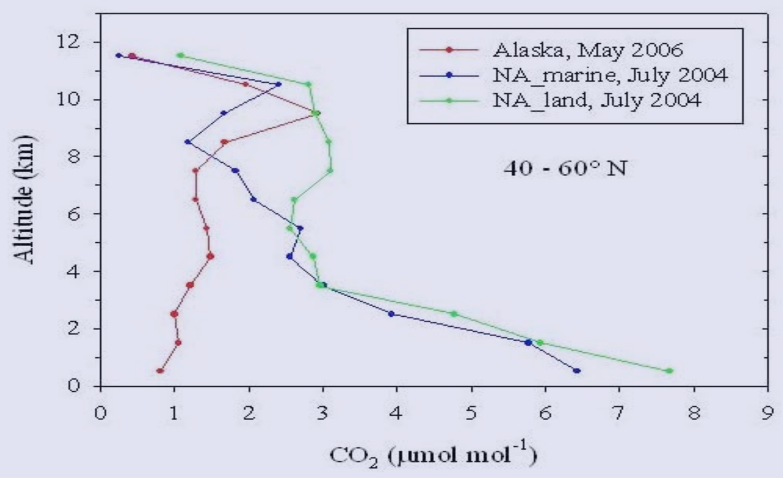
FLIGHT	FILE	Start Hour	End Hour	Altitude	CO2 Optical Depths (OD) & Mixing Ratios (MR)					
					OD MEASURED (M)	MR MEASURED (M)	OD MODELED (A)	MR MODELED (A)	OD DIFF (%)	MR DIFF (ppm)
1	2	16.213	16.325	4701	0.4955	378.6	0.5005	382.5	-1.01	-3.8
	3	16.383	16.445	4702	0.4934	376.7	0.5008	382.5	-1.49	-5.6
	4	16.585	16.634	4700	0.4909	374.8	0.5010	382.5	-2.00	-7.6
2	3	10.795	10.806	4725	0.5081	385.0	0.5045	382.3	0.70	2.7
	4	10.95	10.97	4715	0.4986	379.8	0.5032	382.3	-0.91	-3.5
	7	11.505	11.515	3306	0.3579	394.3	0.3474	382.4	3.05	11.6
	9	11.988	12.024	1720	0.1813	390.2	0.1778	382.4	1.98	7.5
5*	5	11.31	11.44	5382	0.6127	383.8	0.6142	384.7	-0.25	-0.9
	6	11.56	11.672	3126	0.3574	388.1	0.3560	386.6	0.39	1.5
	7	11.82	12	1526	0.1758	395.7	0.1737	391.2	1.19	4.5
	8	12.07	12.092	1524	0.1771	394.6	0.1755	391.2	0.90	3.4
6*	4	19.9	20	5398	0.6221	389.1	0.6154	385.0	1.07	4.1
	5	20.2	20.354	3141	0.3567	385.6	0.3579	386.9	-0.35	-1.3
7*	5-W	10.94	11.02	3127	0.3567	385.3	0.3554	383.9	0.37	1.4
	7-L	11.145	11.2	3132	0.3536	383.4	0.3541	383.9	-0.14	-0.5
8	2	4.88	4.96	3153	0.3392	391.6	0.3328	384.0	1.92	7.3
	3	5.07	5.17	3144	0.3363	390.2	0.3310	384.0	1.58	6.0
	4	5.28	5.44	1543	0.1631	393.4	0.1599	385.3	2.03	7.7
	5	5.52	5.67	599	0.0606	384.3	0.0608	386.0	-0.48	-1.8
	6	5.73	5.95	597	0.0605	386.2	0.0605	386.0	-0.01	0.0
	7	6.055	6.15	447	0.0444	379.9	0.0451	386.0	-1.62	-6.2
* Operational mode change, in-flight calibration on Flt 7, Leg 8, and altitudes limited to <5500 m.						Average	384.84	0.33	1.25	
						Std Dev	2.62	1.35	5.13	

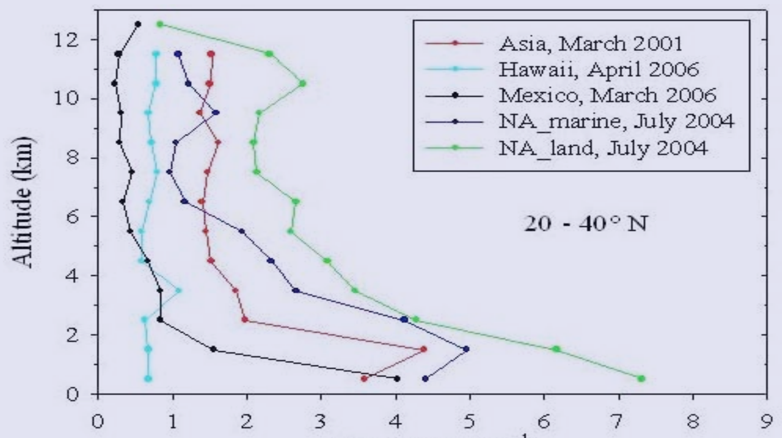
In-situ CO_2 Measurement on 20071018 showing the variation during a level leg and spiral

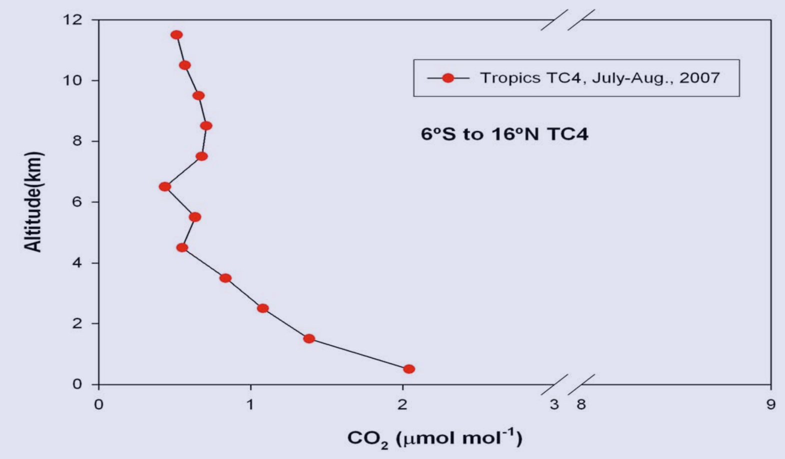


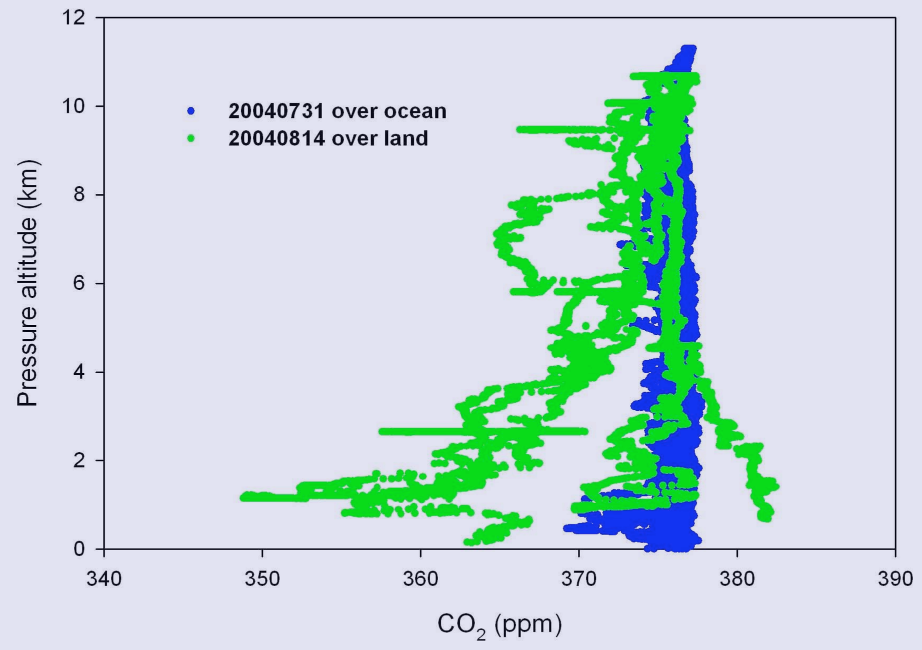
CO_2 OD and Mixing ratio Comparisons

[See Browell et al. Poster #61]









CO_2 vertical distributions observed during INTEX-NA over land vs. ocean without averaging effects and the standard deviation of the mean profiles from prior campaigns show the spatiotemporal variability of CO_2 within the free troposphere; a region where it has been presumed that CO_2 exhibits a uniform distribution. This relatively large variability is mostly unaccounted for in global simulations of CO_2 by three-dimensional chemistry and transport models. Remote sensors can contribute to reducing the uncertainty in retrieved fluxes on regional scales given their large spatial and temporal coverage.

References:
•Washenfelder et al., Carbon dioxide column abundances at the Wisconsin Tall Tower site, J. Geophys. Res., D22305, doi:10.1029/2006JD07154, 2006
•Peylin et al., Evaluation of Television Infrared Observation Satellite (TIROS-N) Operational Vertical Sounder (TOVS) spaceborne CO_2 estimates using model simulations and aircraft data, J. Geophys. Res., 112, D09313, doi:10.1029.2005JD007018, 2007
•Chahine et al., First Satellite Remote Sounding of the Global Distribution of Mid-Tropospheric CO_2, Nature, submitted, 2008

Acknowledgements: This research was supported by NASA Langley Research Center and NASA's Tropospheric Chemistry and Radiation Science Programs.