Earth System Research Laboratory
Global Monitoring Division

Global Greenhouse Gas Reference Network

Gradients of Column CO_2 across North America from Aircraft and Tall Tower Measurements in the NOAA/ESRL Global Greenhouse Gas Reference Network

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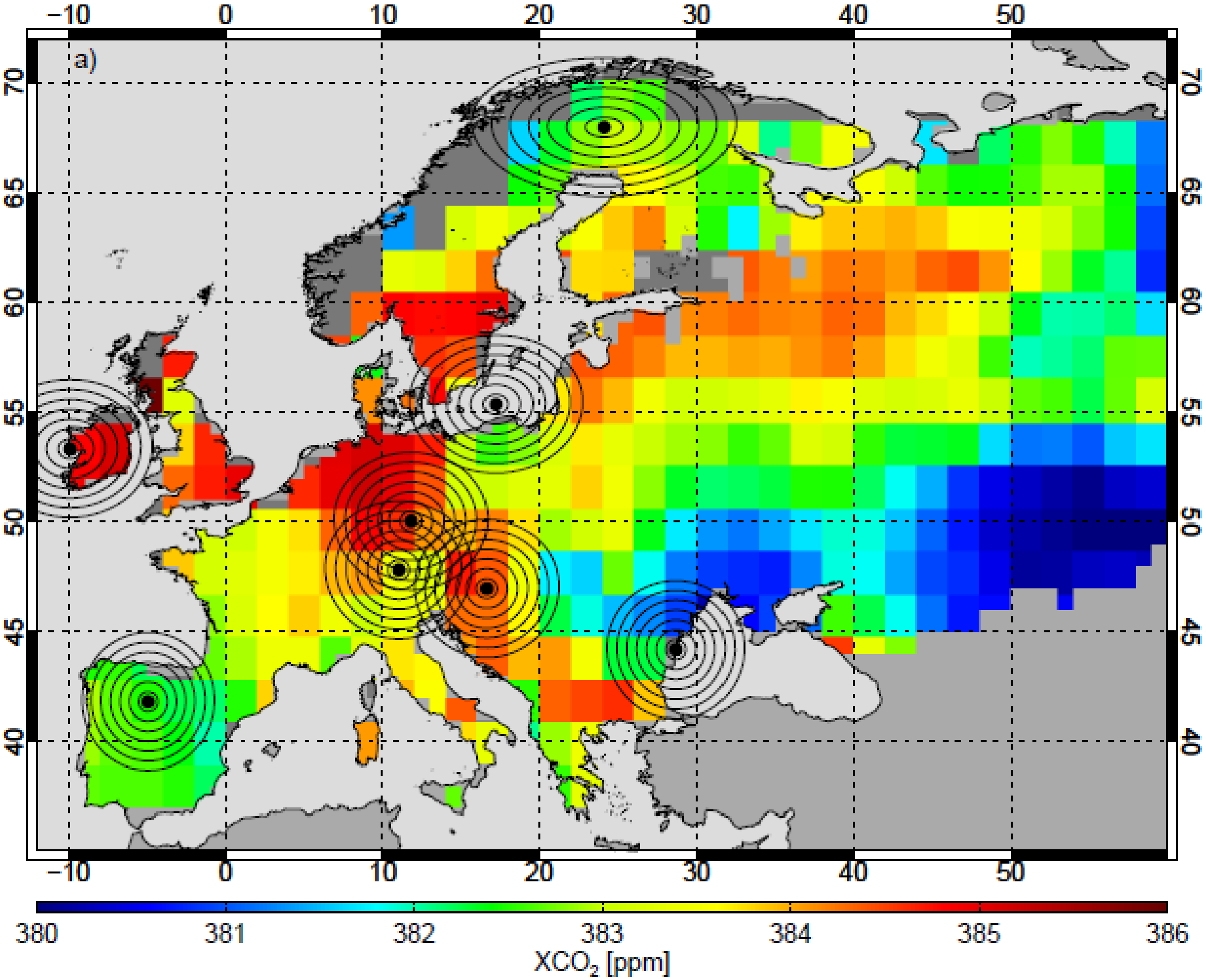
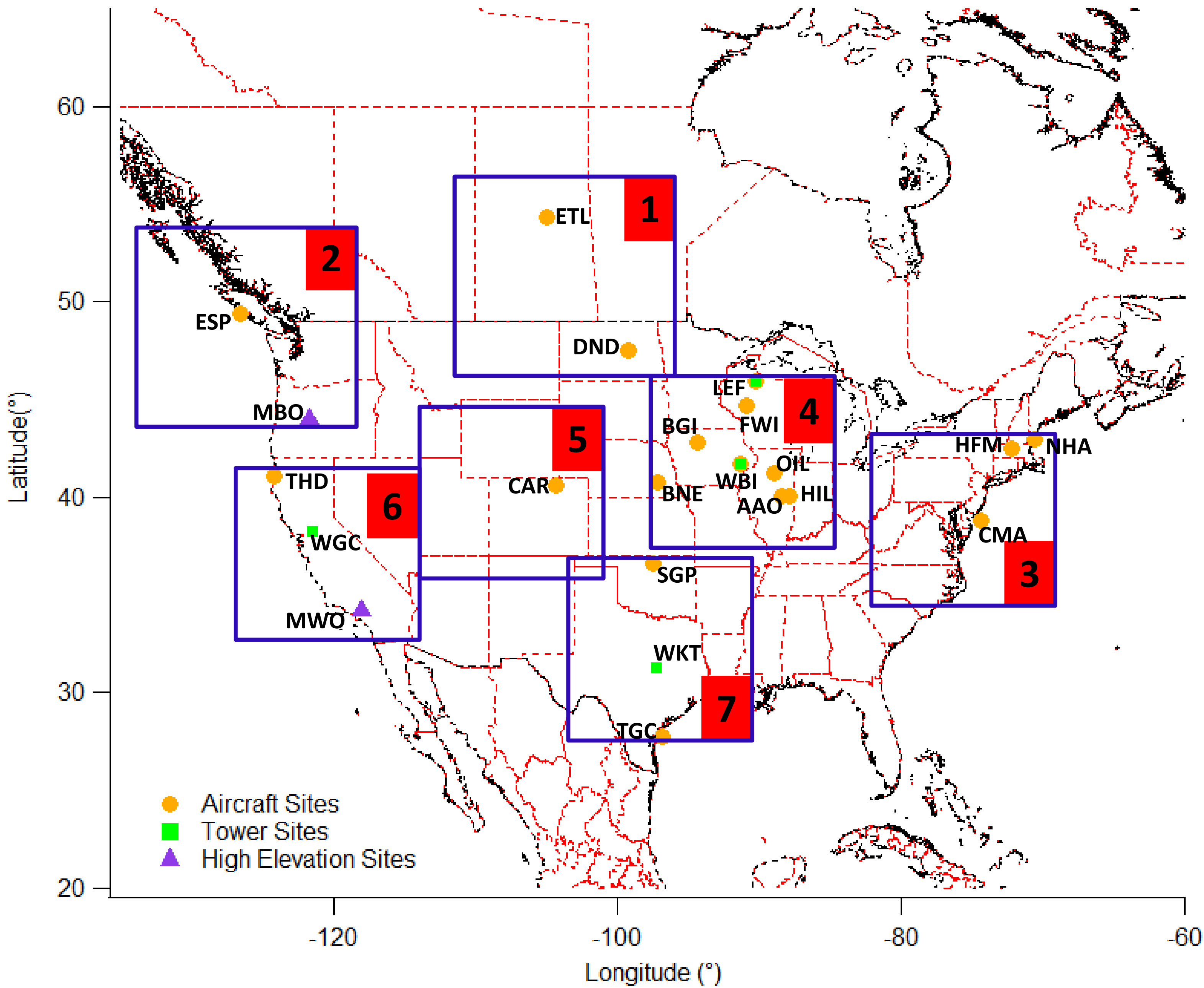
M. Reuter et al.: Satellite-inferred European carbon sink larger than expected (ACP, 2014)

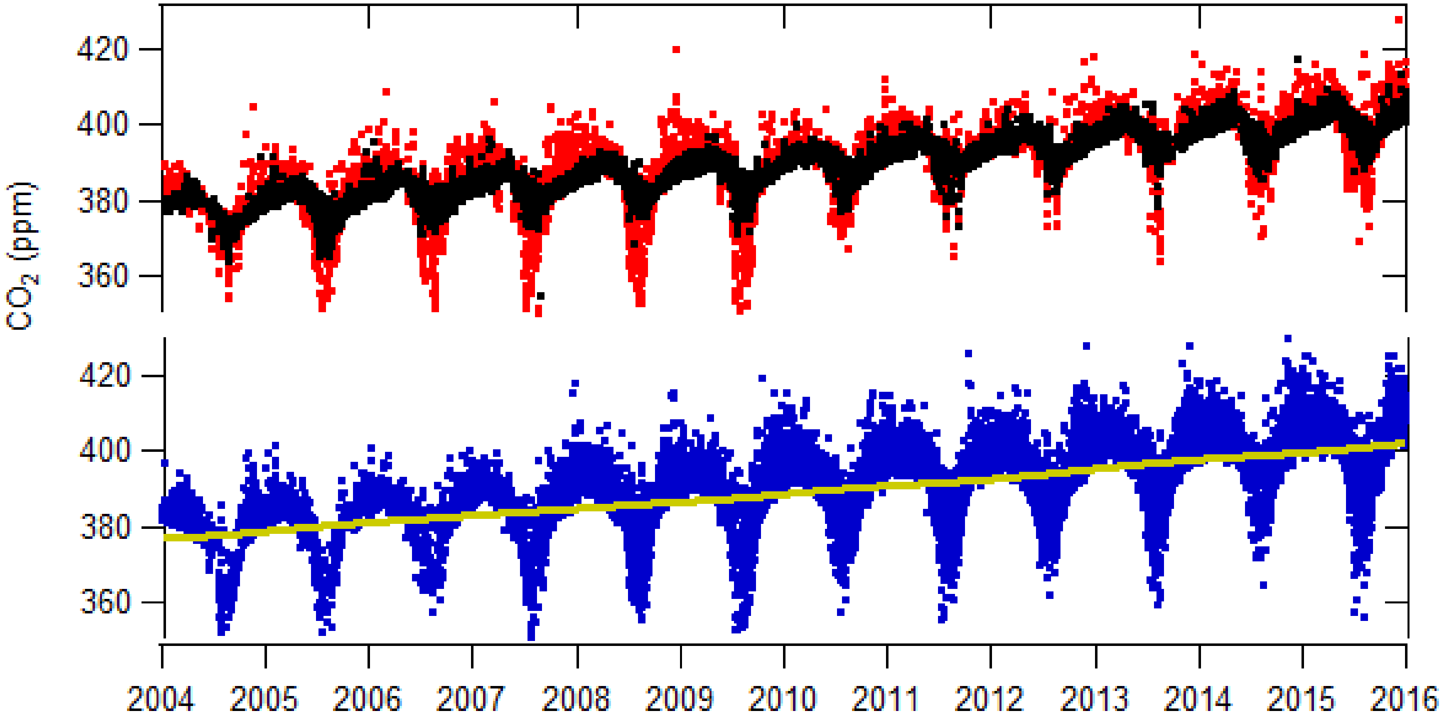


Multi-year(2003-2010) June-August averaged satellite-retrieved XCO2 (SCIMACHNY and GOSAT), calculated from annual seasonal anomalies in order to minimize effects due to different annual samplings. Gridded to a regular $2^o \times 2^o$ grid and smoothed with a Hann function with $5^o \times 5^o$ effective width.



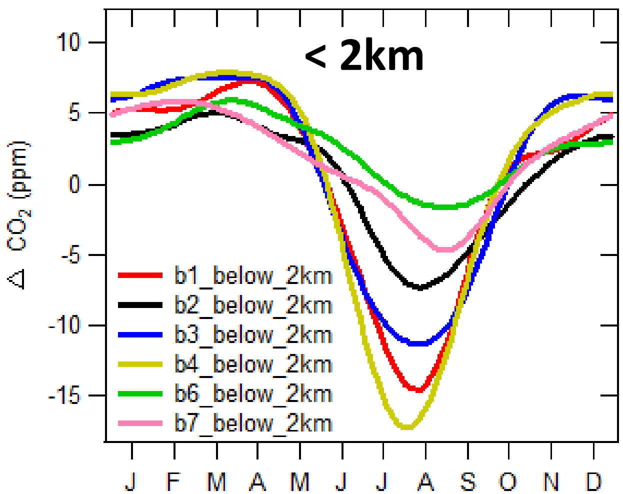
Aircraft measurements: normally conducted at late morning to early afternoon.
Flask samples were collected up to 8km.

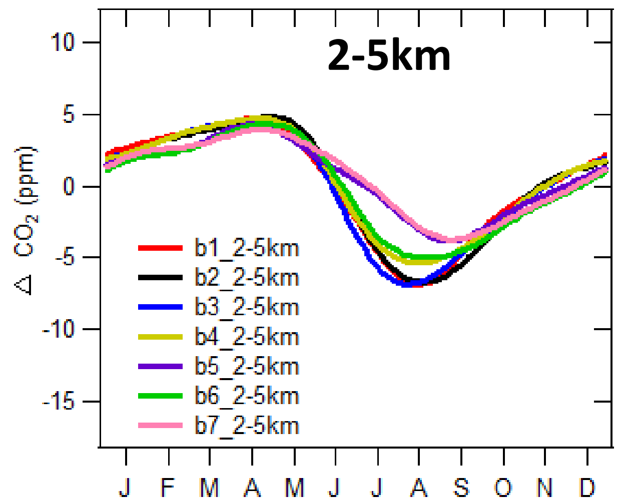
Time series of aircraft and tower data

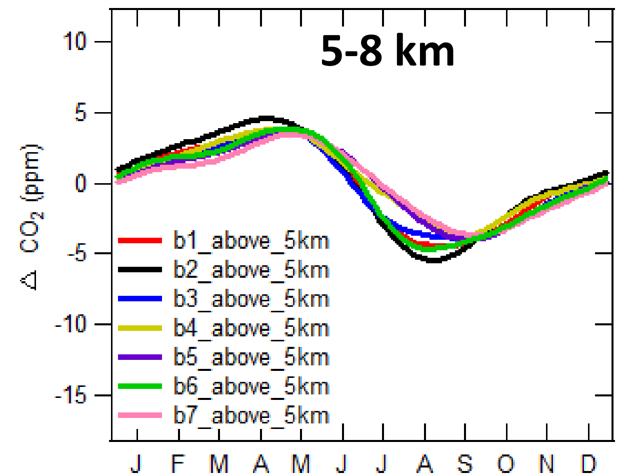


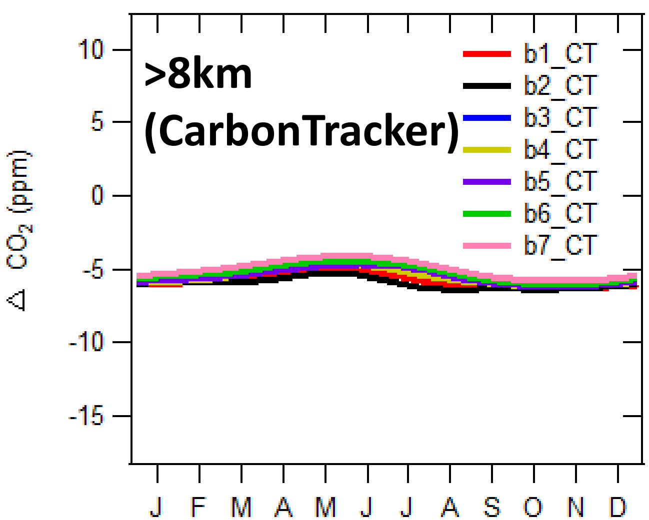
Aircraft (in red, data above 2km is in black) and tower data(in blue) at 10:00-17:00 Local Standard Time. Yellow solid line shows the trend curve calculated from Mauna Loa site.

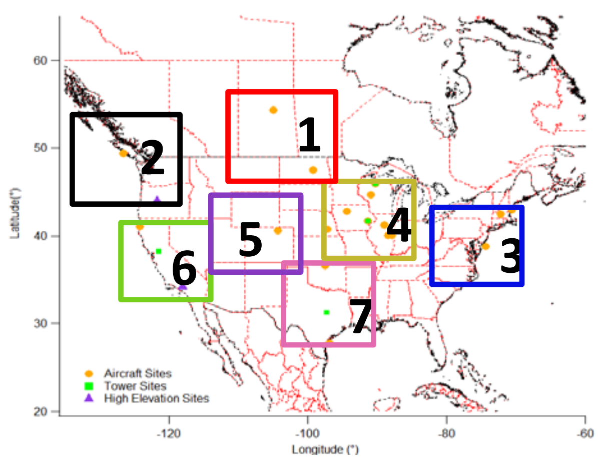
Long-term mean gradients at different vertical layers





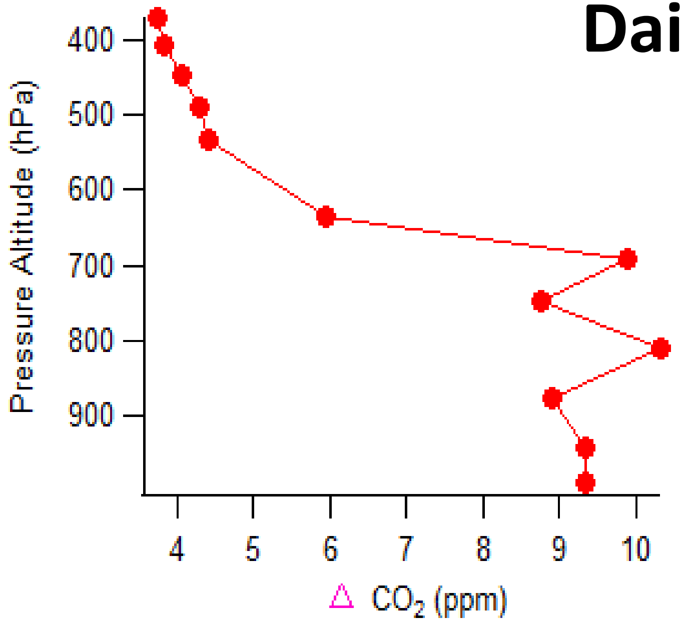




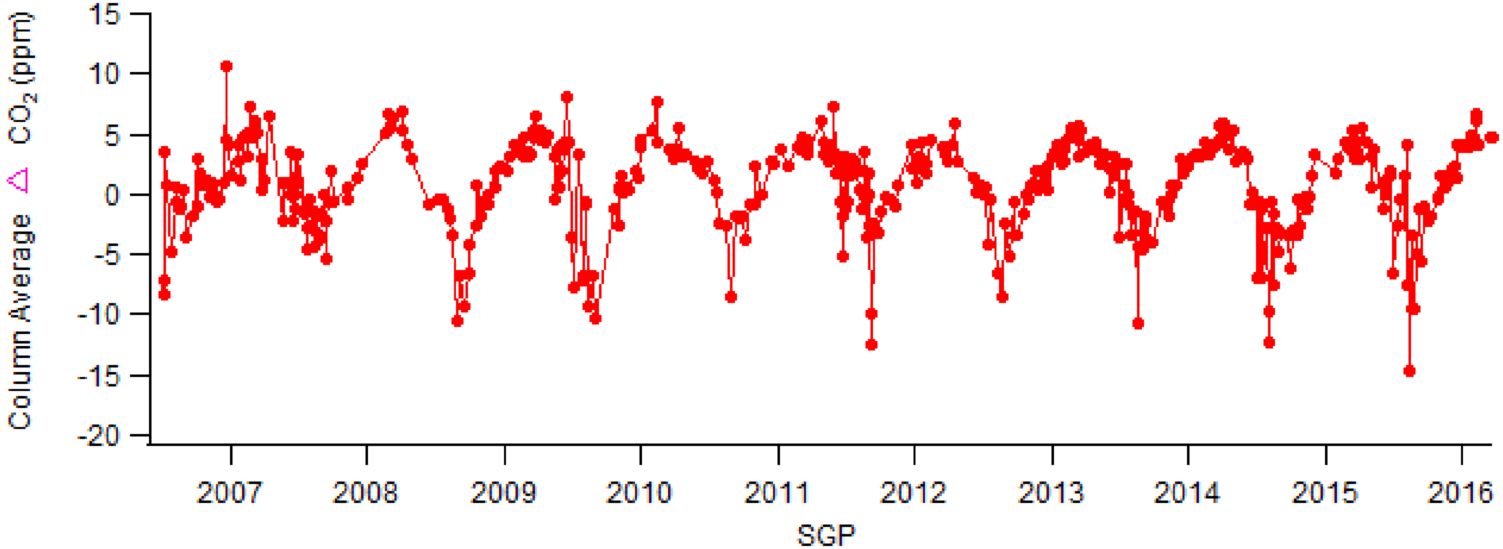


Very little gradients above 8km, which also imply that adding these data for XCO2 calculation is not going to introduce larger spatial gradients than the partial XCO2.

Daily profiles

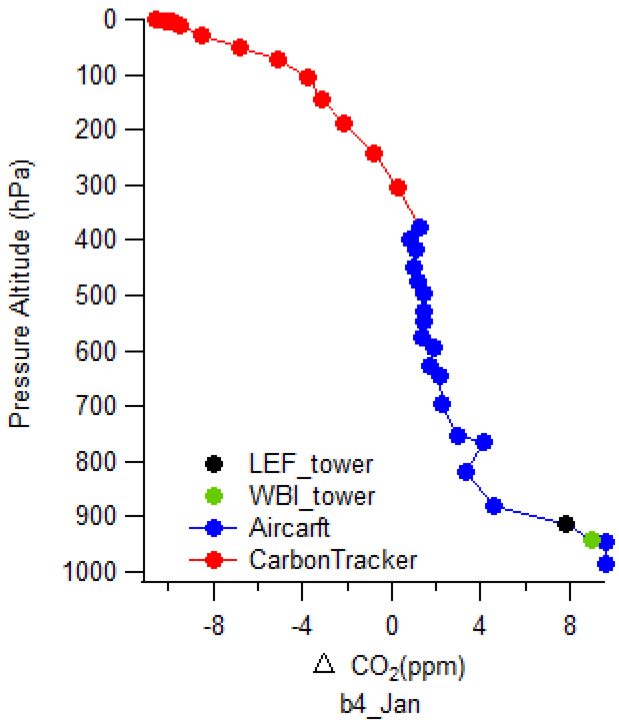


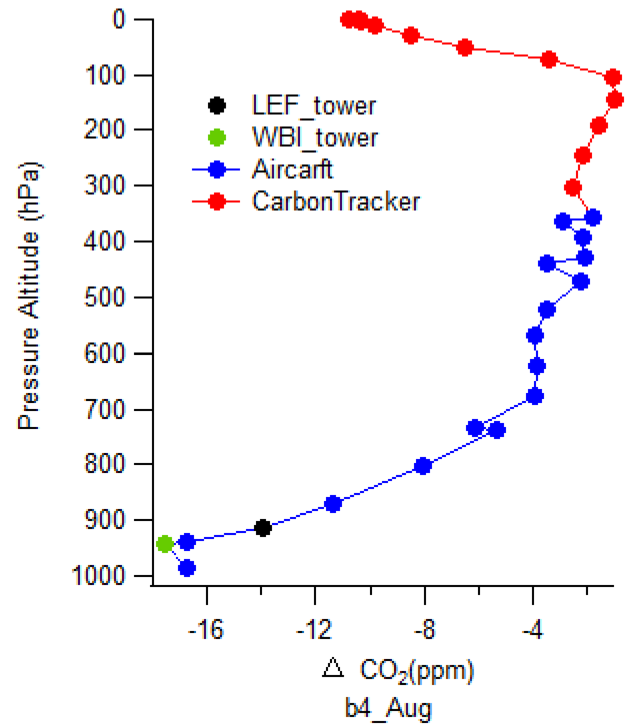
Column averages (pressure weighted) are calculated using a trapezoidal integration method.



Time series of partial XCO_2 calculated from each daily profile.

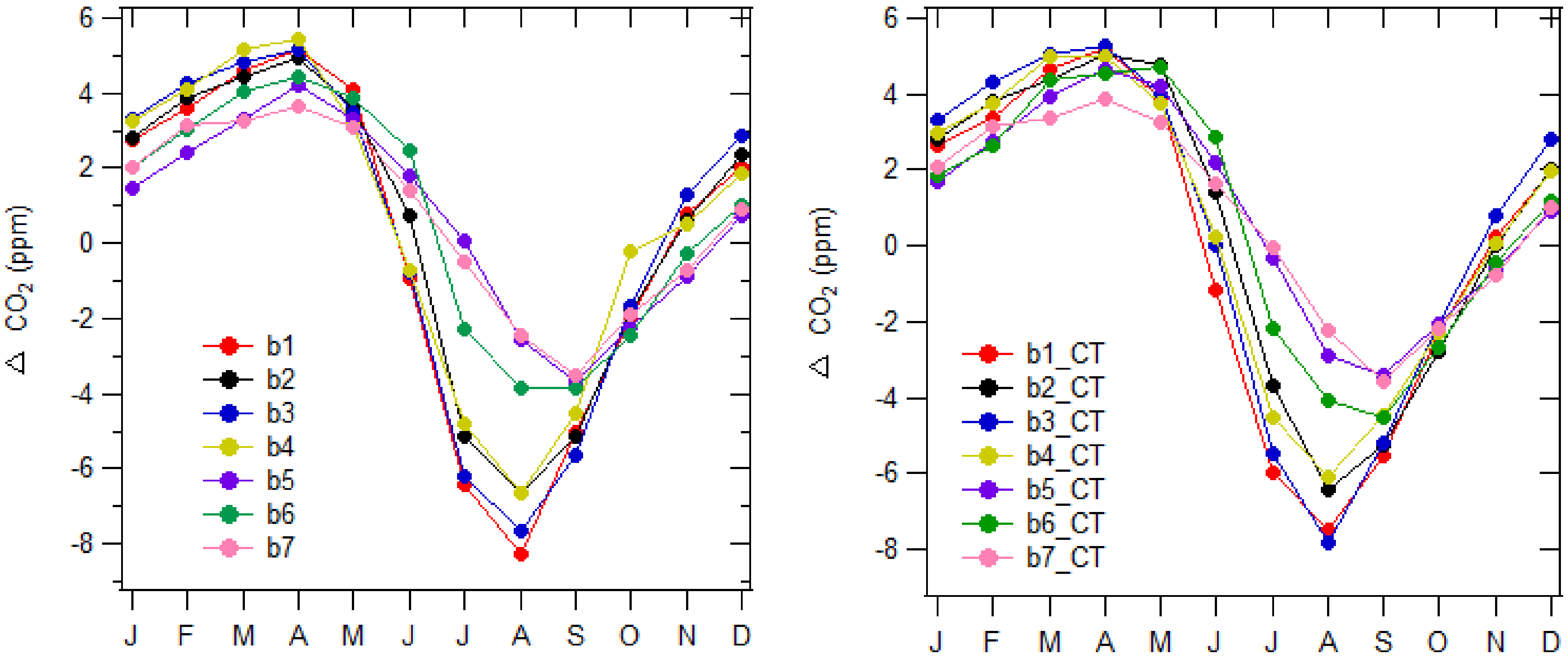
Long-term mean vertical profiles





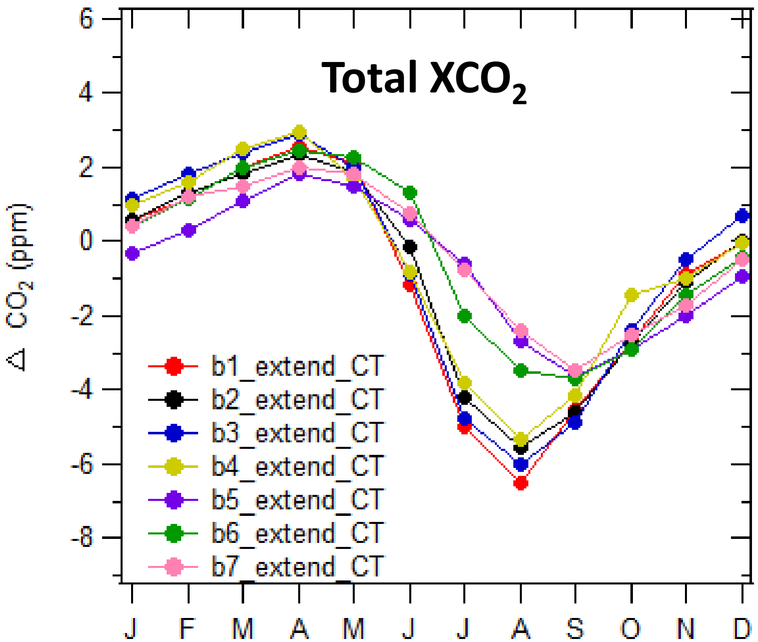
- We used tower data at highest in-take level.
- Only days with aircraft measurements were selected from tower data.
- Tower data fit well in long-term monthly vertical profiles.

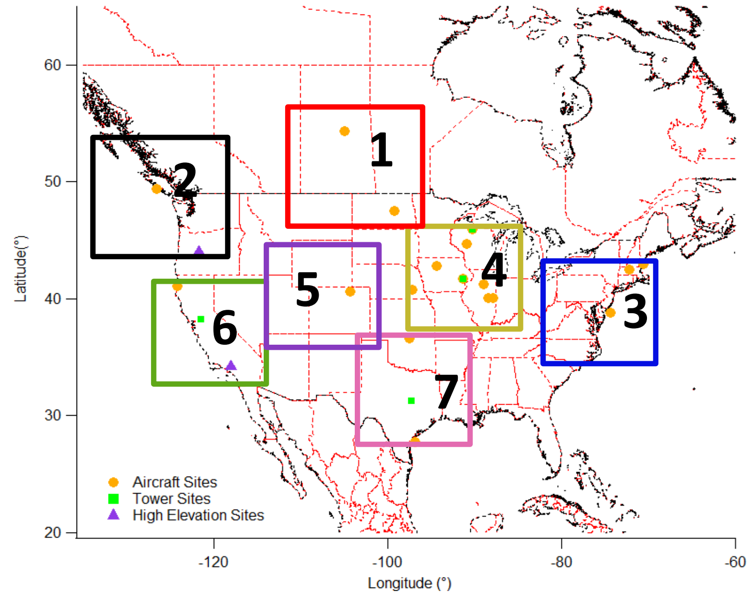
Long-term mean monthly column average (partial XCO_2)

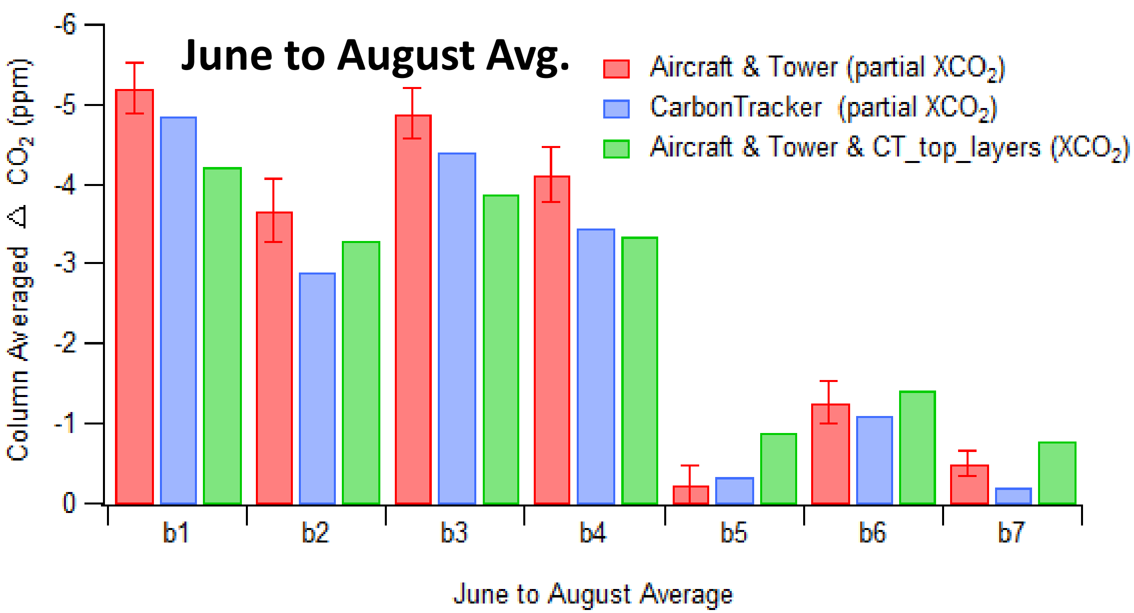


Partial XCO2 calculated from aircraft & tower data (left) and CarbonTracker modeled data(right, note that aircraft profiles were not assimilated in CarbonTracker). Same sites are selected for comparison.

CarbonTracker evaluation: http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/profiles.php

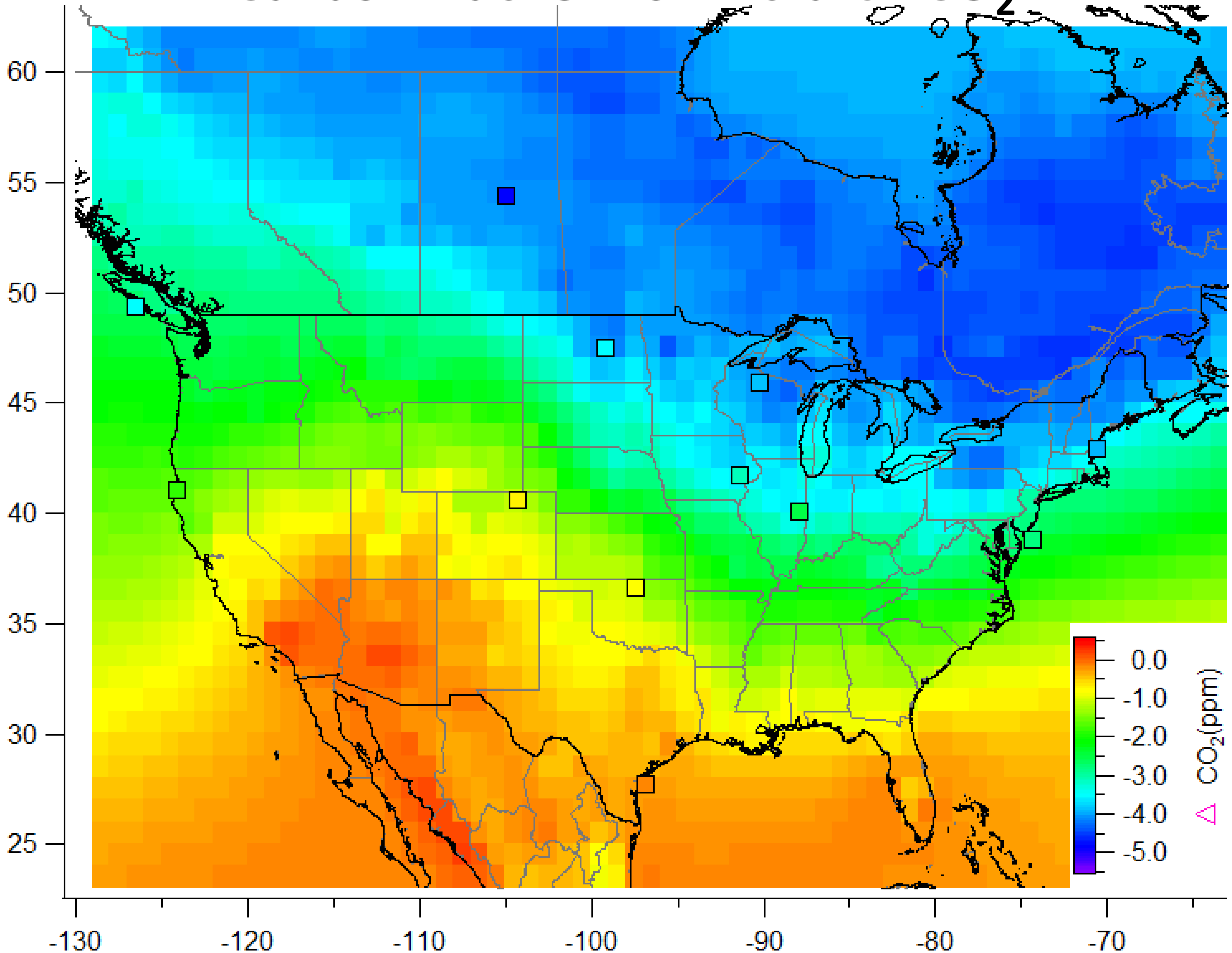






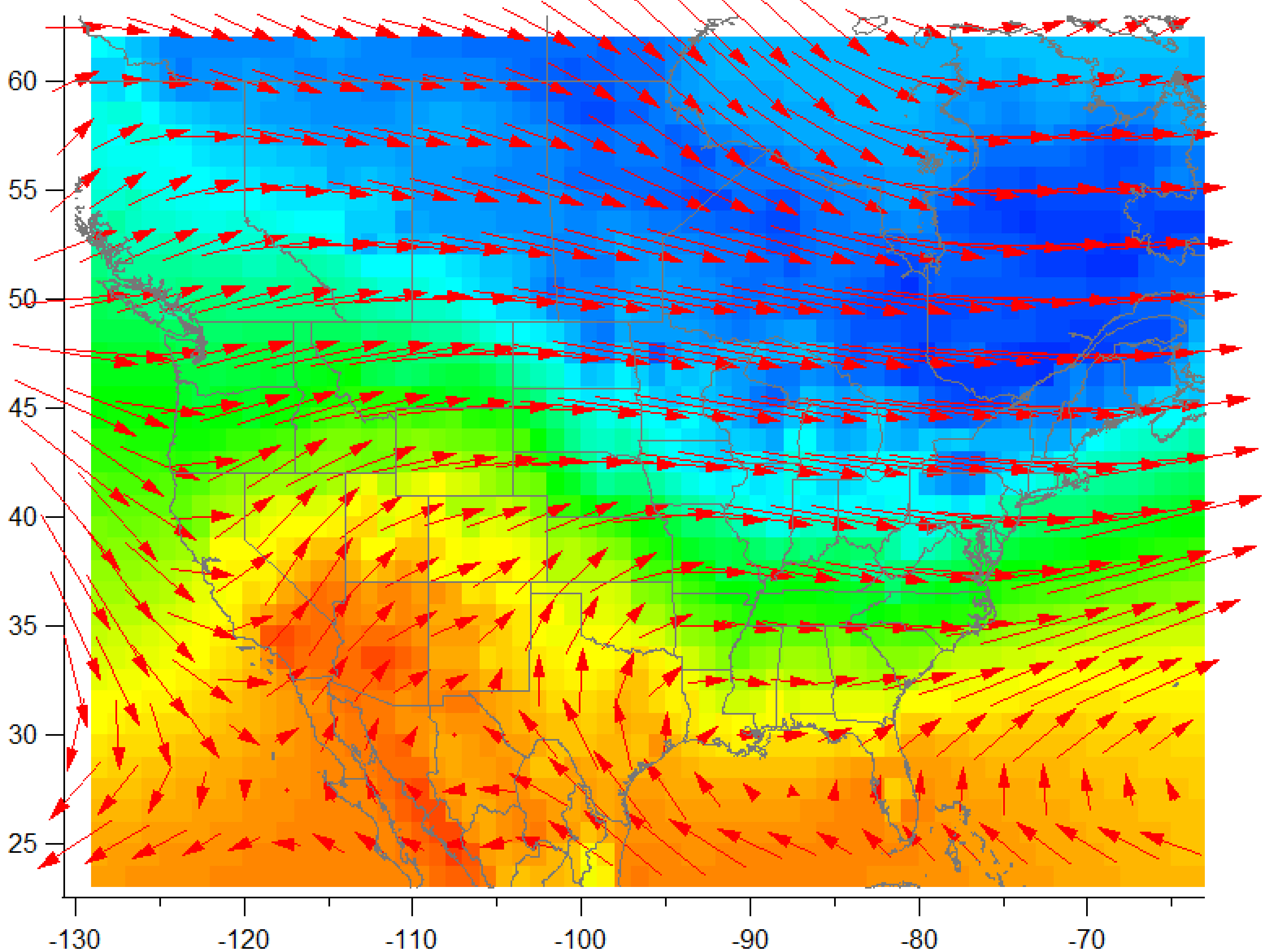
The long-term mean June to August drawdowns at the northern regions are stronger by ~ 3ppm than the southern regions.

Long-term mean Jun. to Aug.
CarbonTracker vs Aircraft XCO_2



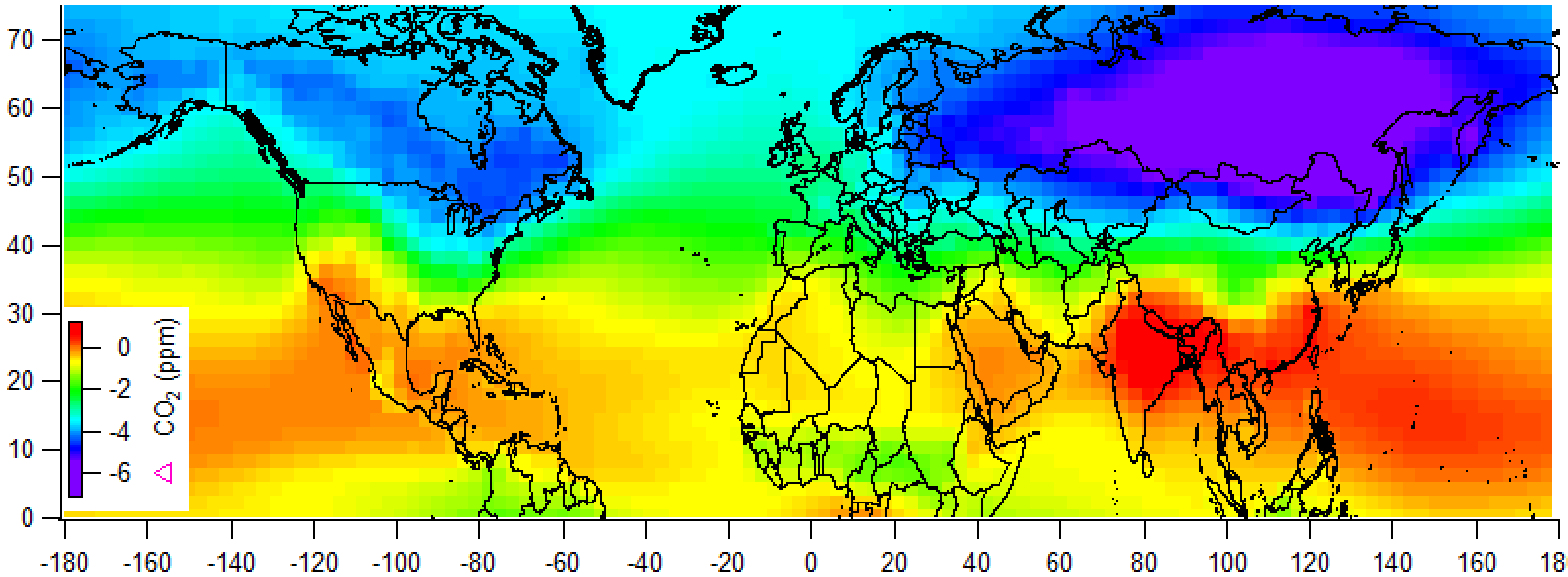
Aircraft XCO_2: CT data from upper layers are used with aircraft data.

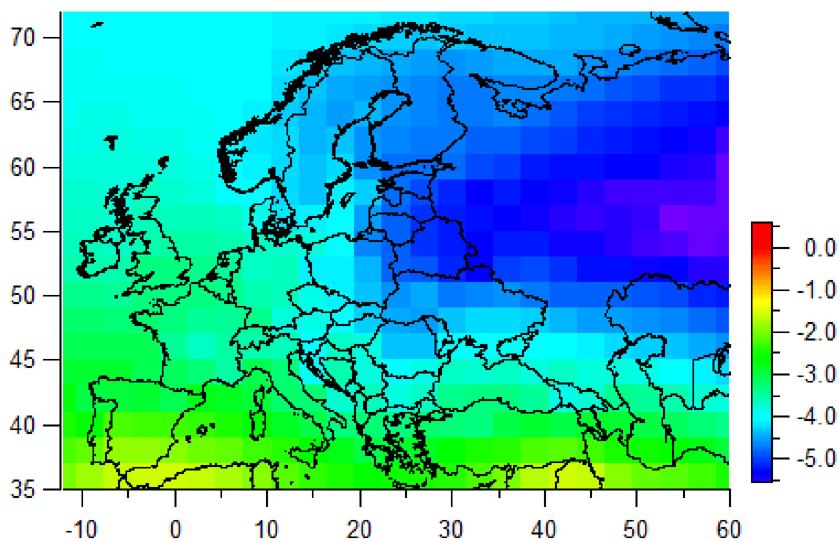
Long-term mean Jun. to Aug. wind vector

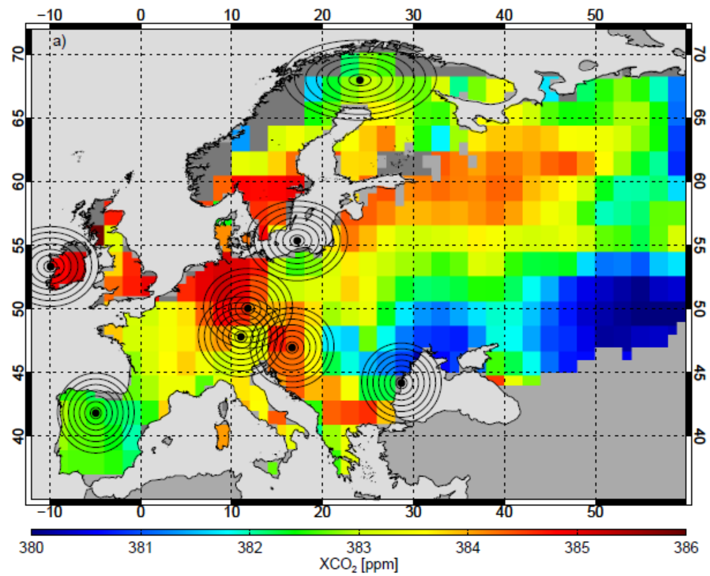


Pressure-weighted column mean wind(1000-500hPa).
Wind data are from NCEP/NCAR Reanalysis.

Long-term mean Jun. to Aug. CarbonTracker XCO_2







(Reuter et al., 2014)

Conclusion

- The largest spatial gradients of CO_2 across North America appear below 2km during summer time, while upper layer data (above 5km) show little contribution to spatial gradients.
- Large spatial gradients of long-term mean XCO_2 mainly occurred during June to August with strong summer drawdowns.
- The long-term mean summer drawdowns at the northern regions are stronger by ~ 3ppm than the southern regions.
- XCO_2 pattern does not reflect surface sources and sinks directly. Instead, it reflects the large-scale circulation.

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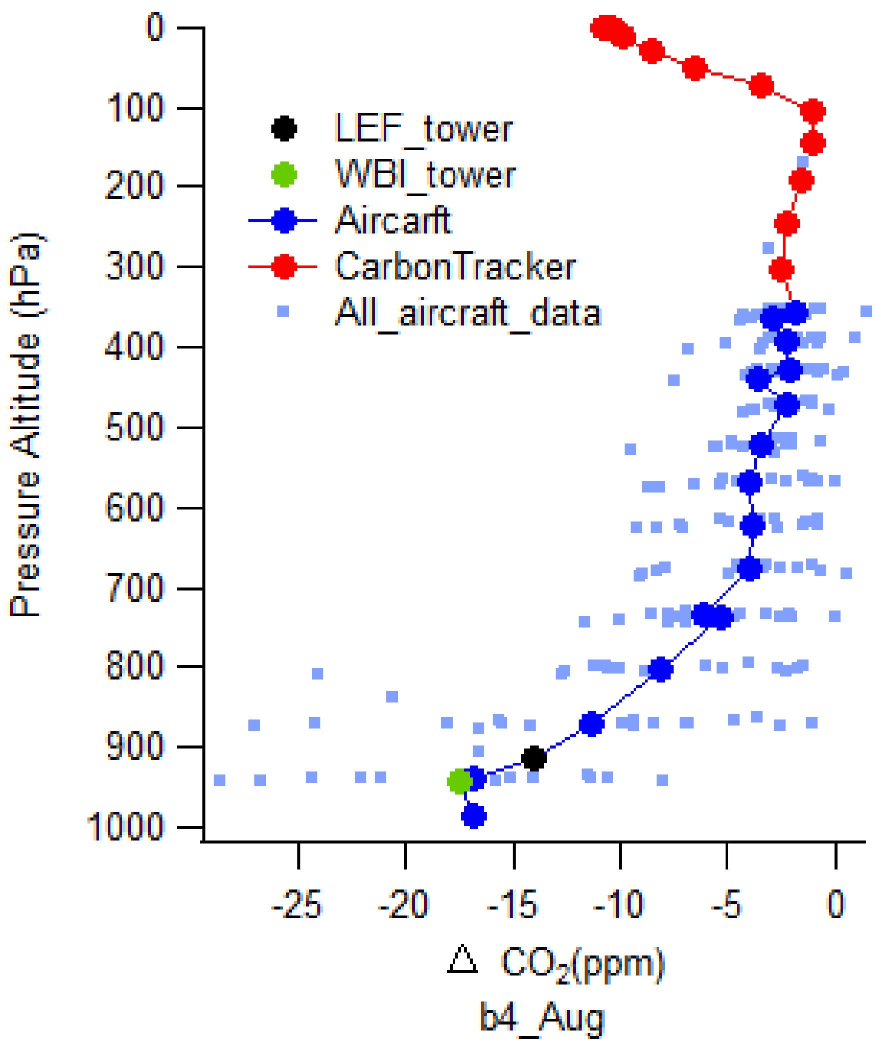
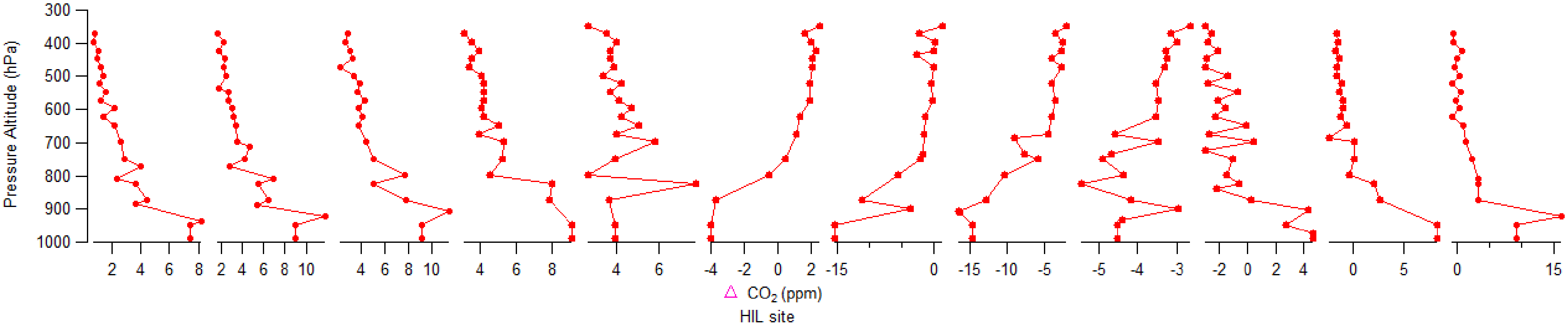
Supporting Materials

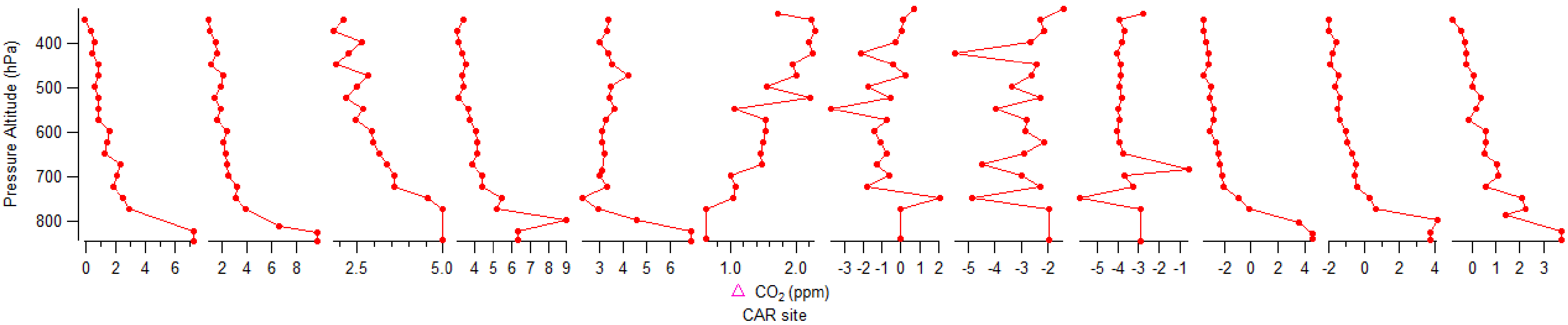
Code	Name	Latitude	Longitude	Site Elevation(masl)	Top Altitude(masl)	Time start	Time end
AAO	Airborne Aerosol Observing	40.050	-88.370	230	4572	06/07/2006	09/18/2009
BGI	Bradgate, Iowa	42.820	-94.410	355	7620	09/13/2004	11/18/2005
BNE	Beaver Crossing, Nebraska	40.800	-97.180	466	8120	09/15/2004	05/11/2011
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, British Columbia, Canada	49.383	-126.544	7	5695	11/22/2002	Ongoing
ETL	East Trout Lake, Saskatchewan, 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
MBO	Mt. Bachelor Observatory(Tower)	43.977	-121.686	2731+11	NA	10/14/2011	Ongoing
MWO	Mt. Wilson Observatory (Tower)	34.225	-118.059	1728	NA	04/30/2010	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
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

Long Term Average
Monthly Vertical Profiles

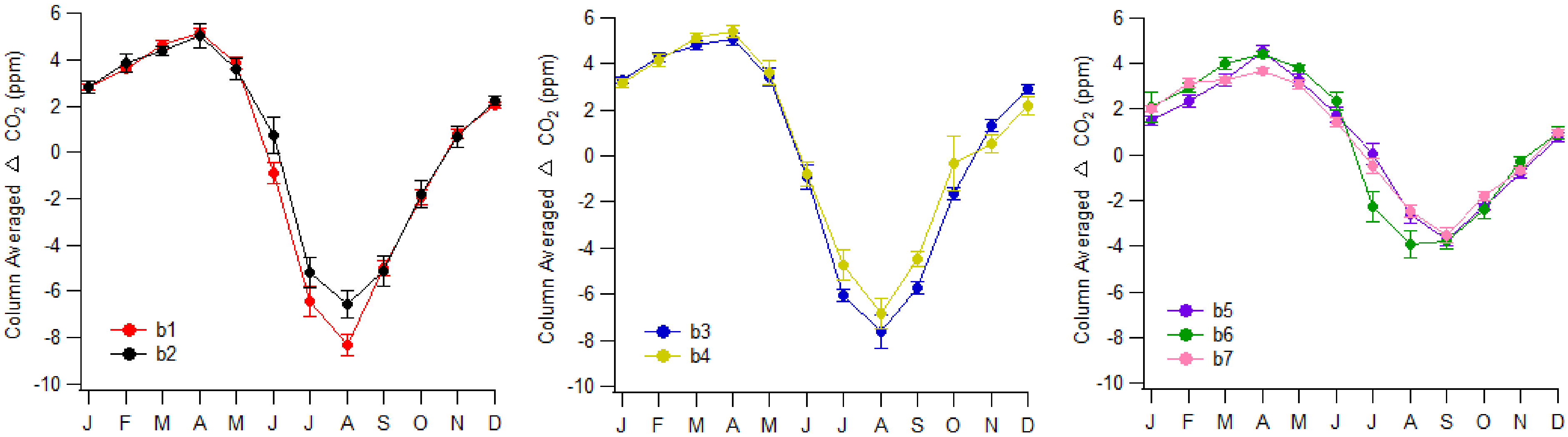


Long-term mean monthly vertical profiles



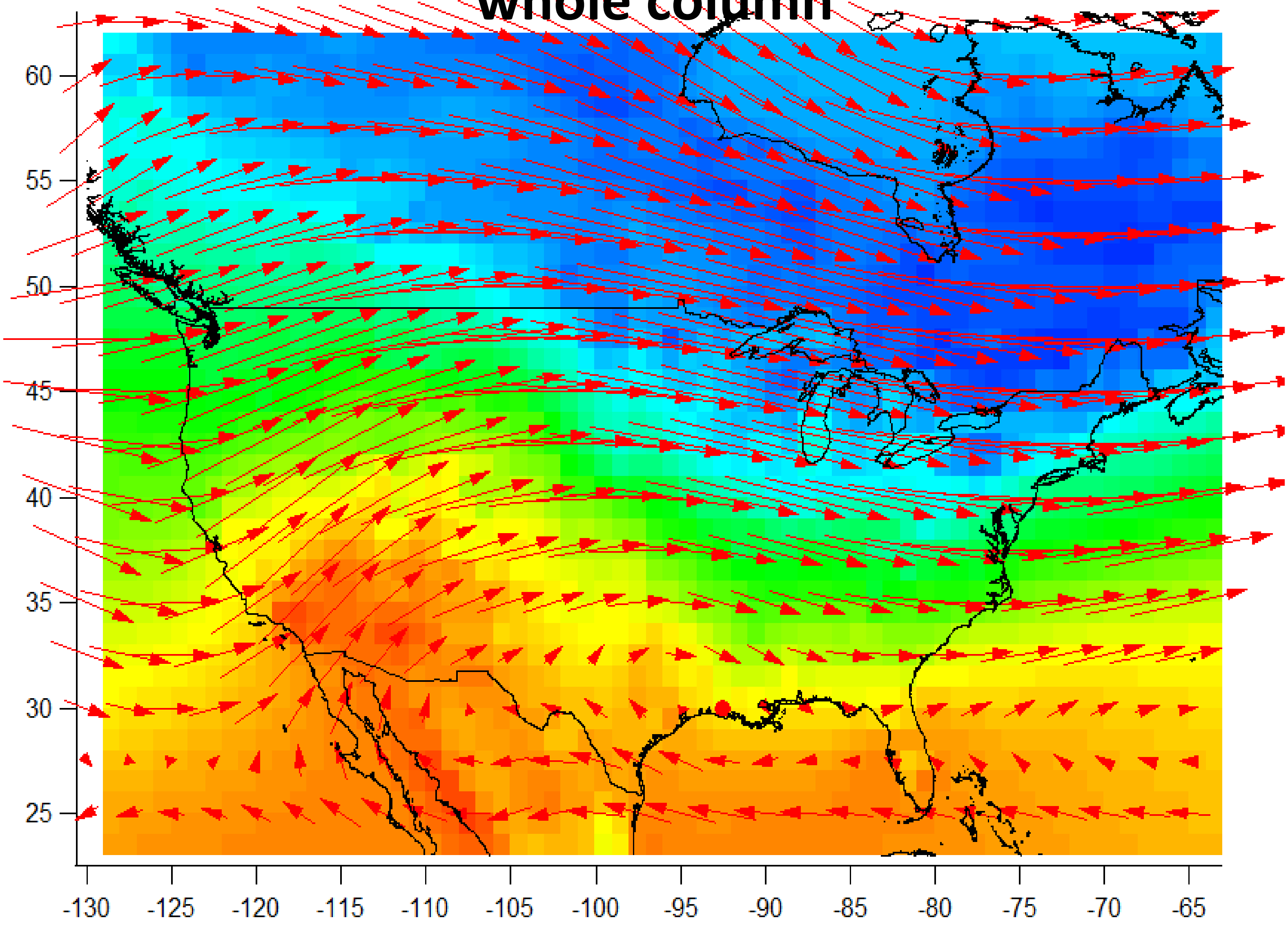


Uncertainty from aircraft & tower data

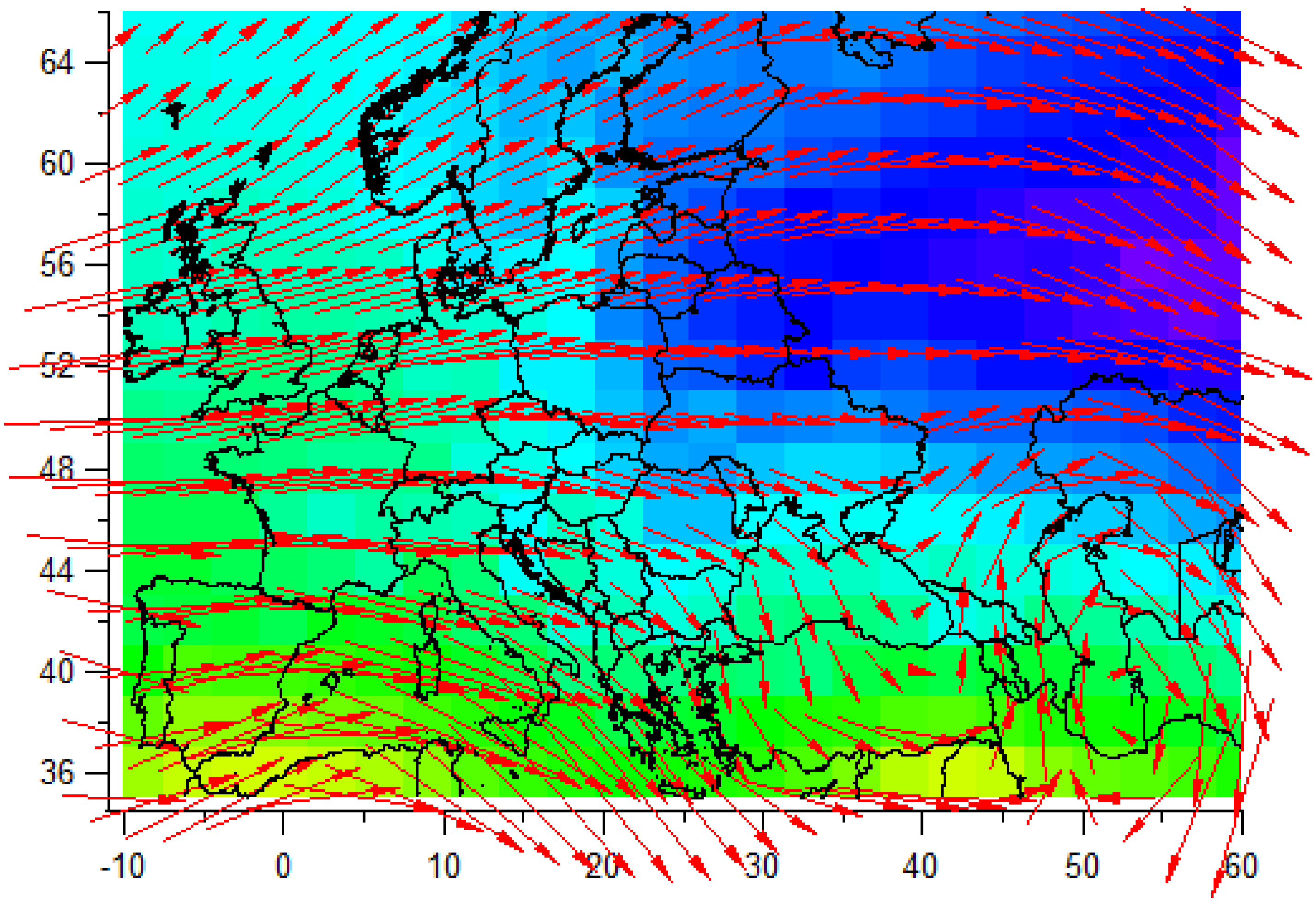


Method : Bootstrap-Monte Carlo (100 runs), random selections of daily profiles.
No limits on repetition.

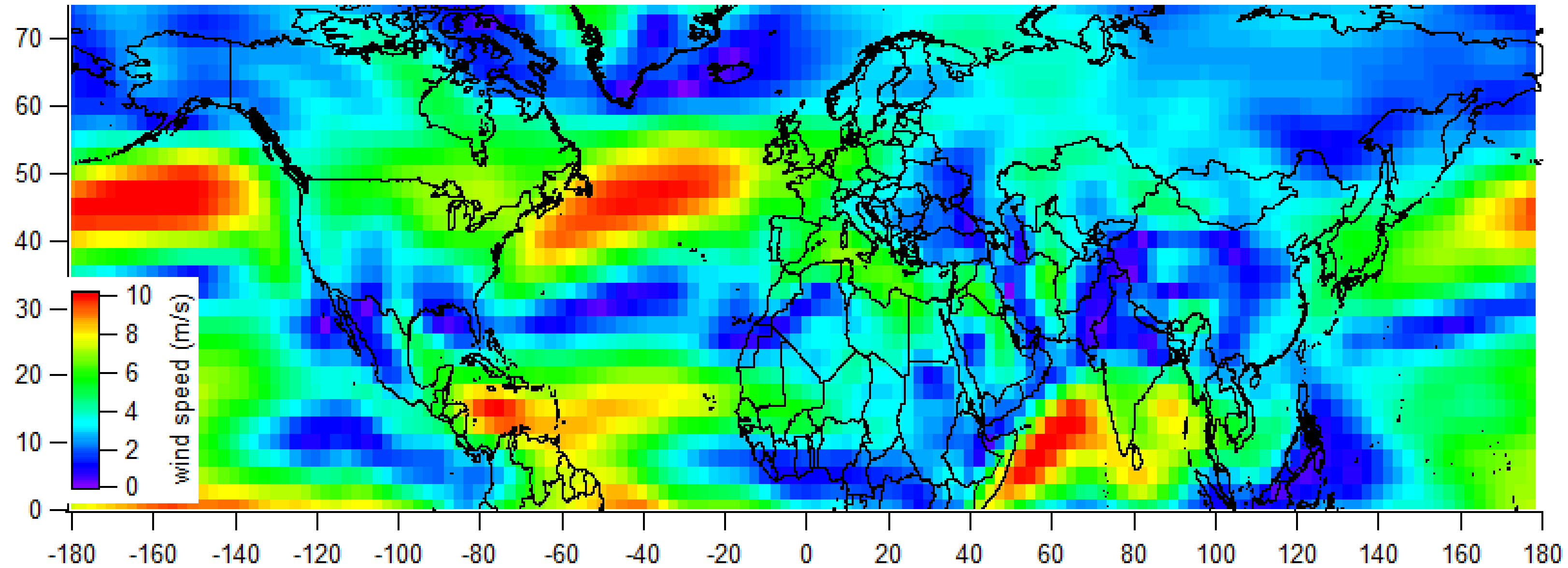
Long-term mean Jun. to Aug. wind vector whole column



Long-term mean Jun. to Aug. wind vector 1000-500hPa



Long-term mean Jun. to Aug. wind speed 1000-500hPa



Long-term mean Jun. to Aug. wind vector 1000-500hPa