Supplement of Atmos. Chem. Phys., 17, 15151–15165, 2017
https://doi.org/10.5194/acp-17-15151-2017-supplement

Atmospheric Chemistry and Physics
Open Access
EGU

Supplement of

Gradients of column CO_2 across North America from the NOAA Global Greenhouse Gas Reference Network

Xin Lan et al.

Correspondence to: Xin Lan (xin.lan@noaa.gov)

Code	Name	Latitude	Longitude	Site Elevation(masl)*	Top Altitude(masl)	Time start	Time end
AAO	Airborne Aerosol Observatory, Bondville, Illinois	40.050	-88.370	230	4572	06/07/2006	09/18/2009
AMT	Argyle, Maine (Tower)	45.035	-68.682	53+107	NA	09/18/2003	Ongoing
BGI	Bradgate, Iowa	42.820	-94.410	355	7620	09/13/2004	11/18/2005
BNE	Beaver Crossing, Nebraska	40.800	-97.180	466	8120	09/15/2004	05/11/2011
CAR	Briggsdale, Colorado	40.635	-104.327	1488	8410	11/09/1992	Ongoing
CMA	Cape May, New Jersey	38.830	-74.320	0	7620	08/17/2005	Ongoing
DND	Dahlen, North Dakota	47.500	-99.240	472	8131	09/21/2004	Ongoing
ESP	Estevan Point, B C, Canada	49.383	-126.544	7	5695	11/22/2002	Ongoing
ETL	East Trout Lake, SK, Canada	54.350	-104.983	492	7228	10/15/2005	Ongoing
FWI	Fairchild, Wisconsin	44.660	-90.960	334	7620	09/20/2004	11/18/2005
HFM	Harvard Forest, Massachusetts	42.538	-72.171	340	7620	11/11/1999	11/18/2007
HIL	Homer, Illinois	40.070	-87.910	202	8059	09/16/2004	Ongoing
LEF	Park Falls, Wisconsin	45.945	-90.273	472	5060	04/10/1998	Ongoing
LEF	Park Falls, Wisconsin (Tower)	45.945	-90.273	472+396	NA	08/01/2003	Ongoing
NHA	Worcester, Massachusetts	42.950	-70.630	0	7620	09/12/2003	Ongoing
OIL	Oglesby, Illinois	41.280	-88.940	192	7620	09/16/2004	11/19/2005
SCA	Charleston, South Carolina	32.770	-79.550	0	12802	08/22/2003	Ongoing
SCT	Beech Island, South Carolina (Tower)	33.406	-81.833	115+305	NA	08/14/2008	Ongoing
SGP	Southern Great Plains, Oklahoma	36.607	-97.489	314	5330	09/17/2002	Ongoing
TGC	Sinton,Texas	27.730	-96.860	0	8107	09/09/2003	Ongoing
THD	Trinidad Head, California	41.054	-124.151	107	7953	09/02/2003	Ongoing
WBI	West Branch, Iowa	41.725	-91.353	242	8073	09/14/2004	Ongoing
WBI	West Branch, Iowa (Tower)	41.725	-91.353	241.7+379	NA	06/28/2007	Ongoing
WGC	Walnut Grove, California (Tower)	38.265	-121.491	0+483	NA	09/20/2007	Ongoing
WKT	Moody, Texas (Tower)	31.315	-97.327	251+457	NA	07/11/2003	Ongoing
MLO	Mauna Loa, Hawaii	19.536	-155.576	3397	NA	08/20/1969	Ongoing

* In this column, number before '+' is the surface elevation, and number after '+' shows the highest intake height for the tall tower from which data were used in this study.

Table S1. Site information from the NOAA/ESRL GGGRN.

Site Code	Lat.	Long.	Below 800 hPa[#]	Below 800 hPa /CT*	Below 800 hPa Dif.[&]	800 to 330 hPa[#]	800 to 330 hPa /CT*	800 to 330 hPa Dif.[&]	Total[#]	Total/ CT*	Total Dif.[&]	Excluded years between 2004-2014®
CAR	40.635	-104.327				-0.30	-0.74	-0.44	-0.72	-1.26	-0.54	None
CMA	38.83	-74.32	-4.70	-4.65	0.05	-2.77	-1.86	0.91	-2.90	-2.46	0.44	2004/2010/ 2011/2013
DND	47.5	-99.24	-9.32	-10.56	-1.24	-2.57	-2.05	0.52	-3.73	-3.96	-0.23	2004
ESP	49.383	-126.544	-3.97	-3.18	0.79	-3.10	-2.30	0.80	-3.30	-2.79	0.51	None
ETL	54.35	-104.983	-7.08	-6.98	0.10	-4.38	-3.60	0.78	-4.50	-4.08	0.42	2004
HIL	40.07	-87.91	-7.52	-9.37	-1.85	-1.36	-2.31	-0.95	-2.70	-3.65	-0.95	2004/2005/ 2012/2013
LEF	45.945	-90.273	-10.55	-10.36	0.19	-2.90	-3.15	-0.25	-4.00	-4.11	-0.11	2006
NHA	42.95	-70.63	-7.30	-6.07	1.23	-3.10	-2.74	0.36	-3.80	-3.32	0.48	None
SGP	36.607	-97.489	-0.80	-1.84	-1.04	-0.23	-0.57	-0.34	-0.80	-1.14	-0.34	2004/2005/ 2009
TGC	27.73	-96.86	0.00	-0.04	-0.04	-0.05	0.20	0.25	-0.32	-0.33	-0.01	None
THD	41.054	-124.151	-1.47	-2.31	-0.84	-1.43	-1.11	0.32	-1.65	-1.75	-0.10	None
WBI	41.725	-91.353	-8.27	-10.79	-2.52	-1.90	-2.19	-0.29	-3.02	-3.67	-0.65	2004/2011/ 2012/2013
SCA	32.77	-79.55	-1.67	-1.35	0.32	-0.94	-0.50	0.44	-1.16	-1.00	0.16	None

[#] Values (in ppm) based on aircraft measurements.

* Values (in ppm) based on CT2015

[&] Dif. (in ppm) means CT2015 minus aircraft based values

®These years are excluded when calculate column CO_2 based on measurements at individual aircraft site due to temporal coverage concerns, but not excluded in the mayor analysis by regions that includes more than one site.

Table S2. Comparisons of long-term mean (2004-2014) June-August column ΔXCO2 from CT2015 versus total column ΔXCO2 for 13 individual aircraft sites, corresponded to Fig.9.

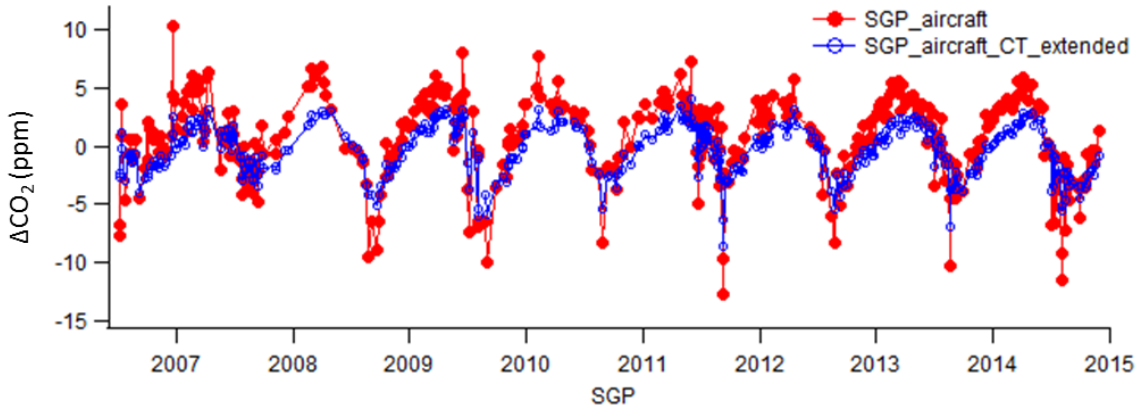

Fig. S1. Time series of detrended partial (red) and total (blue) ΔXCO_2 at SGP, calculated from each individual vertical profile. CO_2 measurements at MLO were used to subtract the trend. (Note that some sites have lower sampling frequency that may impair their ability to capture the year-to year variation of column ΔXCO_2, thus a long-term mean average method is utilized in this study (see section 2.3 and 3.2).

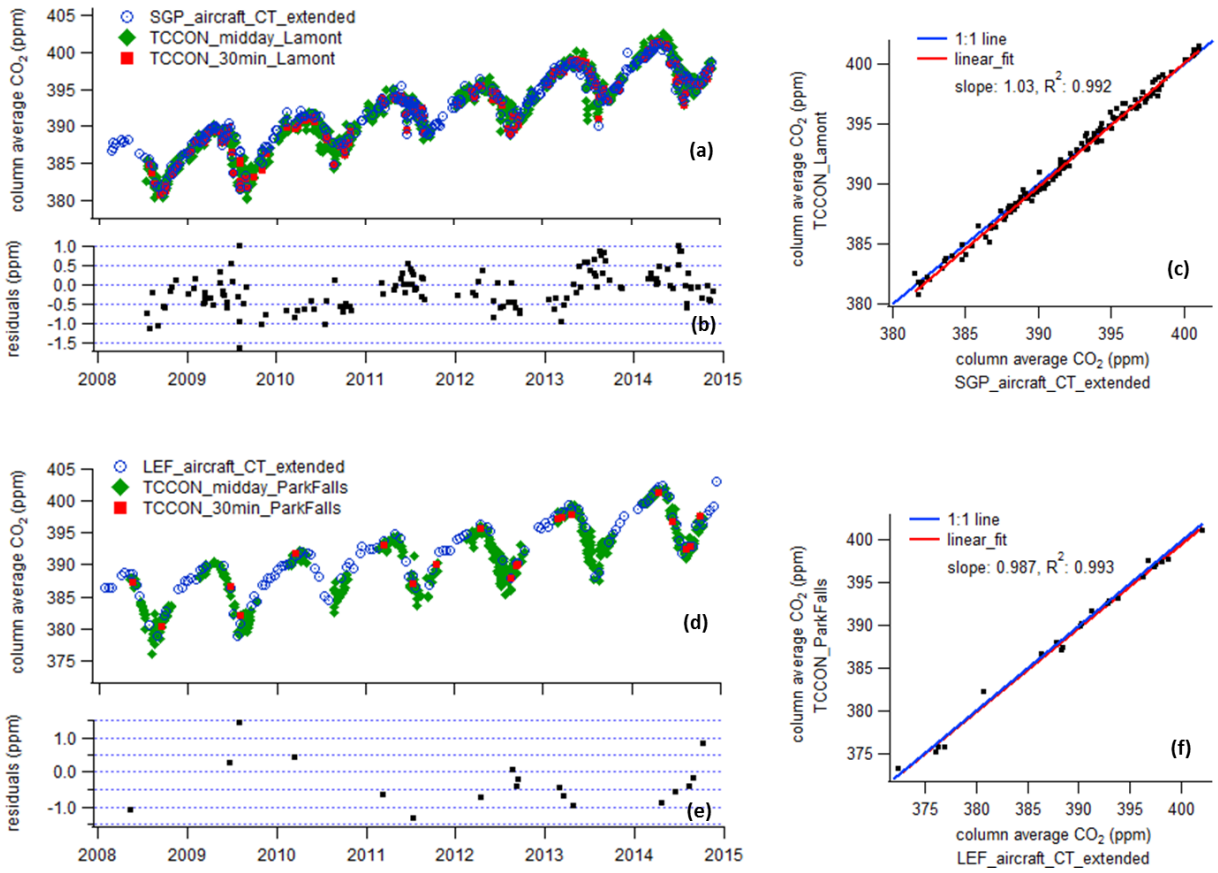

Fig. S2 Comparisons between aircraft and CT based total column CO2 with TCCON total column CO2. TCCON data with Solar Zenith Angle larger than 60^0 are not included in these comparisons. (a), (b), and (c) are time series, residuals (TCCON - aircraft_CT_extended), and scatter plot comparisons between SGP and TCCON Lamont site (36.60^0N, -97.49^0E), respectively. (d), (e), and (f) are the same comparisons between LEF and TCCON Park Falls site (45.94^0N, -90.27^0E), respectively. In (a) and (d), TCCON midday values are the averages between 10:00 to 15:00 LST; TCCON 30 min. values are the averages within 30 min. of aircraft sampling time. TCCON 30 min. values are used in (b), (c), (e), and (f).

TCCON Data DOIs:

10.14291/tccon.ggg2014.lamont01.R0/1149159

10.14291/tccon.ggg2014.parkfalls01.R0/1149161

TCCON reference:

Wunch, D., G. C. Toon, J.-F. L. Blavier, R. A. Washenfelder, J. Notholt, B. J. Connor, D. W. T. Griffith, V. Sherlock, and P. O. Wennberg (2011), The total carbon column observing network, Philosophical Transactions of the Royal Society - Series A: Mathematical, Physical and Engineering Sciences, 369(1943), 2087-2112, doi:10.1098/rsta.2010.0240. Available from: http://dx.doi.org/10.1098/rsta.2010.0240

Washenfelder, R.A., G.C. Toon, J-F. Blavier, Z. Yang, N.T. Allen P.O. Wennberg, S.A. Vay, D.M. Matross, and B.C. Daube (2006), Carbon dioxide column abundances at the Wisconsin Tall Tower site, Journal of Geophysical Research, 2006, 111, doi:10.1029/2006JD007154.

Wunch, D., P. O. Wennberg, G. C. Toon, G. Keppel-Aleks, and Y. G. Yavin (2009), Emissions of greenhouse gases from a North American megacity, Geophys. Res. Lett., 36, L15810, doi:10.1029/2009GL039825

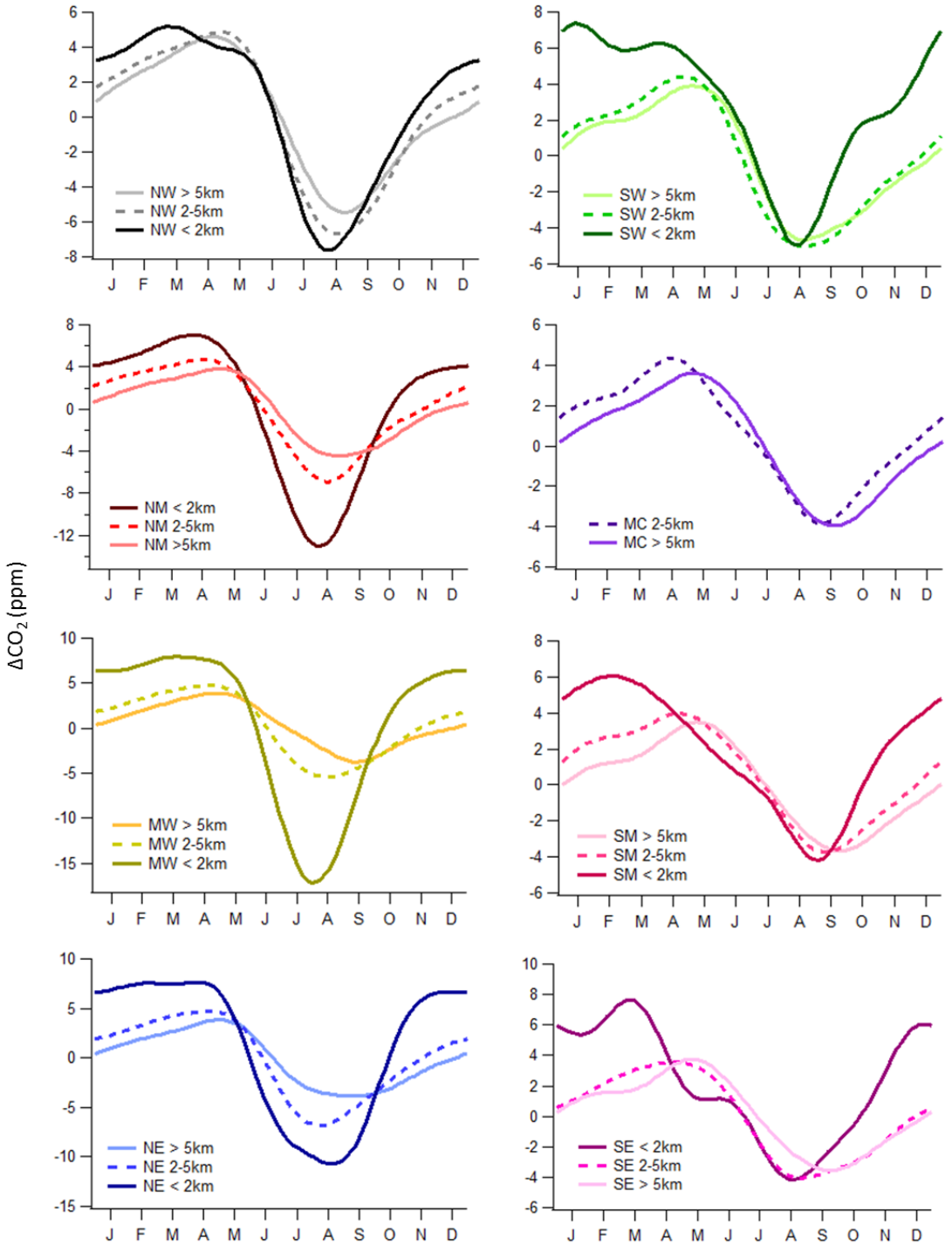

Fig. S3. Multi-year (2004-2014) average smooth seasonal curves of CO_2 relative to the long-term de-seasonalized trend at Mauna Loa for different vertical layers for each region.

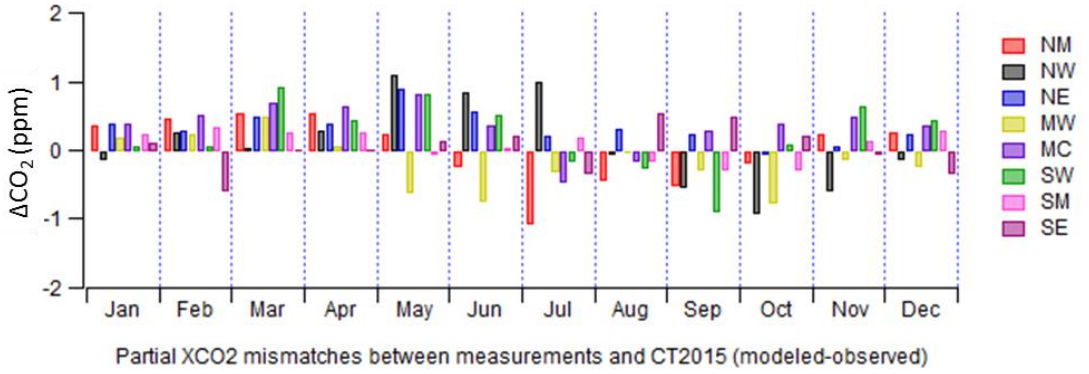

Fig. S4. Monthly differences of partial column ΔXCO_2 (modeled - observed) for each month, eight bars represent eight regions.

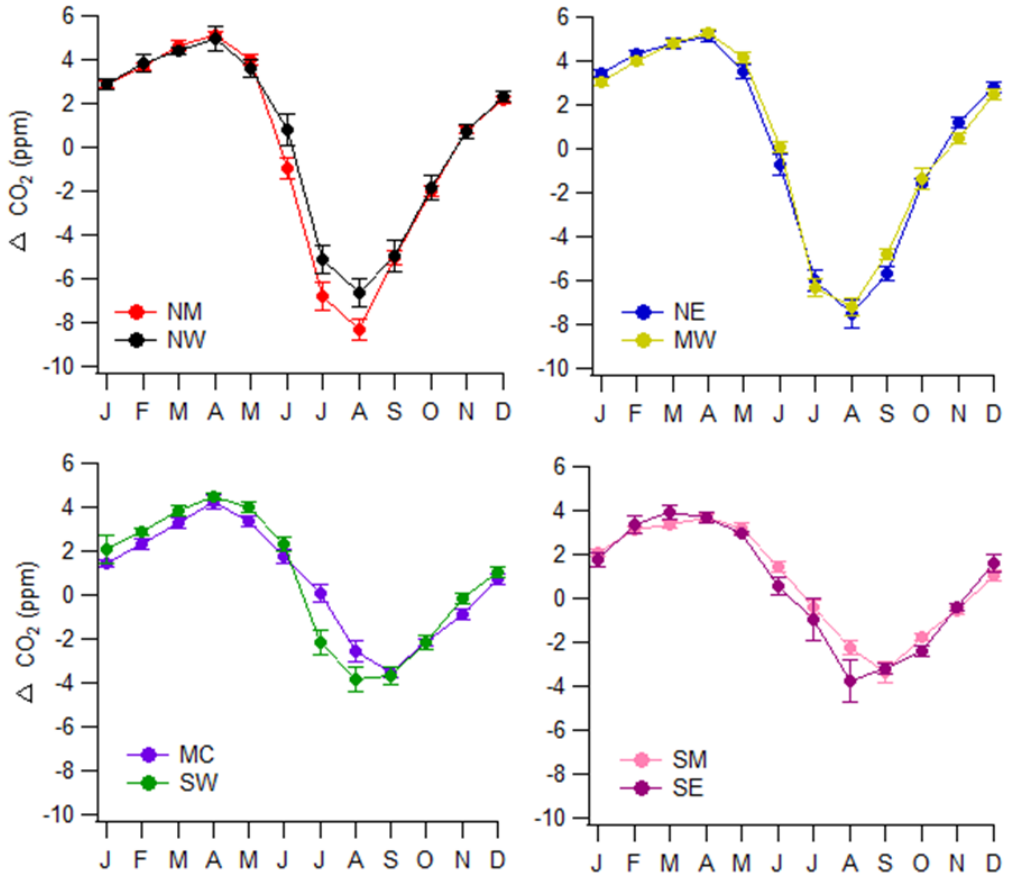

Fig. S5. Uncertainties estimated from 'bootstrap' Monte Carlo method for partial column ΔXCO_2 calculation using measured vertical profiles (aircraft and tower data). Error bar is the one standard deviation from 100 Monte Carlo runs.

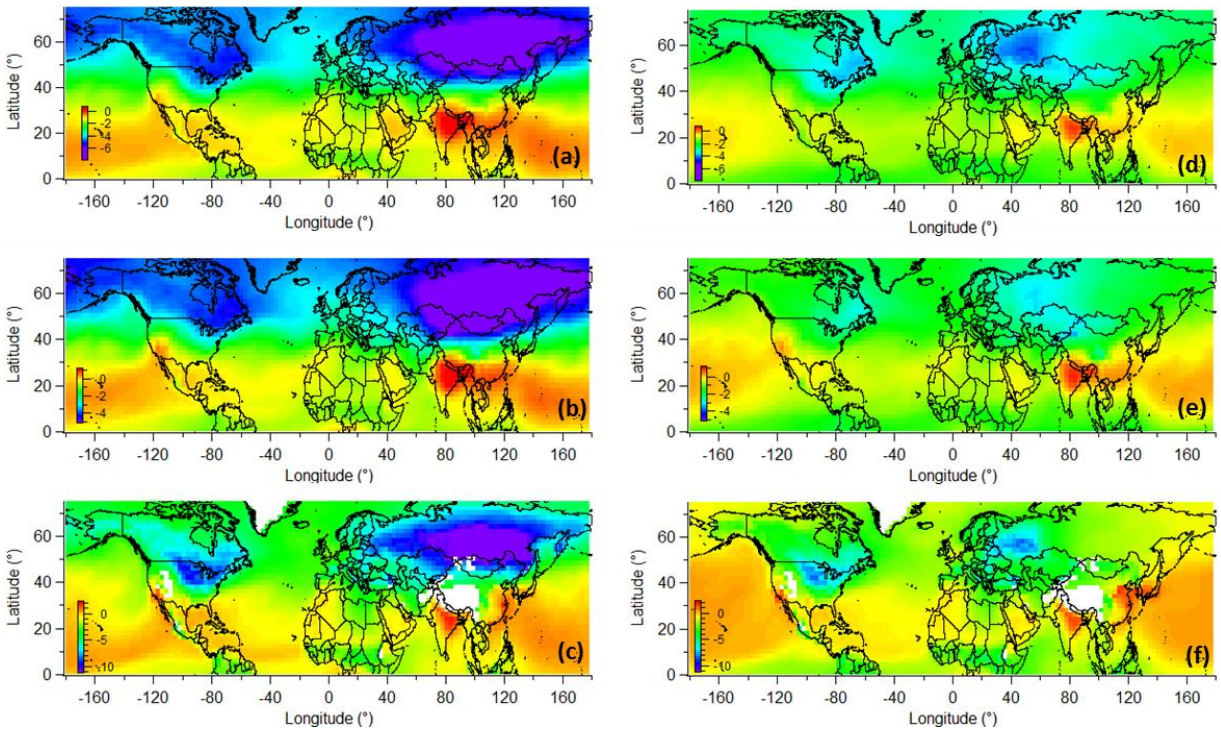

Fig. S6. Total and partial column ΔXCO_2 from Carbon Tracker control (left panels: (a), (b), and (c)) and masked (right panels, (d), (e), and (f), Eurasian boreal flux is masked) runs for 2012 June-August (3° × 2° spatial resolution). MLO trend from each individual scenario is removed before the ΔXCO_2 calculation. (a) and (d) show total column averages, same as in Fig.10. (b) and (e) show partial column averages for free troposphere (800 hPa to 330 hPa). (c) and (f) show partial column averages for lower troposphere (below 800 hPa). (a) and (d) use the same color scale as in Fig. 9a., which reflects maximum 6 ppm gradient. Color scale in (b) and (e) also shows maximum 6 ppm gradient for comparisons with (a) and (d); however, the color values are different. Color scales in (c) and (f) are larger to reflect large spatial gradients in lower troposphere.

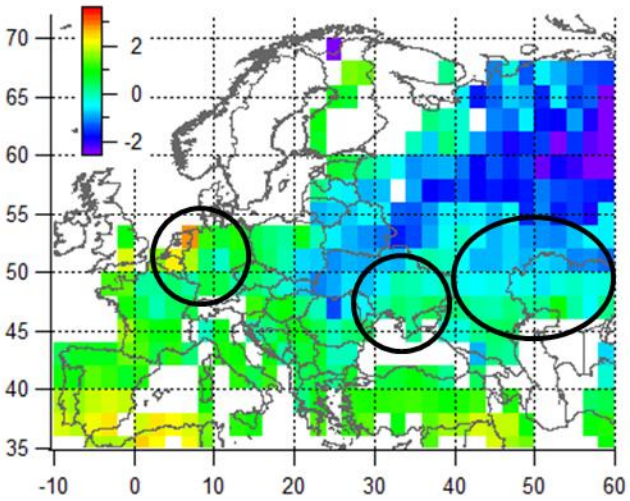

Fig. S7. 2003-2010 averaged June-August column CO_2 (in ppm) pattern from sampling CT2015 with latitude/longitude/hour from all available SCIAMACHY BESD data (v02.00.08). Black circles show the locations of extreme hot/cold spots with up to 6 ppm differences from Reuter et al. (2014), Fig.2. Seasonal mean is first removed from each year before combining 8-year data together and averaged within a $2^0 \times 2^0$ grid. Girds with less than 24 soundings for 8 summers are excluded; color scale shows maximum 6 ppm difference, similar as Reuter et al. (2014), Fig.2.
SCIAMACHY latitude/longitude/hour information is attained from: http://www.esa-ghg-cci.org/sites/default/files/documents/public/documents/GHG-CCI_DATA.html.

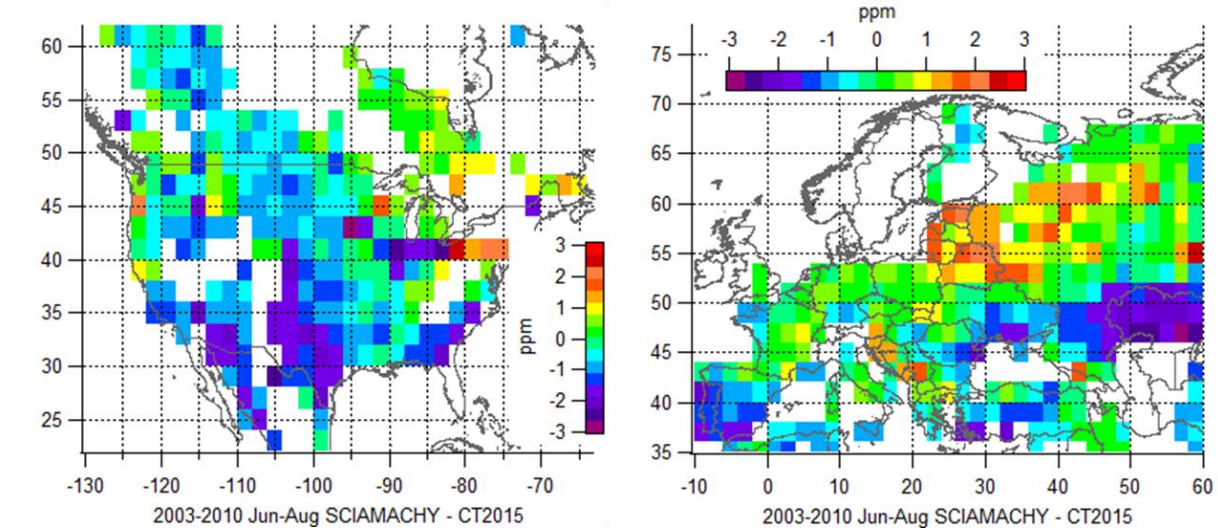

Figure S8. Differences between SCIAMACHY BESD column CO_2 and CT2015 over North America (left panel) and Europe (right Panel) for 2003-2010 June-August. CT2015 is sampled using SCIAMACHY BESD latitude/longitude/hour. Point-to-point differences (SCIAMACHY BESD – CT2015) are averaged within a $2^0 \times 2^0$ grid. Grid cells with less than 24 soundings for 8 summers are excluded.

SCIAMACHY data is attained from:
http://www.esa-ghg-cci.org/sites/default/files/documents/public/documents/GHG-CCI_DATA.html.
SCIAMACHY BESD reference:
Reuter, M., Bovensmann, H., Buchwitz, M., Burrows, J. P., Connor, B. J., Deutscher, N. M., Griffith, D. W. T., Heymann, J., Keppel-Aleks, G., Messerschmidt, J., Notholt, J., Petri, C., Robinson, J., Schneising, O., Sherlock, V., Velazco, V., Warneke, T., Wennberg, P. O. and Wunch, D.: Retrieval of atmospheric CO2 with enhanced accuracy and precision from SCIAMACHY: Validation with FTS measurements and comparison with model results, J. Geophys. Res. Atmos., 116, 2011.