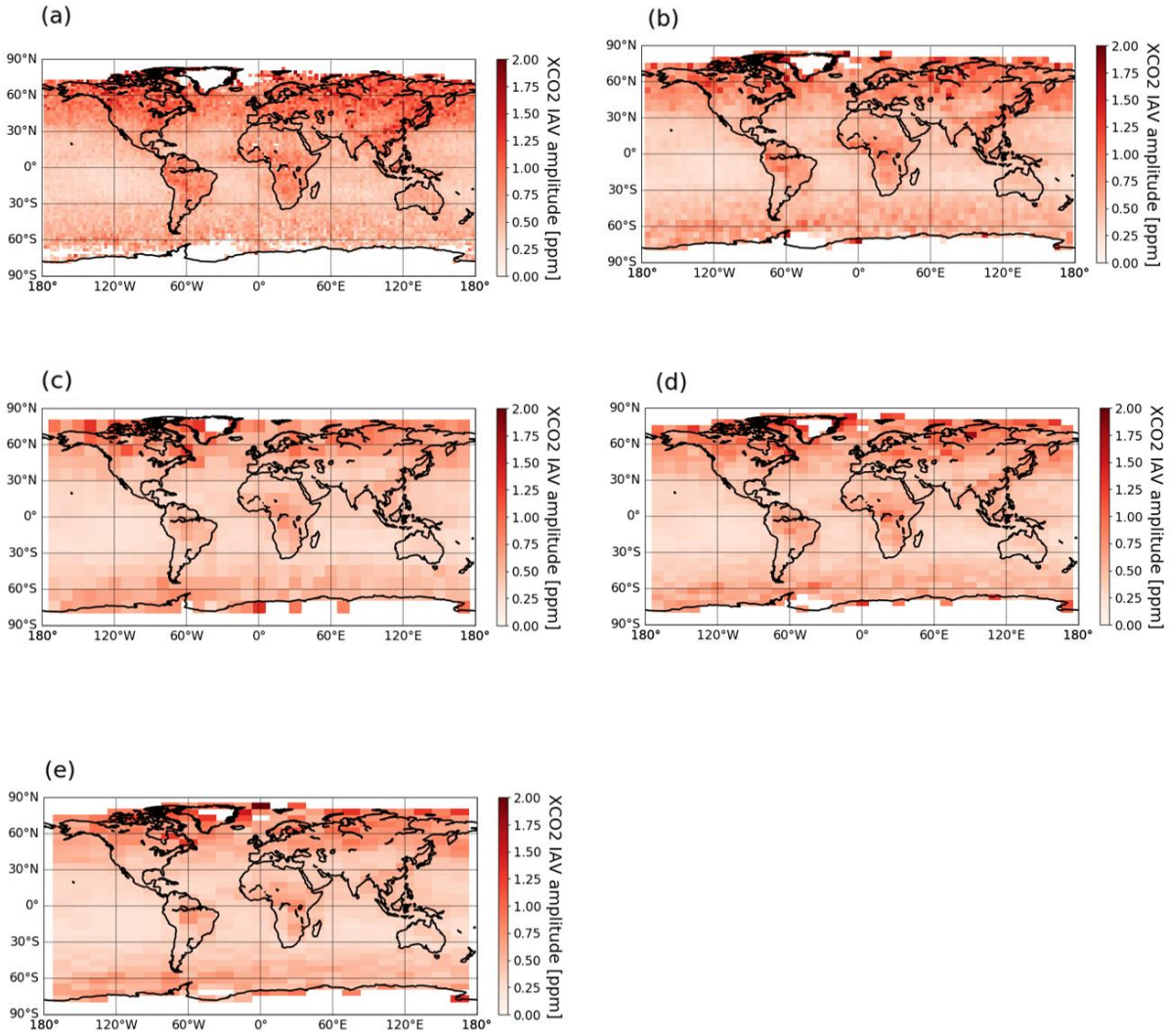
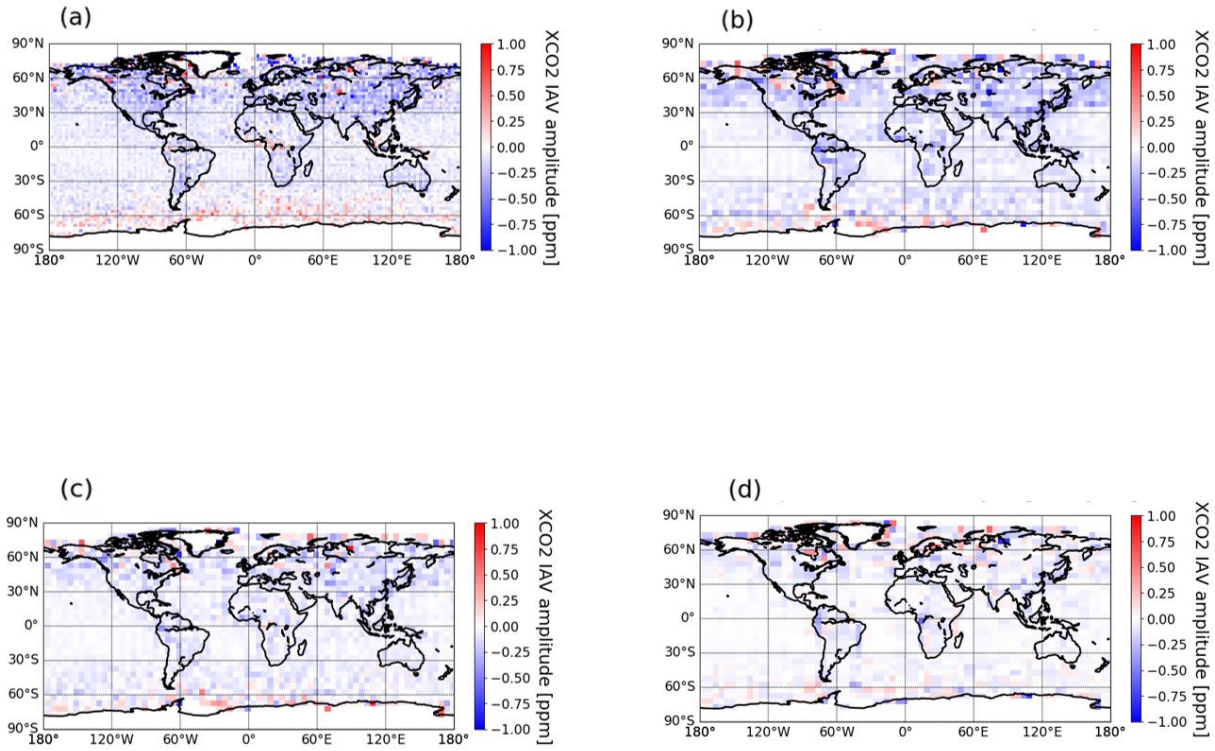
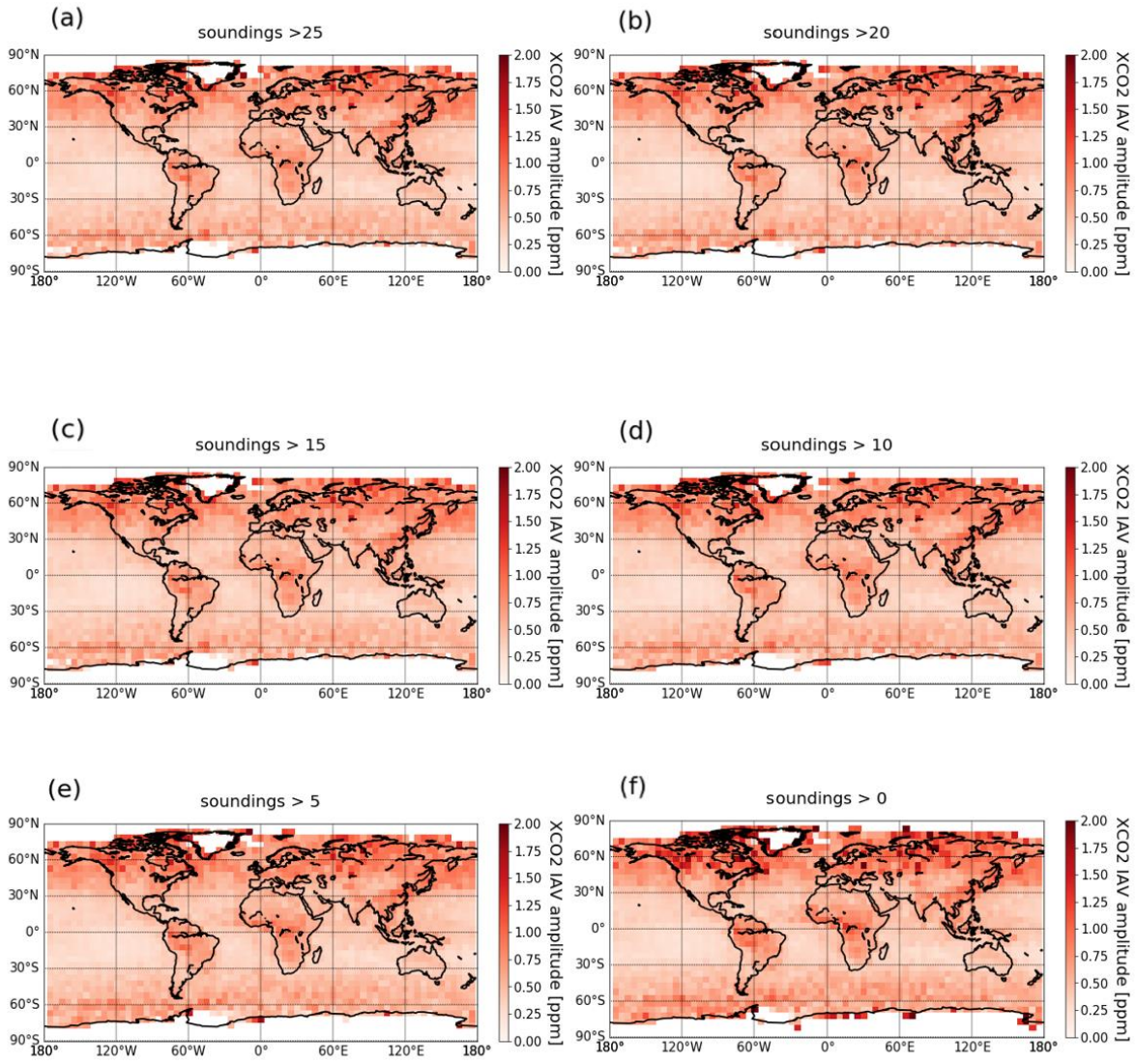


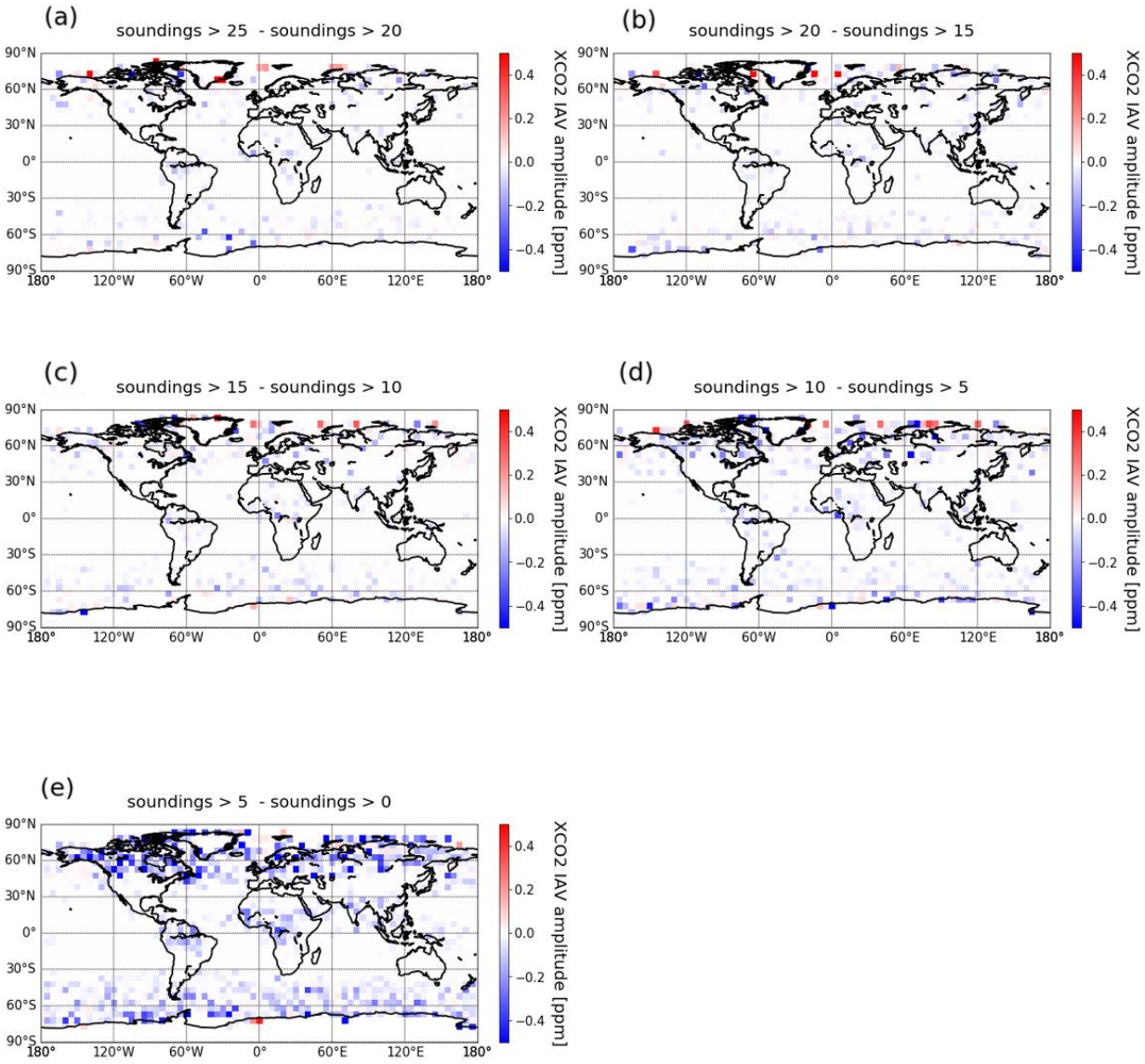
Supplementary Figure 1. The IAV amplitude map, with different resolution from (a) 2.5° longitude by 2.5 ° latitude , to (b) 5 ° longitude by 5 ° latitude, to (c) 10 ° longitude by 10 ° latitude , to (d) 5 ° longitude by 10 ° latitude and (e) 5 ° longitude by 15 ° latitude.



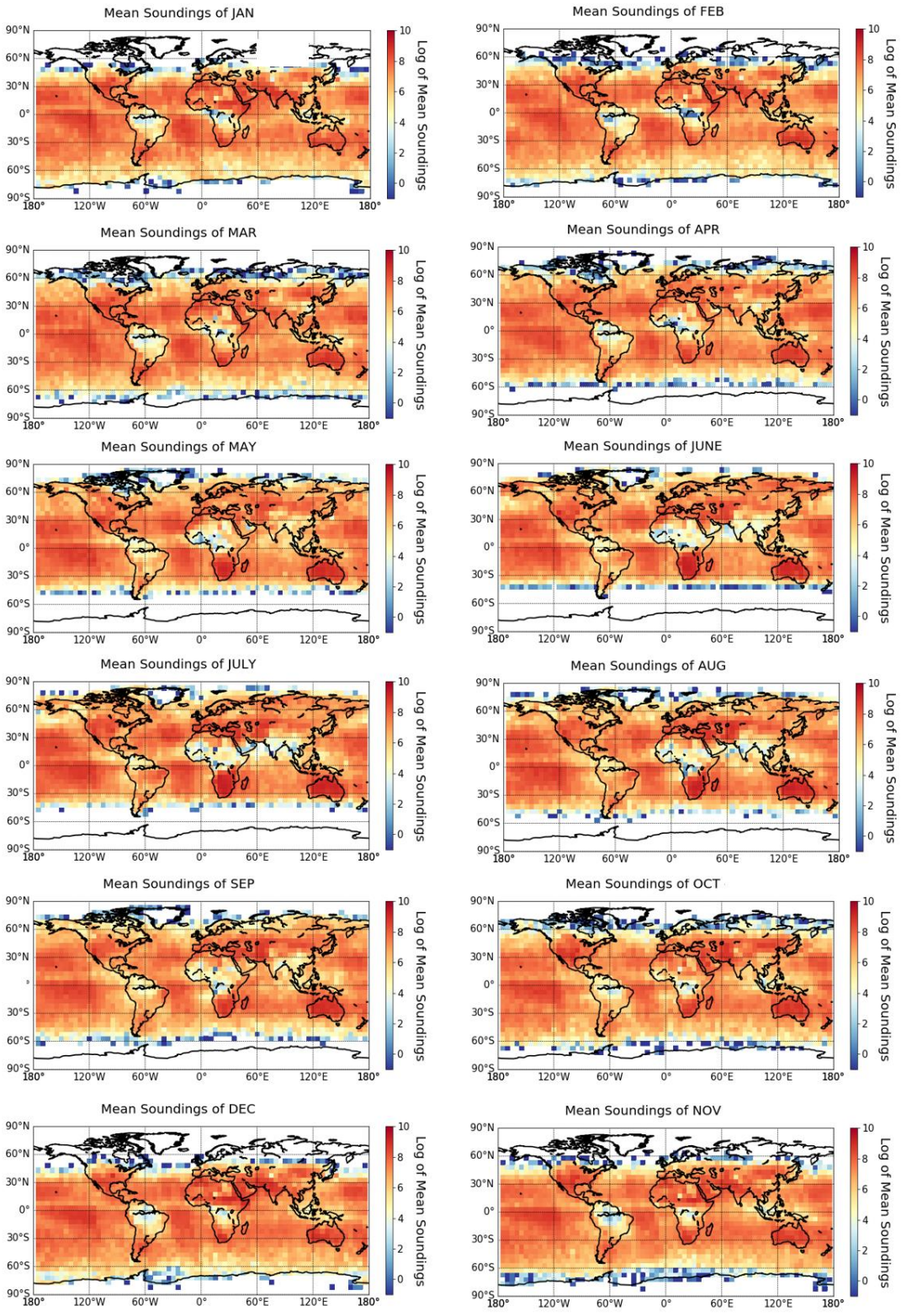
Supplementary Figure 2. The IAV amplitude difference for different resolution. (a) between 5° longitude by 5 ° latitude and 2.5 ° longitude by 2.5 ° latitude, (b) between 10° longitude by 10 ° latitude and 5 ° longitude by 5 ° latitude,(c) between 10° longitude by 5 ° latitude and 5 ° longitude by 5 ° latitude,(d) between 15° longitude by 5 ° latitude and 10 ° longitude by 5 ° latitude.



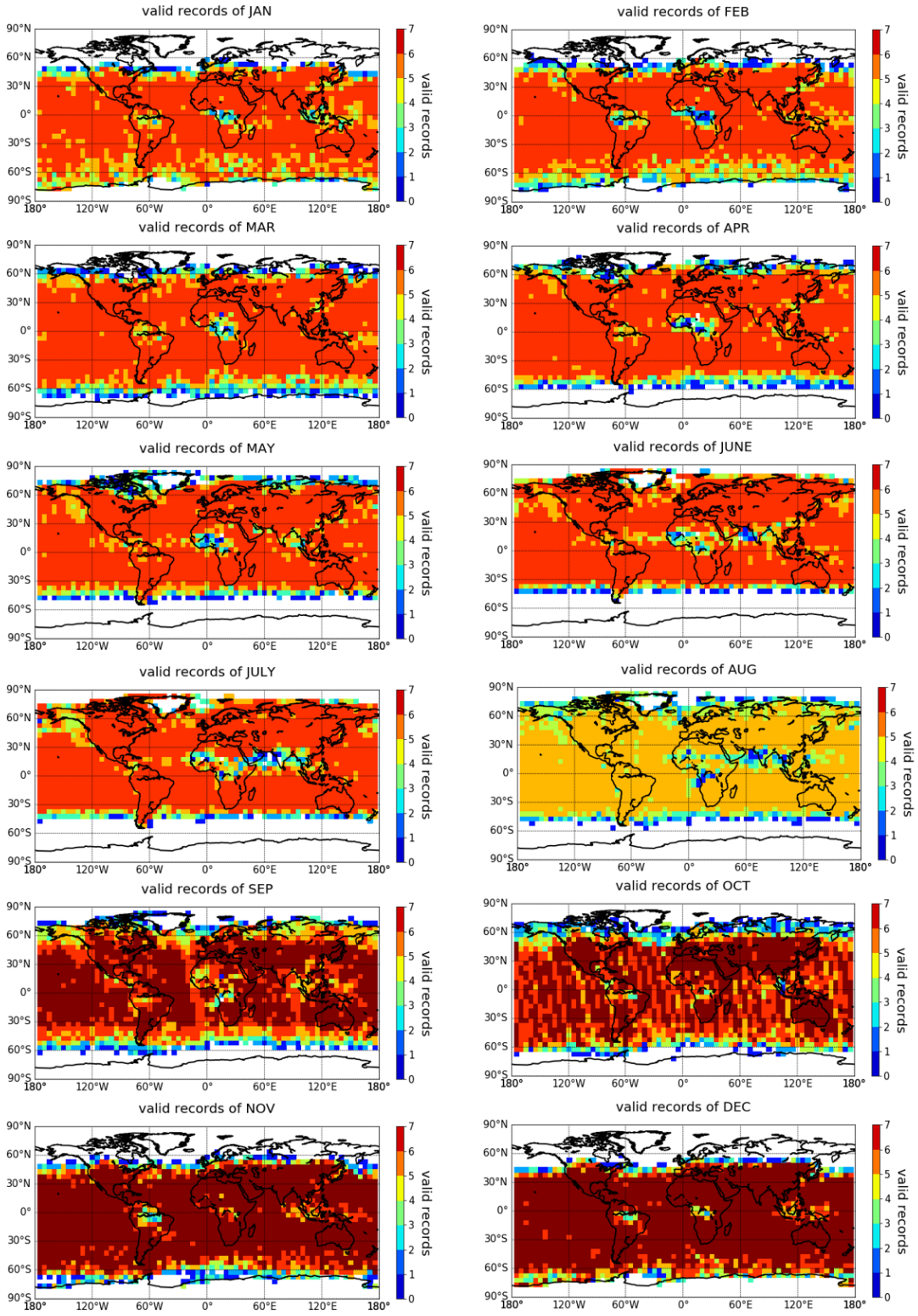
Supplementary Figure 3. The IAV amplitude map, use different sounding numbers as the benchmark to filter and get the aggregated OCO-2 detected XCO_2.



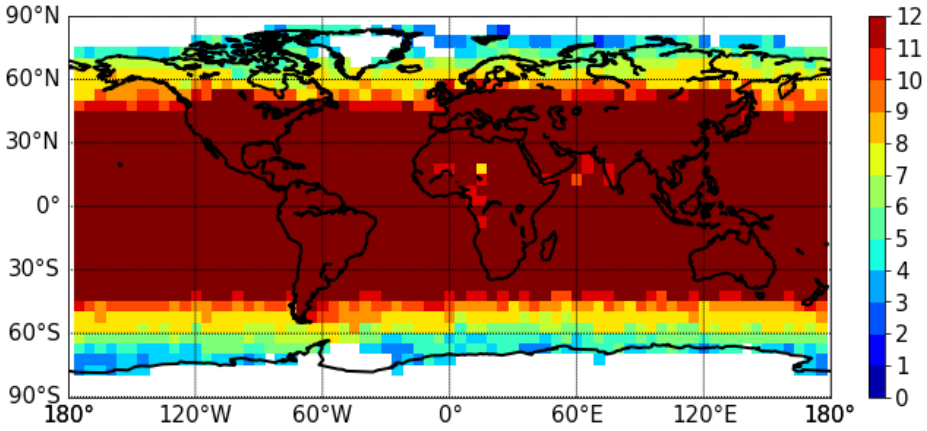
Supplementary Figure 4. The IAV amplitude difference between OCO-2 detected XCO_2 IAV based on different sounding numbers.



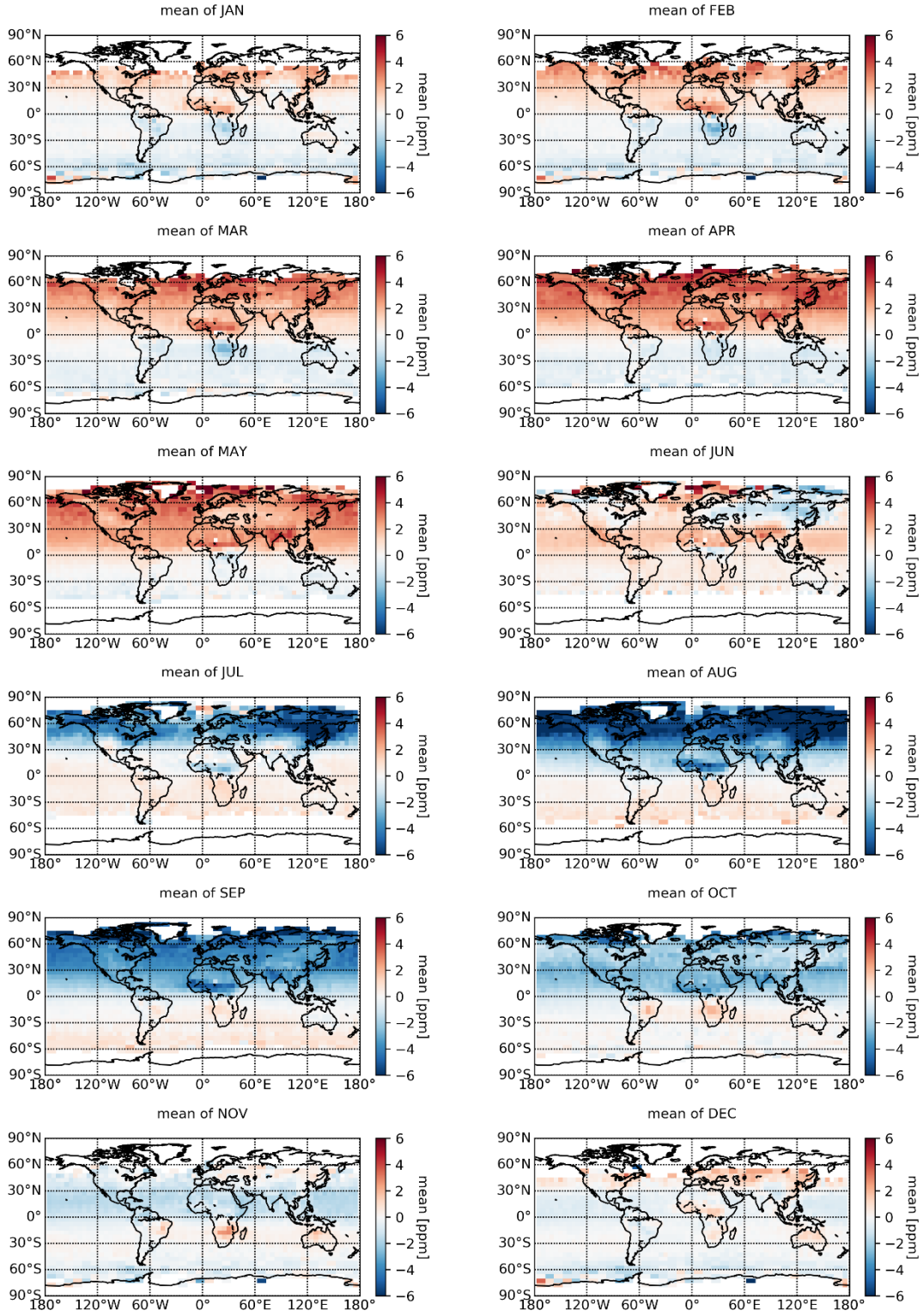
Supplementary Figure 5. The Log of Mean sounding numbers for 12 months for each 5 by 5 ° gridcell all over the world. The colorbar range is set to log -1 to 10 which is equivalent absolute soundings of 0 to 20000.



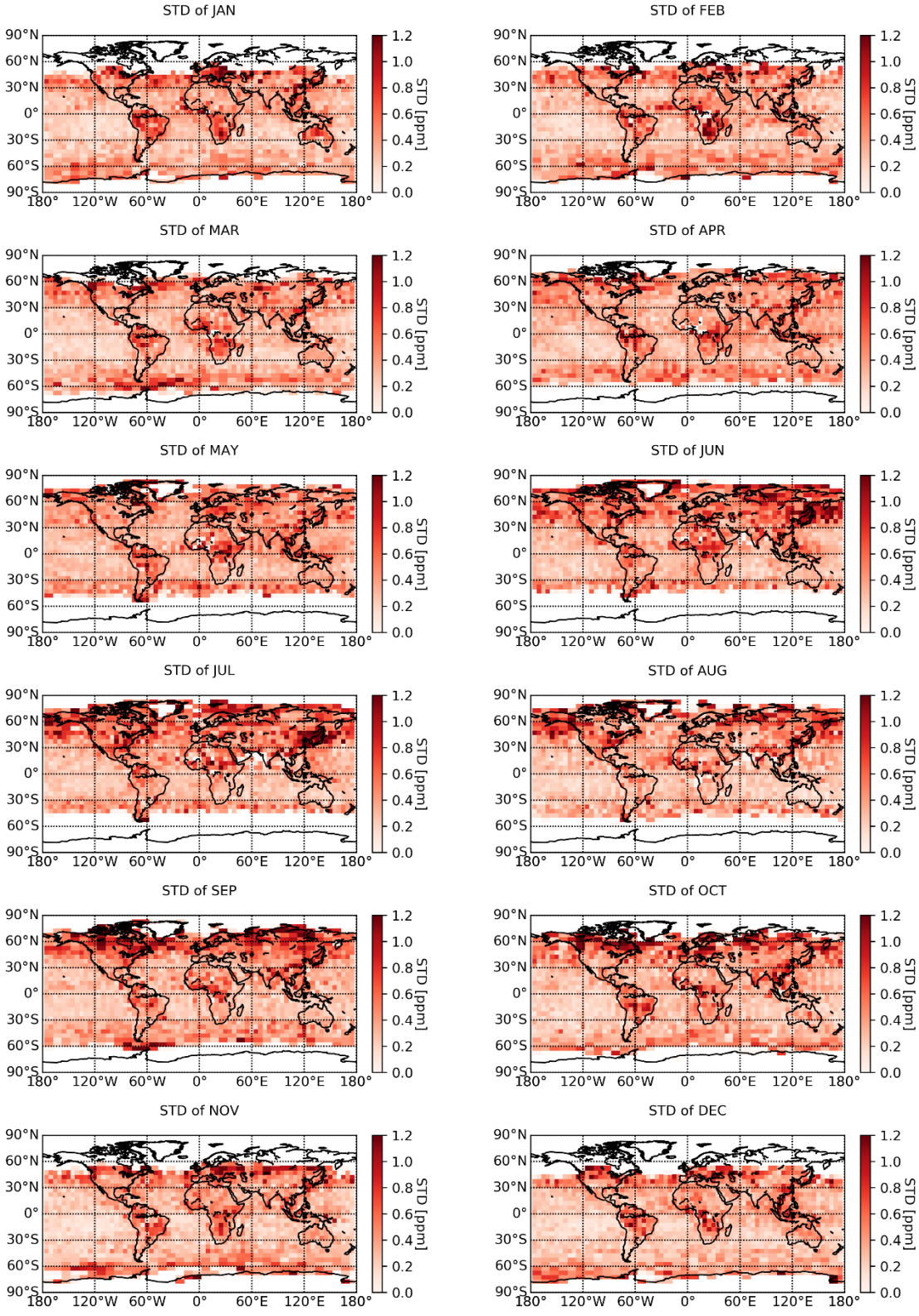
Supplementary Figure 6. The number of valid records (X out of 6 for JAN~JULY, 5 for AUG or 7 for SEP~DEC) for each month (JAN, FEB, etc…) for each 5 by 5 degree gridcell.



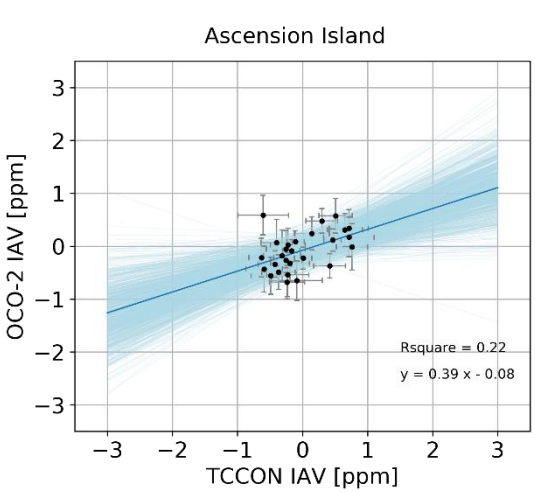
Supplementary Figure 7. The number of months out of 12 months in the year of 2014~2020 (JAN,FEB,MAR…) are available for each grid cell. It shows the OCO-2 XCO_2's capability of detecting, which is related to the validity of our calculated IAV.

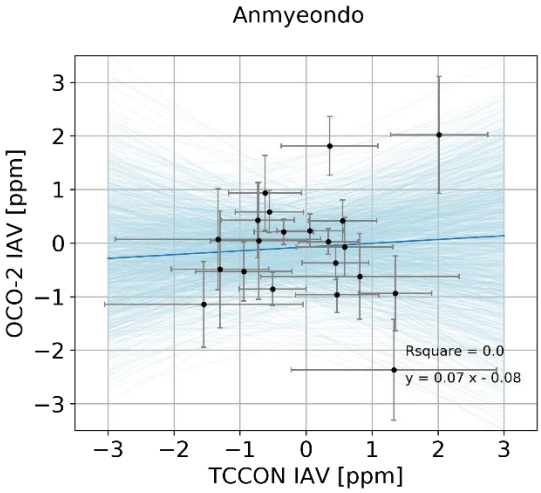


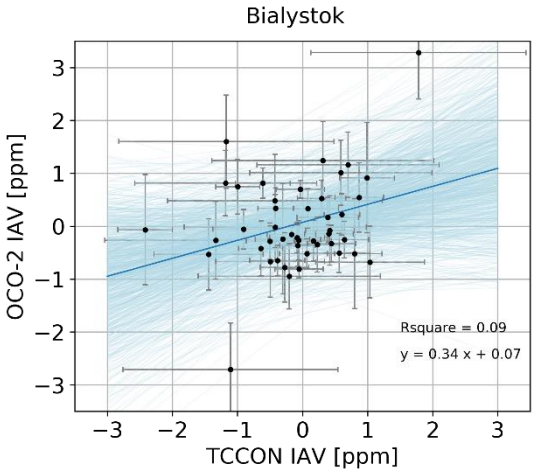
Supplementary Figure 8. Monthly Mean of OCO-2 XCO_2 observation.

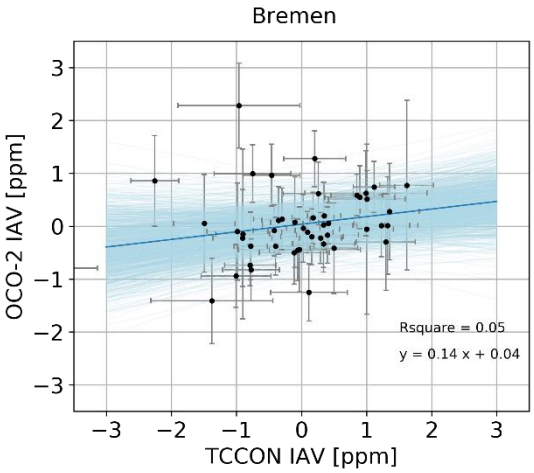


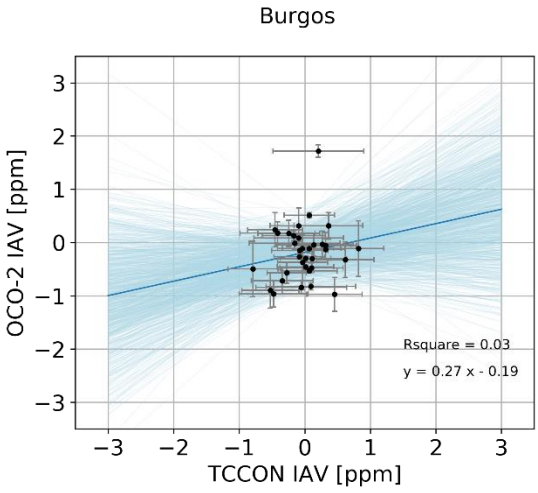
Supplementary Figure 9. Monthly STD of OCO-2 XCO_2 observation.

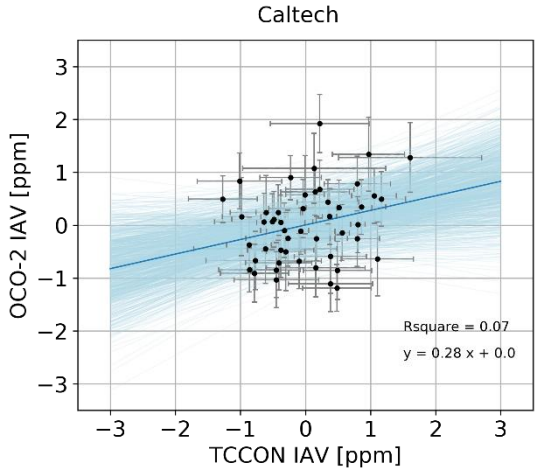

Ascension Island
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.22
y = 0.39 x - 0.08

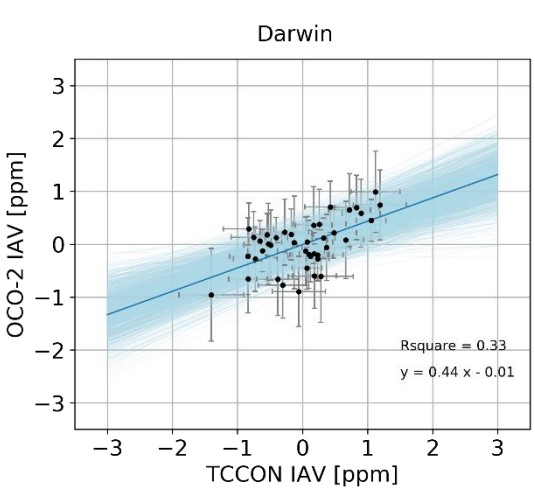

Anmyeondo
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.0
y = 0.07 x - 0.08

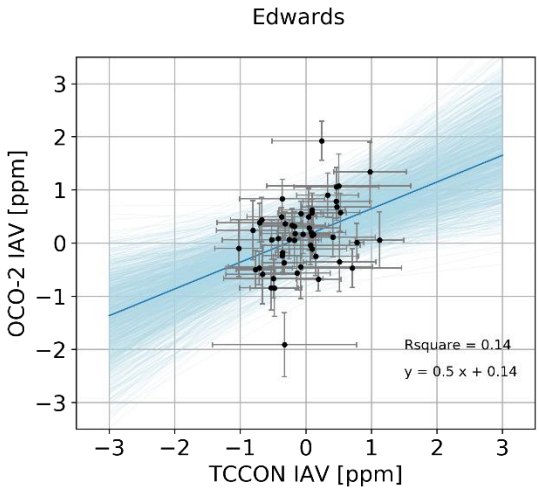

Bialystok
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.09
y = 0.34 x + 0.07

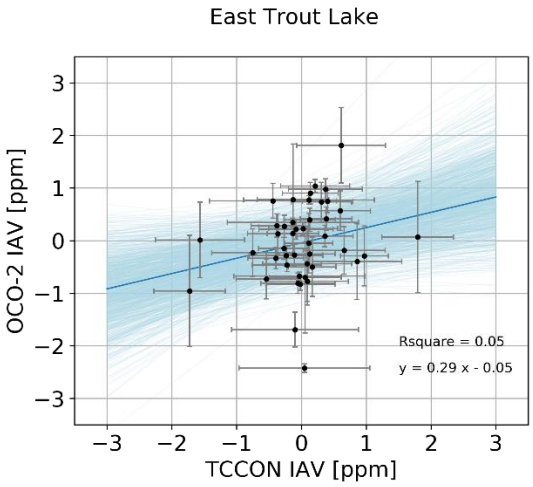

Bremen
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.05
y = 0.14 x + 0.04

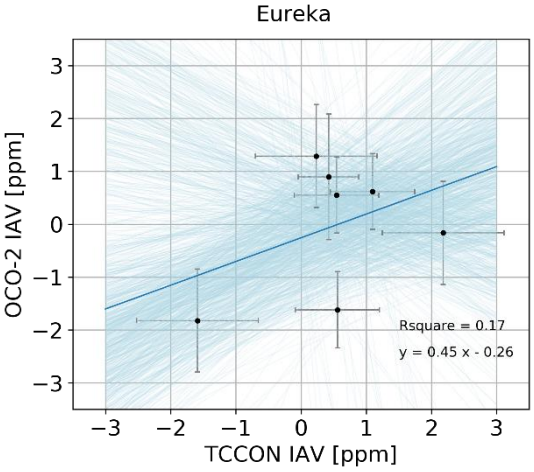

Burgos
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.03
y = 0.27 x - 0.19

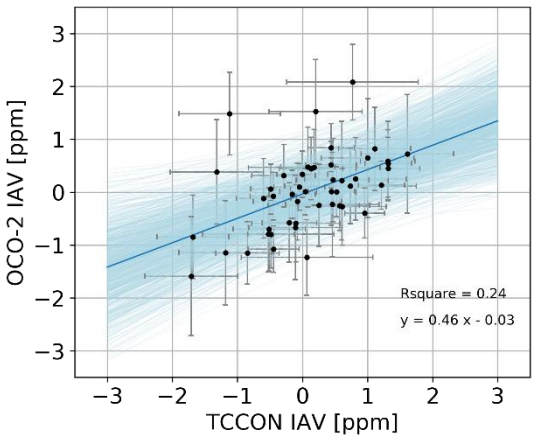

Caltech
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.07
y = 0.28 x + 0.0

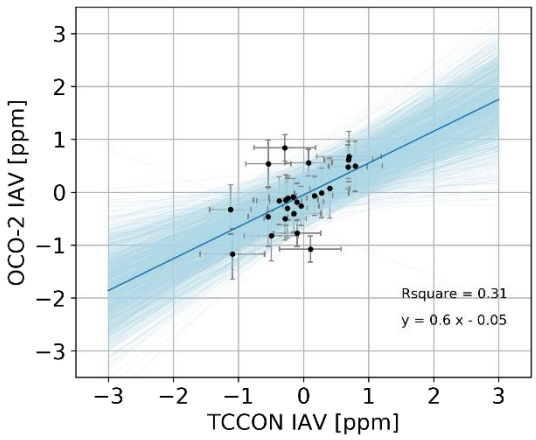

Darwin
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.33
y = 0.44 x - 0.01

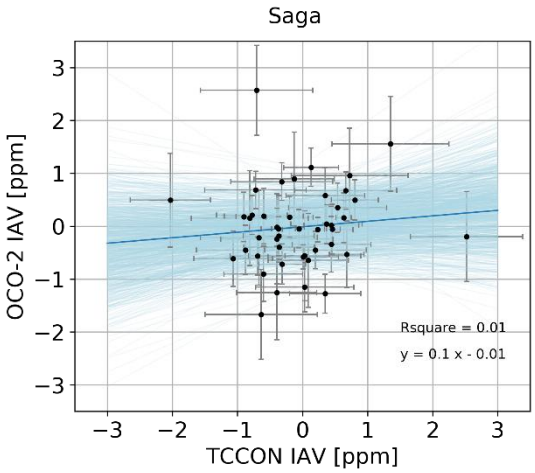

Edwards
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.14
y = 0.5 x + 0.14

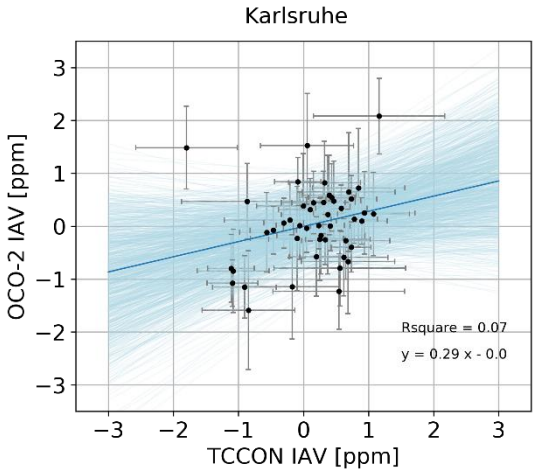

East Trout Lake
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.05
y = 0.29 x - 0.05

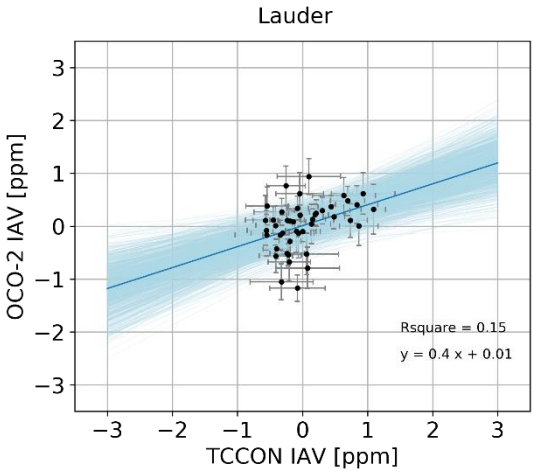

Eureka
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.17
y = 0.45 x - 0.26

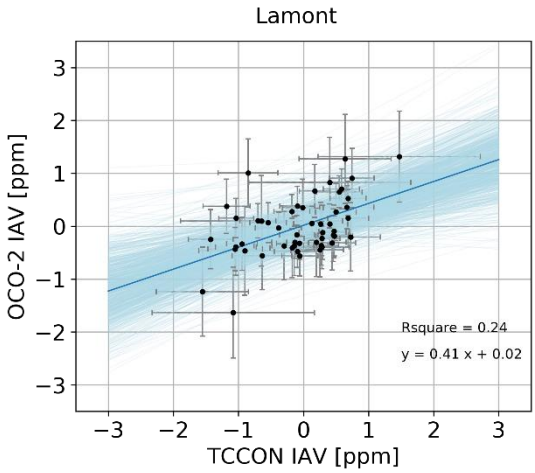

Garmisch
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.24
y = 0.46 x - 0.03

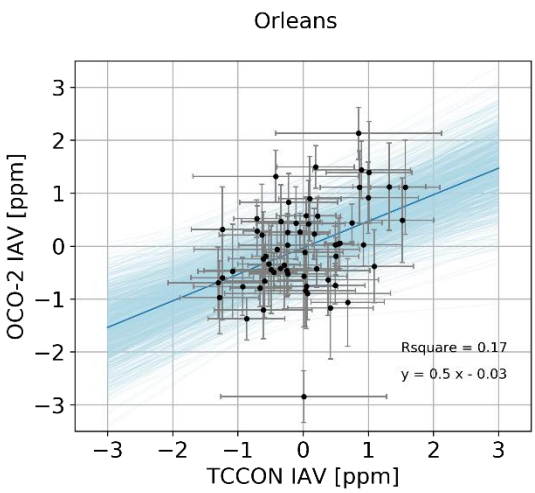

Izana
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.31
y = 0.6 x - 0.05

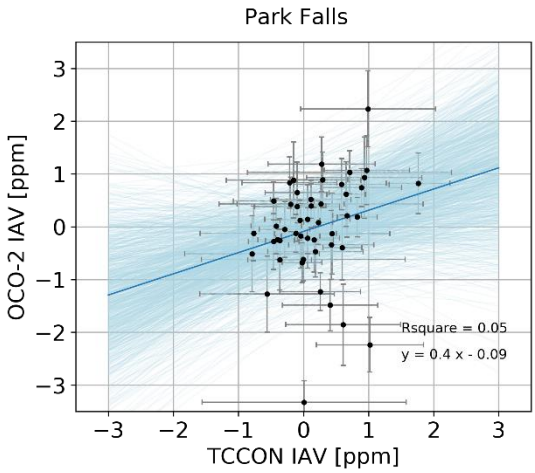

Saga
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.01
y = 0.1 x - 0.01

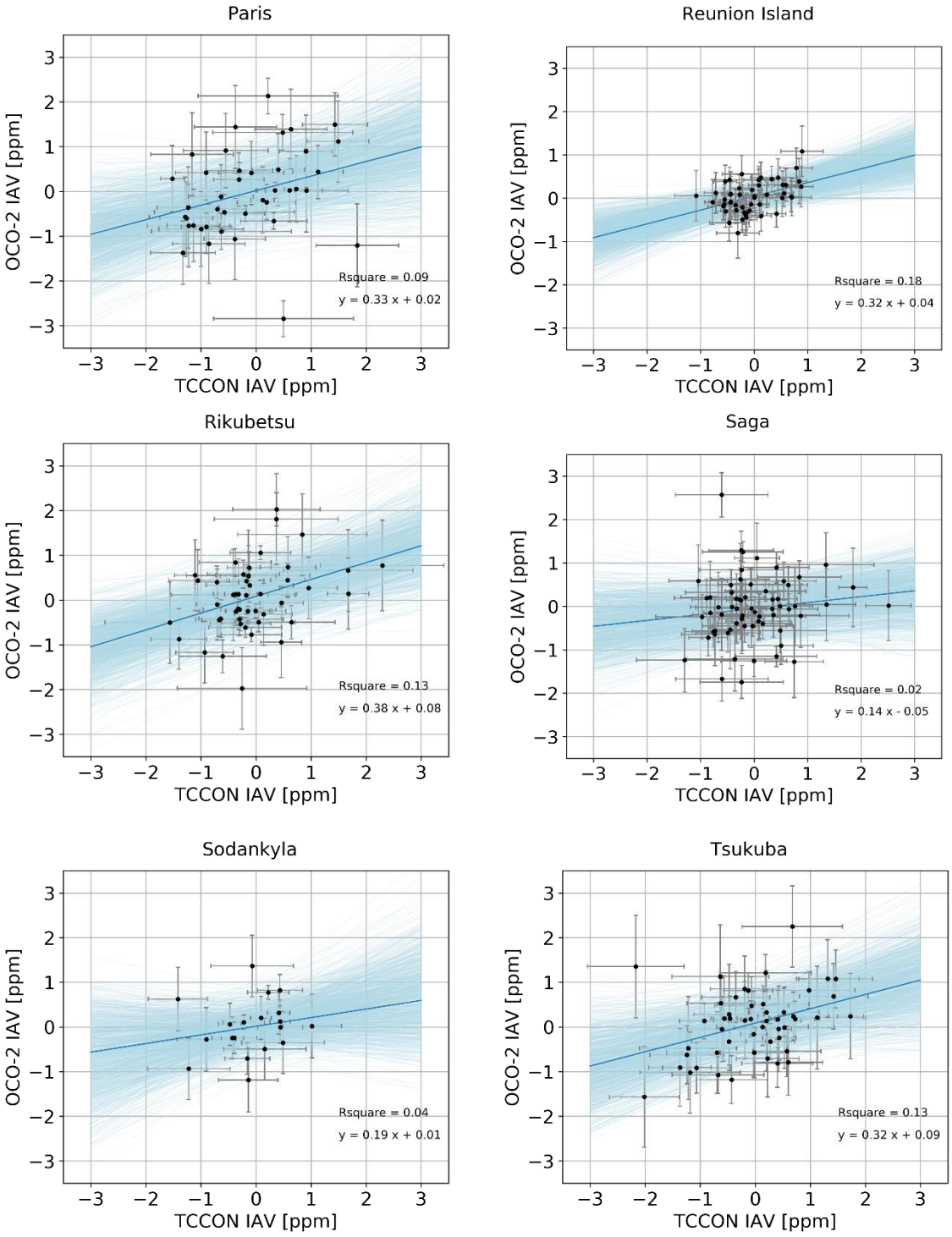

Karlsruhe
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.07
y = 0.29 x - 0.0

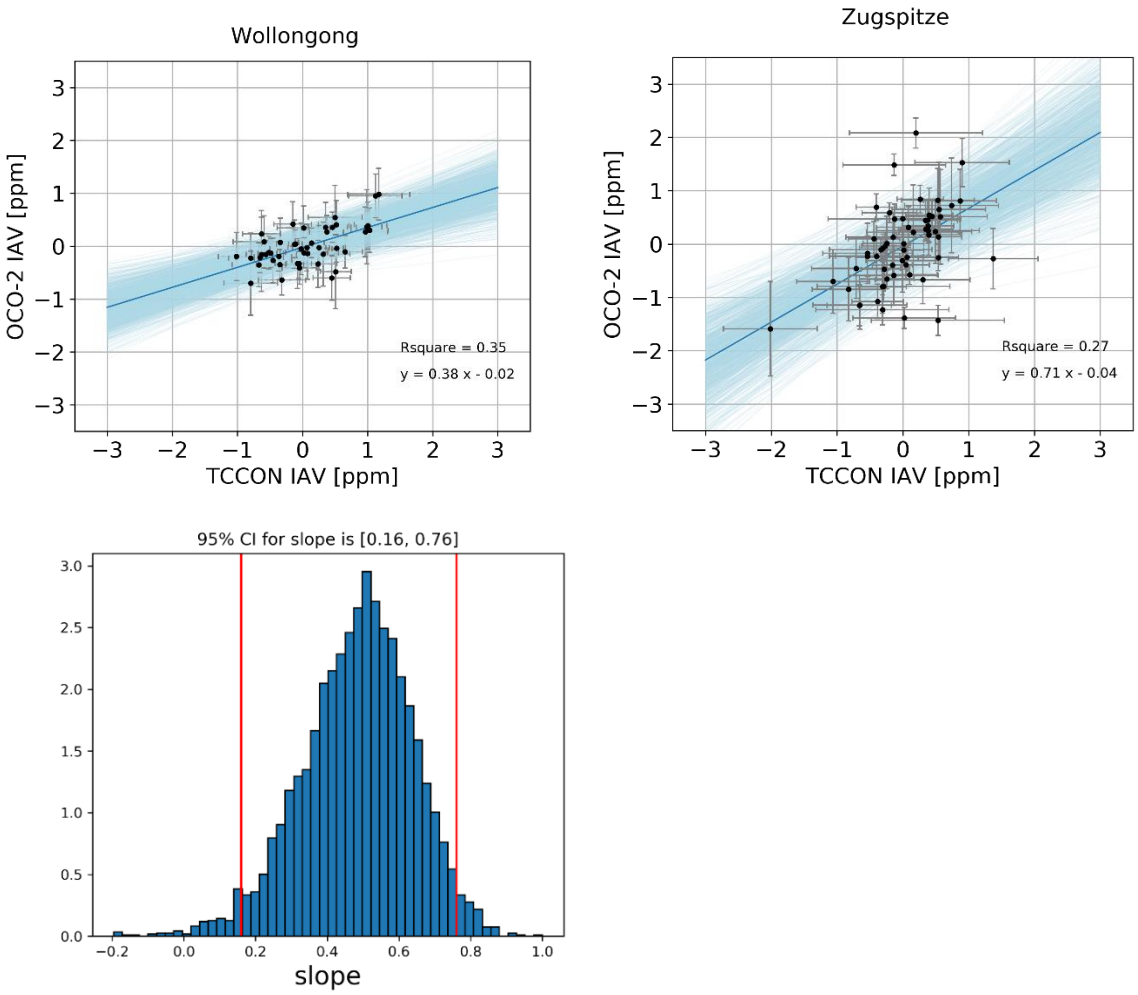

Lauder
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.15
y = 0.4 x + 0.01


Lamont
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.24
y = 0.41 x + 0.02


Orleans
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.17
y = 0.5 x - 0.03


Park Falls
OCO-2 IAV [ppm]
TCCON IAV [ppm]
Rsquare = 0.05
y = 0.4 x - 0.09

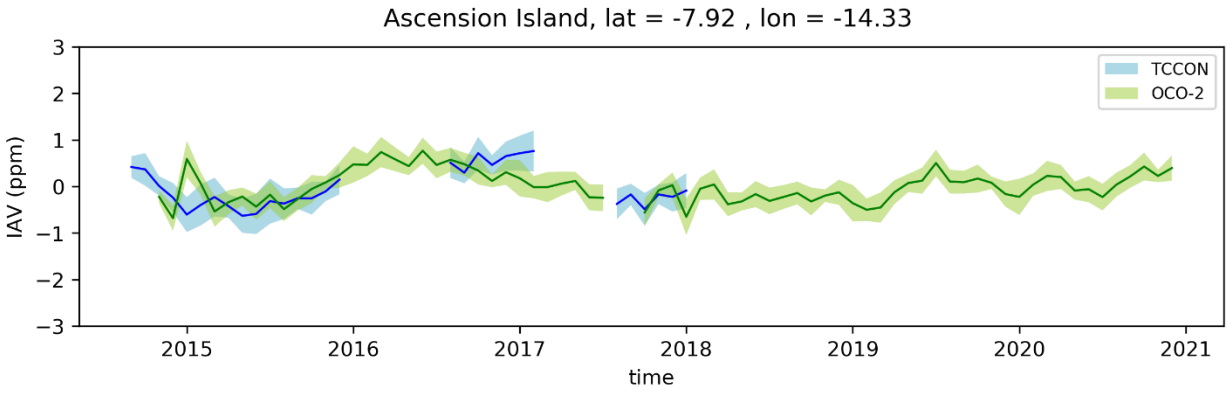

Paris
Rsquare = 0.09
y = 0.33 x + 0.02
Reunion Island
Rsquare = 0.18
y = 0.32 x + 0.04
Rikubetsu
Rsquare = 0.13
y = 0.38 x + 0.08
Saga
Rsquare = 0.02
y = 0.14 x - 0.05
Sodankyla
Rsquare = 0.04
y = 0.19 x + 0.01
Tsukuba
Rsquare = 0.13
y = 0.32 x + 0.09
OCO-2 IAV [ppm]
TCCON IAV [ppm]

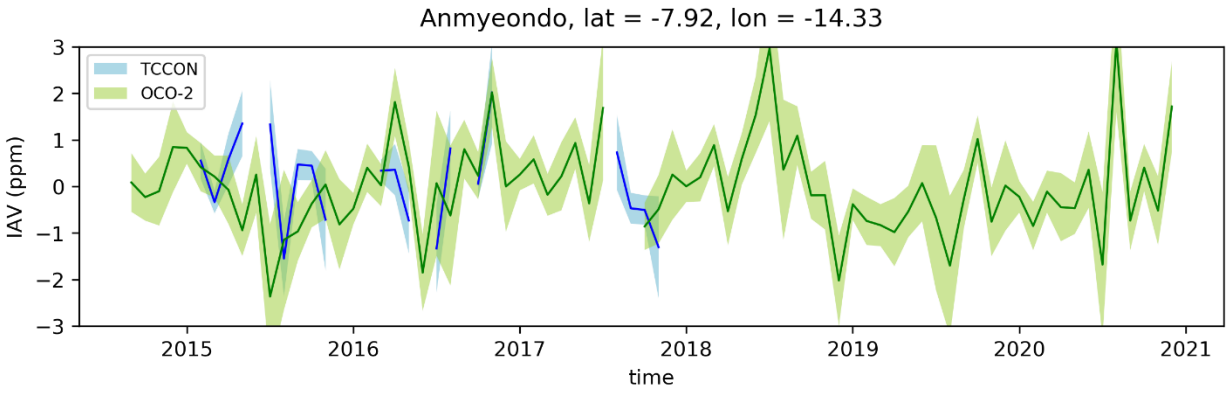


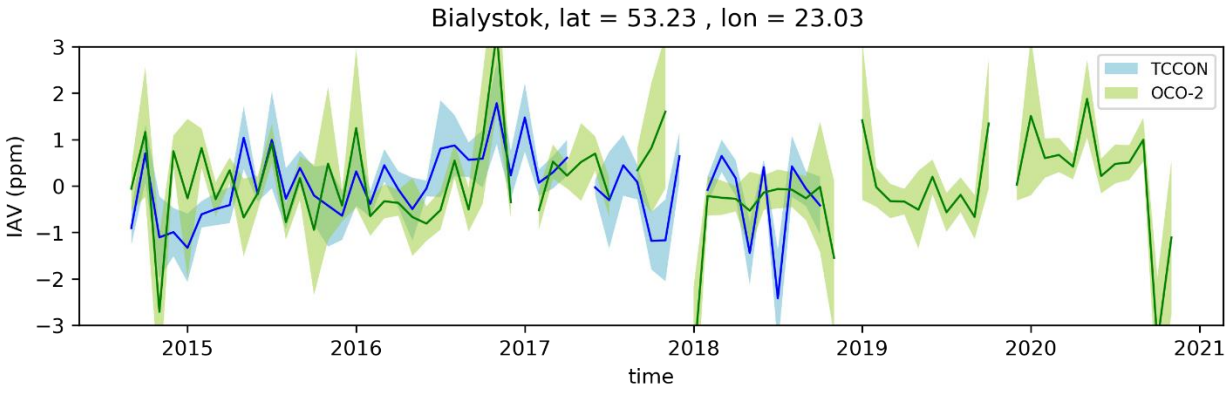
Supplementary Figure 10. Bootsrapping Linear Regression fit between TCCON and OCO-2 monthly averaged XCO_2 IAV over 26 TCCON sites which have records between 2014.09 to 2018.12.

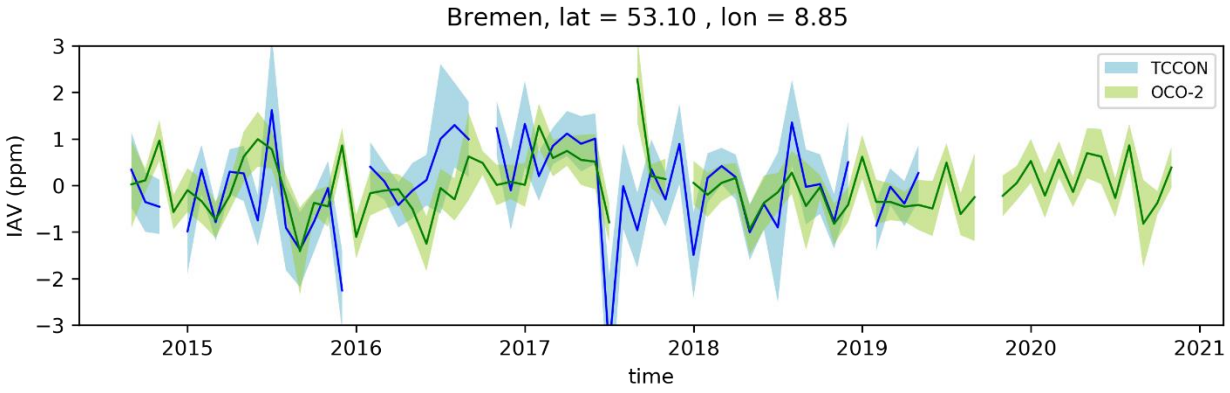
Light-blue regression lines in each plot are based on 1000 times 'resampling' of the original OCO-2 vs. TCCON IAV data points. The Steelblue line in each plot is just a simple polynomial fit between y and x.

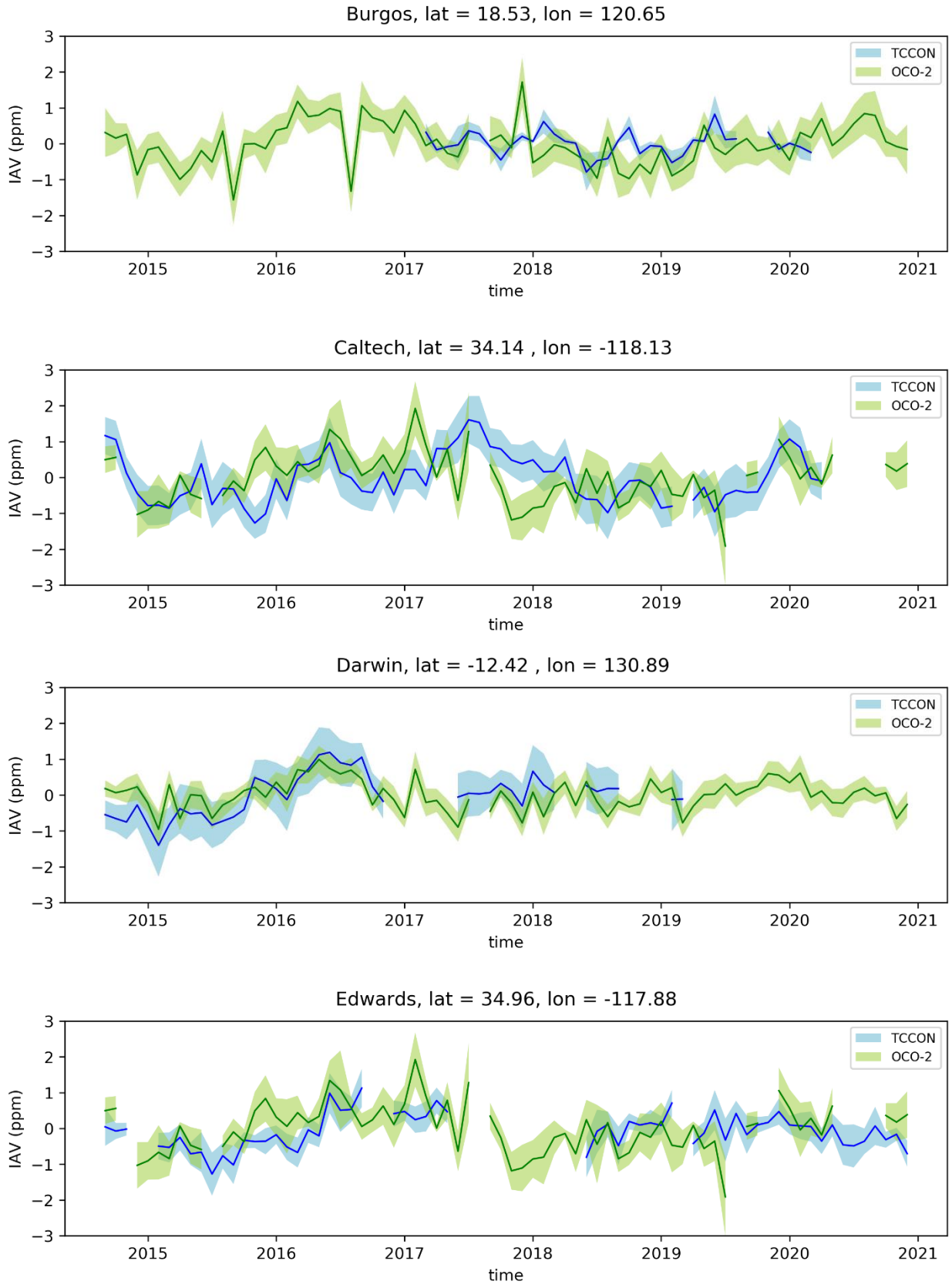
The 95% significant level for regression slope is calculated based on the distribution of the possible 1000 slopes during the bootstrapping. The last figure, which is the histogram of the 1000 slopes for Lauder, gives an example of how I obtain the range of k-slope.

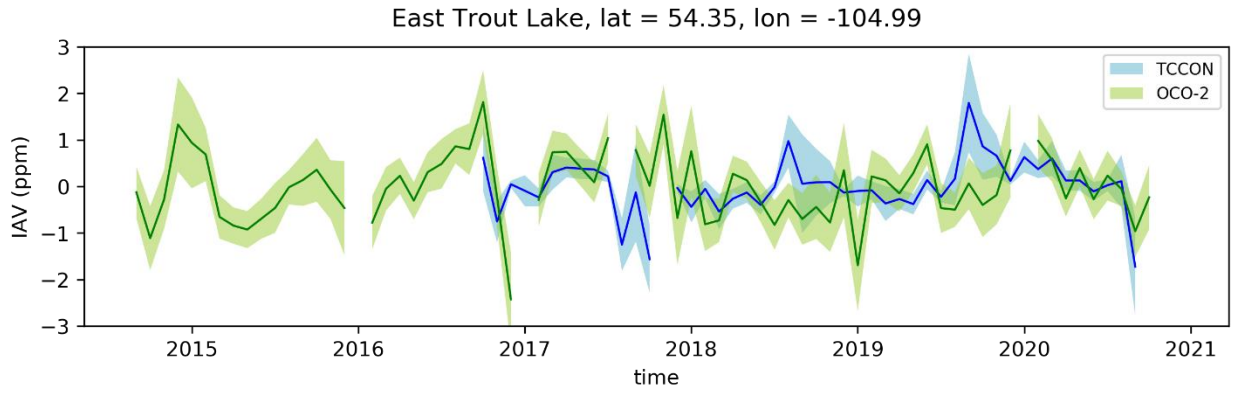

Ascension Island, lat = -7.92 , lon = -14.33
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

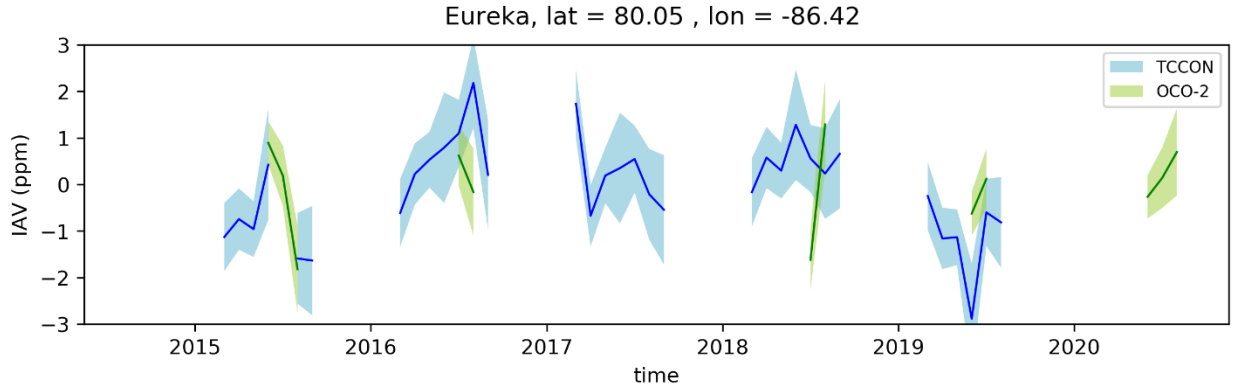

Anmyeondo, lat = -7.92, lon = -14.33
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

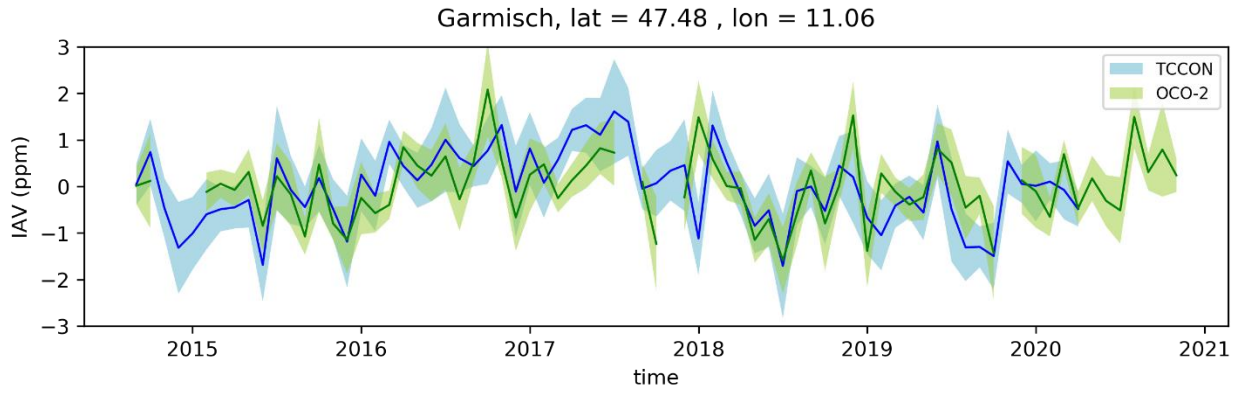

Bialystok, lat = 53.23 , lon = 23.03
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

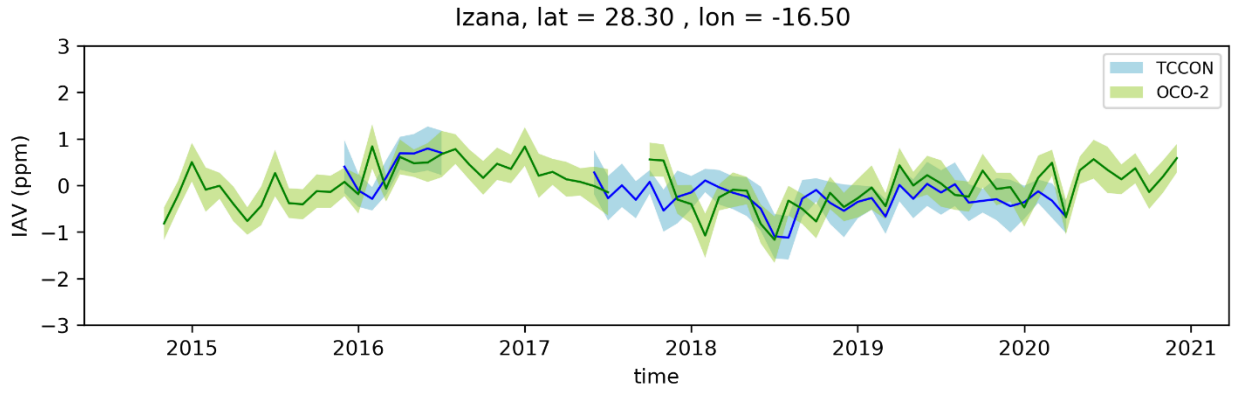

Bremen, lat = 53.10 , lon = 8.85
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

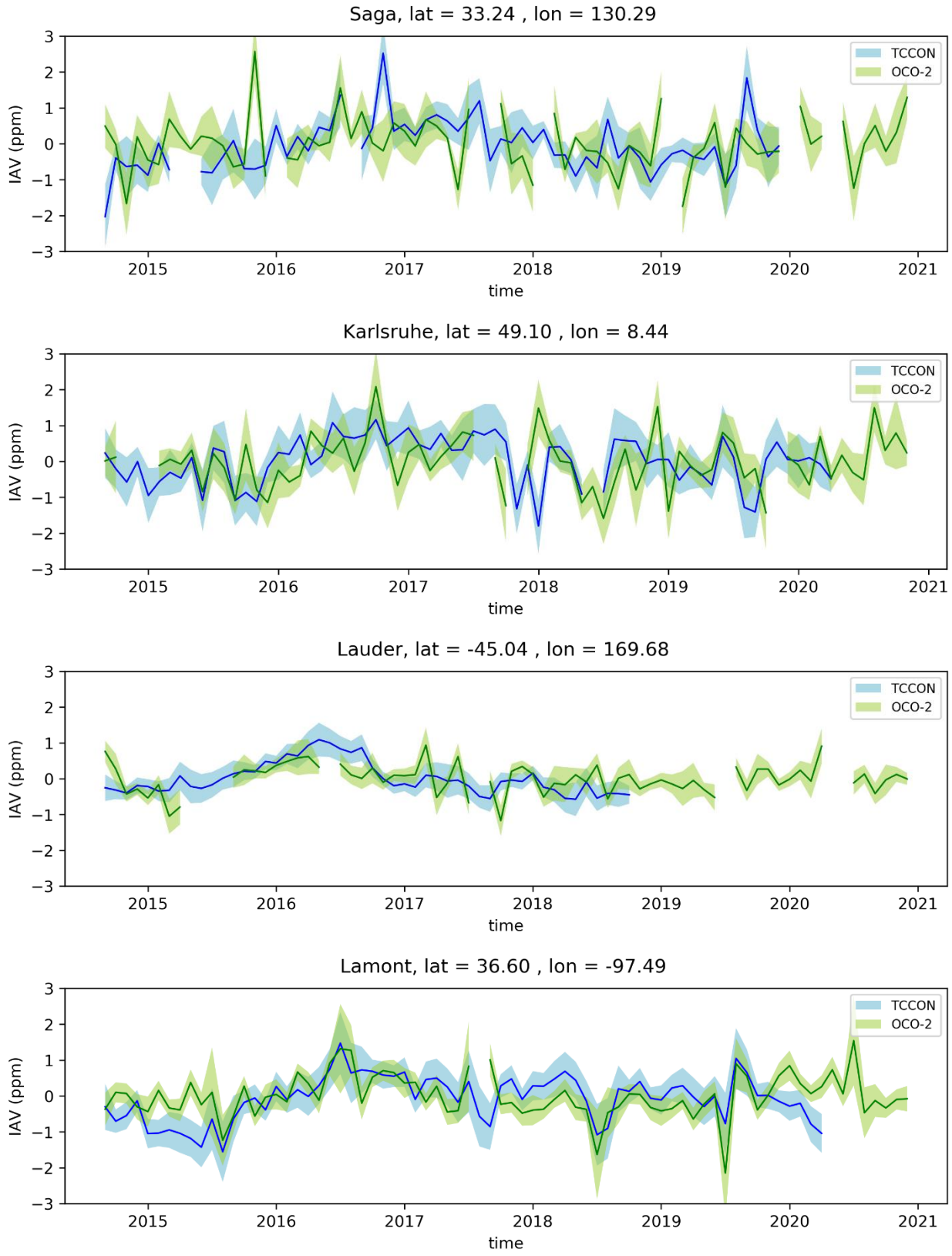

Burgos, lat = 18.53, lon = 120.65
Caltech, lat = 34.14 , lon = -118.13
Darwin, lat = -12.42 , lon = 130.89
Edwards, lat = 34.96, lon = -117.88
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

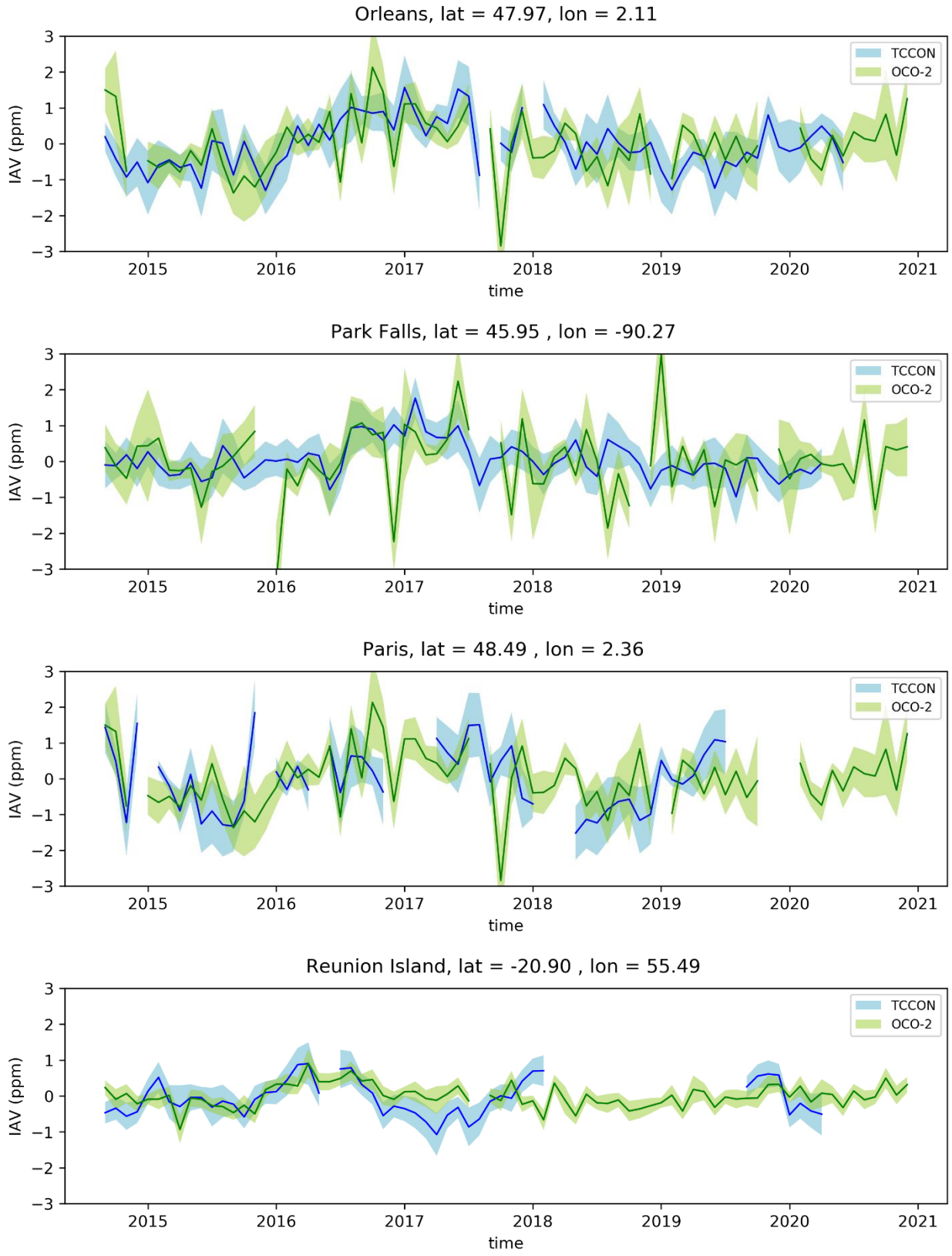

East Trout Lake, lat = 54.35, lon = -104.99
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

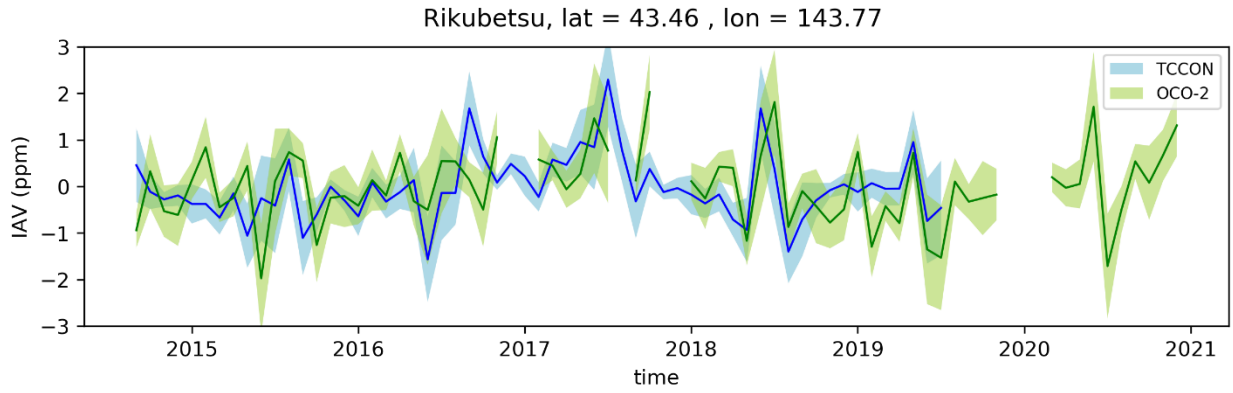

Eureka, lat = 80.05 , lon = -86.42
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020

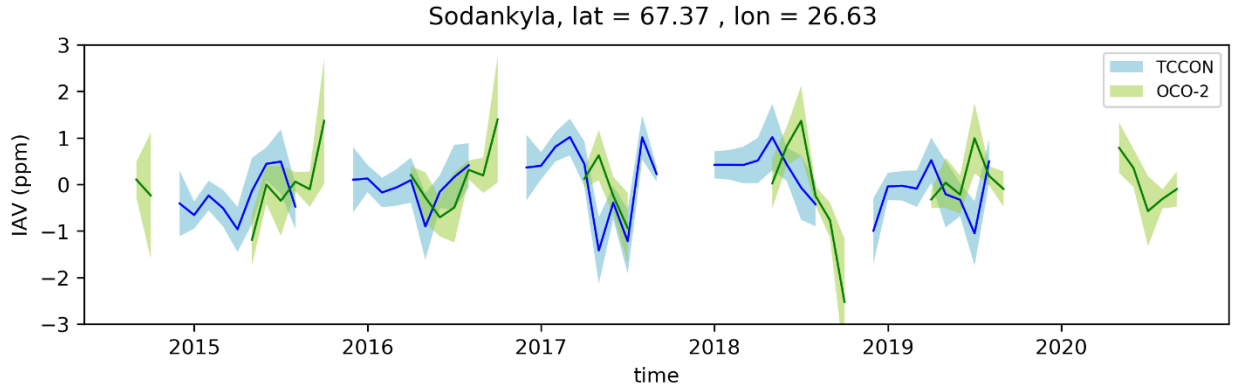

Garmisch, lat = 47.48 , lon = 11.06
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

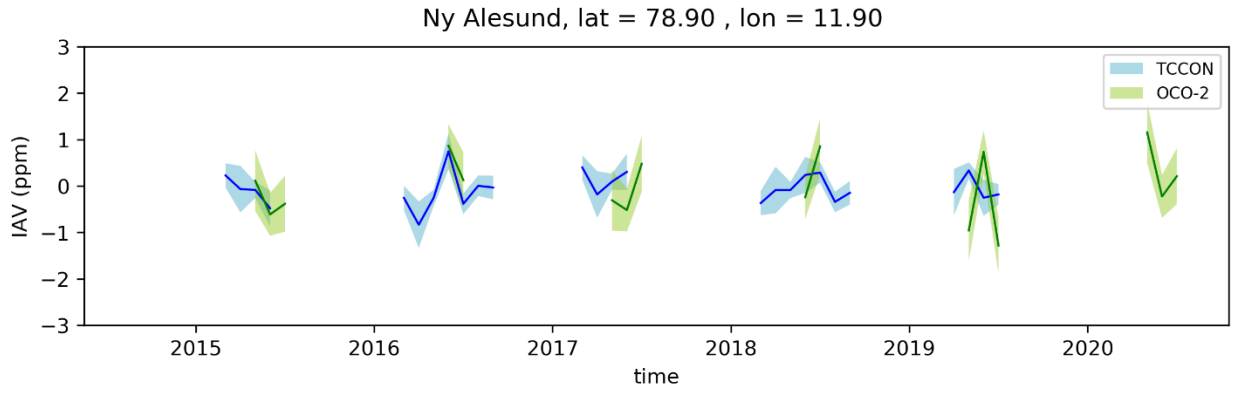

Izana, lat = 28.30 , lon = -16.50
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

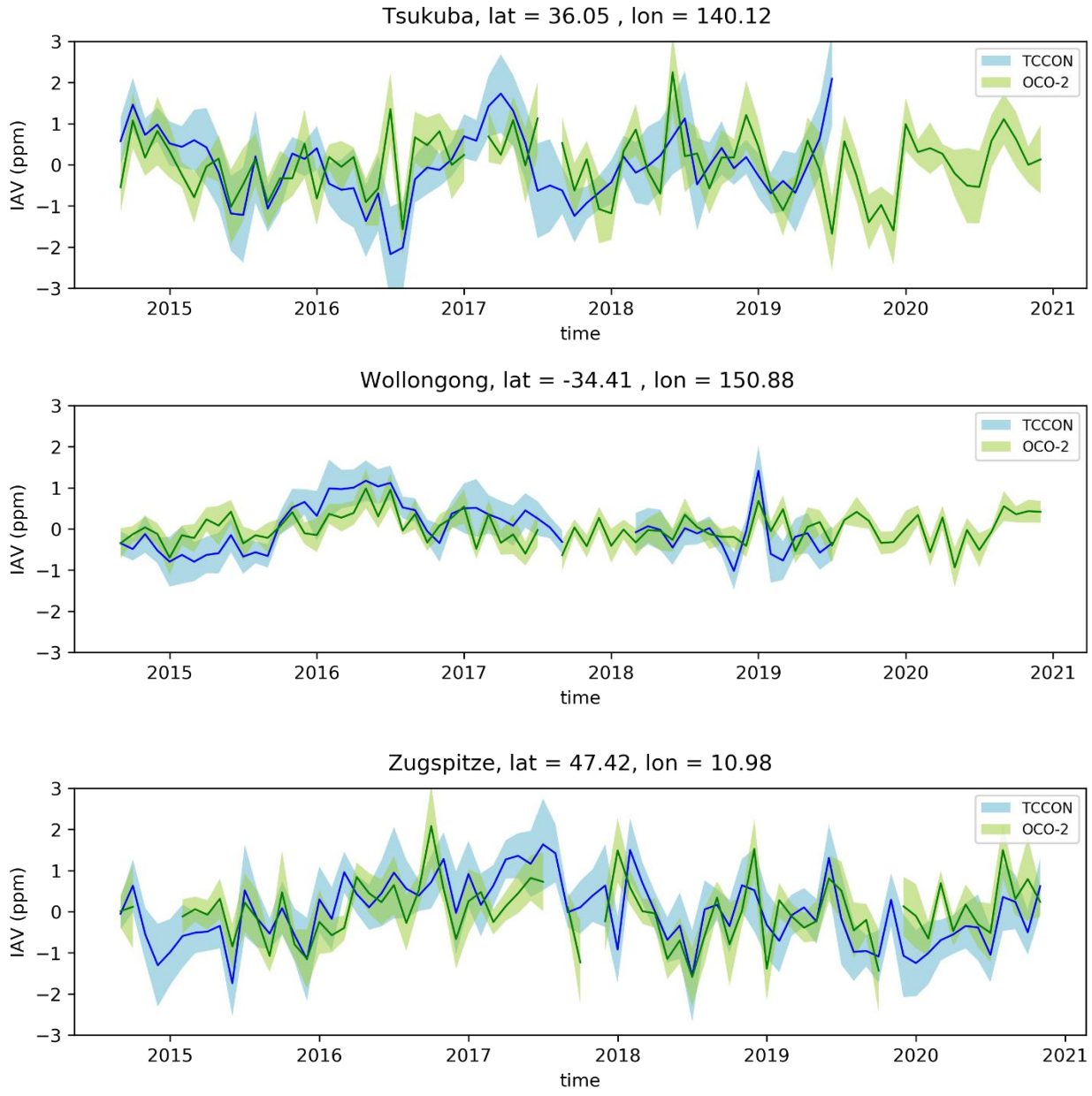

Saga, lat = 33.24 , lon = 130.29
Karlsruhe, lat = 49.10 , lon = 8.44
Lauder, lat = -45.04 , lon = 169.68
Lamont, lat = 36.60 , lon = -97.49
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021


Orleans, lat = 47.97, lon = 2.11
Park Falls, lat = 45.95 , lon = -90.27
Paris, lat = 48.49 , lon = 2.36
Reunion Island, lat = -20.90 , lon = 55.49
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021


Rikubetsu, lat = 43.46 , lon = 143.77
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020
2021

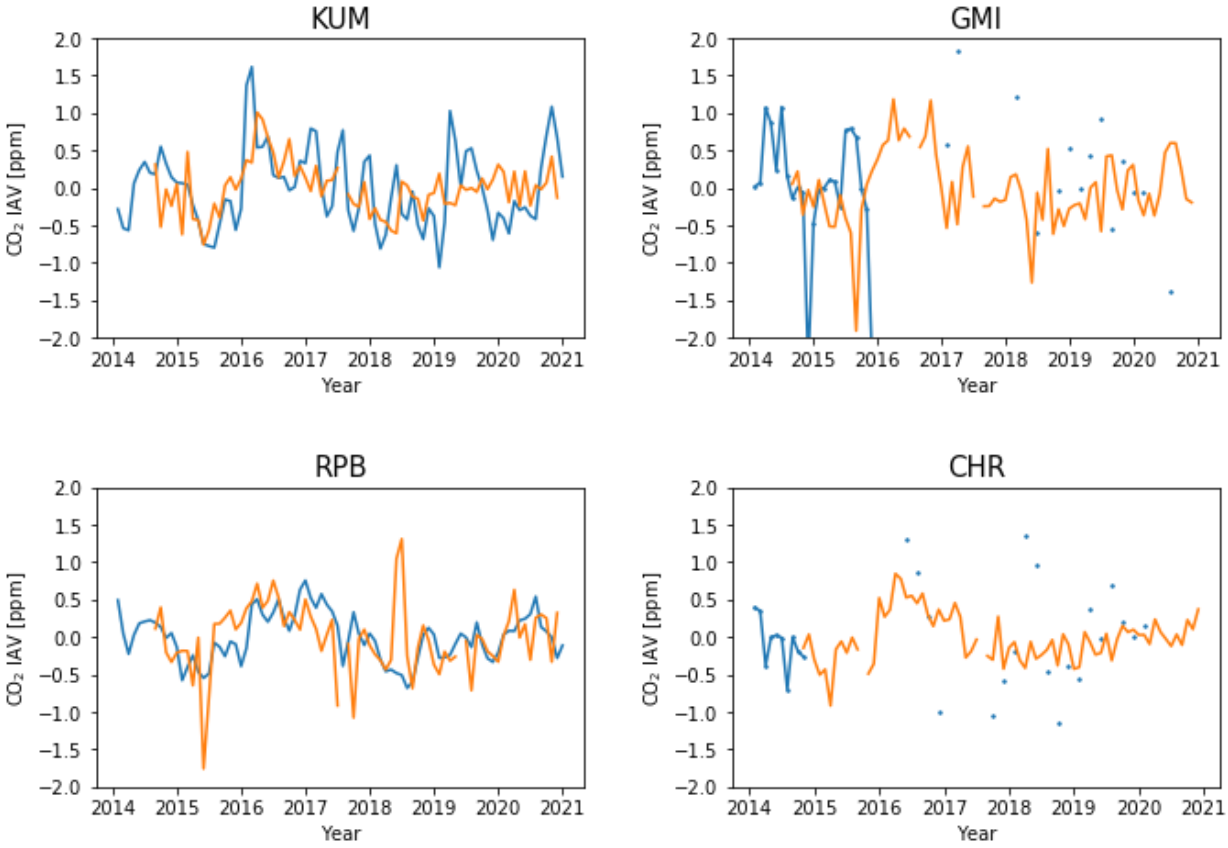

Sodankyla, lat = 67.37 , lon = 26.63
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020

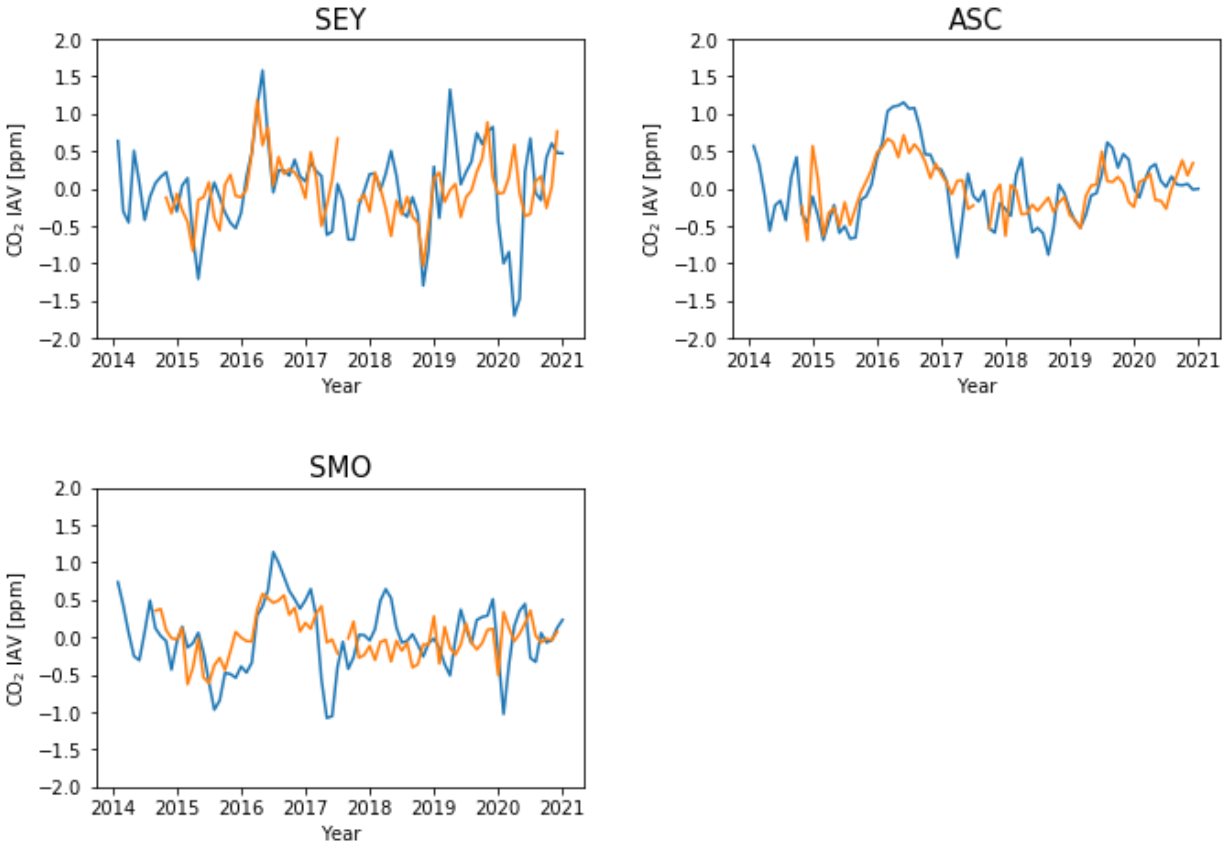

Ny Alesund, lat = 78.90 , lon = 11.90
TCCON
OCO-2
IAV (ppm)
time
3
2
1
0
−1
−2
−3
2015
2016
2017
2018
2019
2020



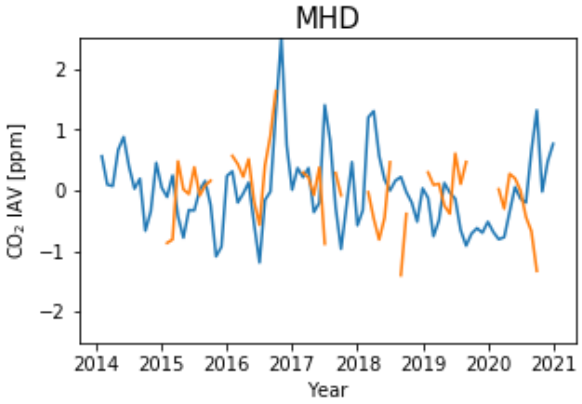
Supplementary Figure 11. Timeseries comparison between the OCO-2 XCO_2 and TCCON IAV, blue shading shows the uncertainty range of TCCON, green for OCO-2.

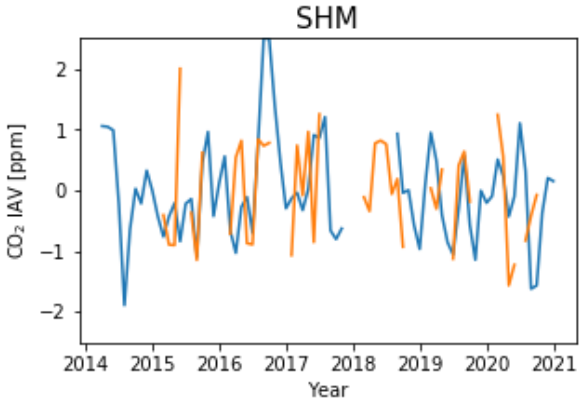
NH Tropical MBL sites

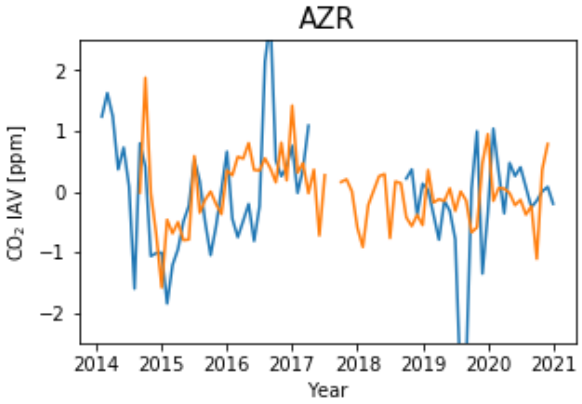


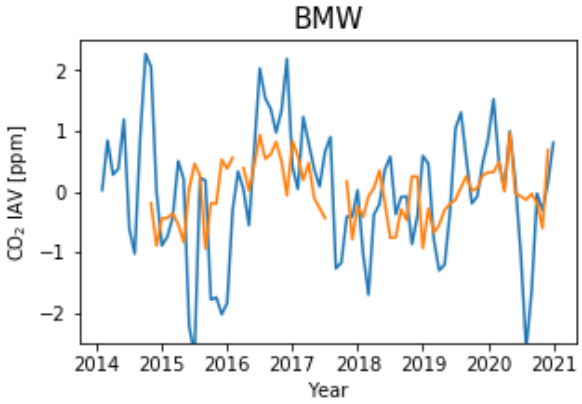

SH Tropical MBL sites
SEY
ASC
SMO
CO_2 IAV [ppm]
Year
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
2014
2015
2016
2017
2018
2019
2020
2021

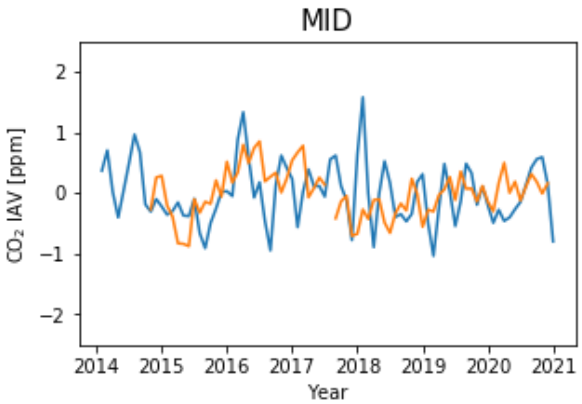
NH Temporate MBL sites - 20N to 60N

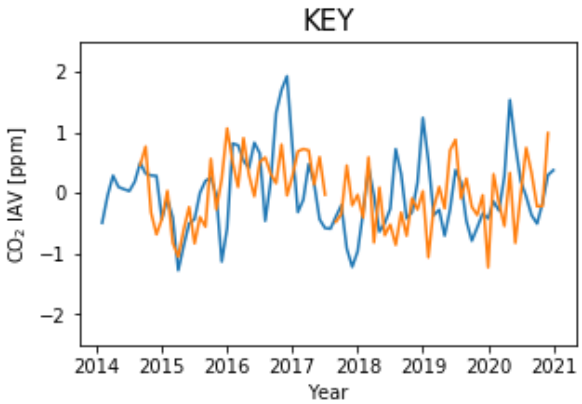


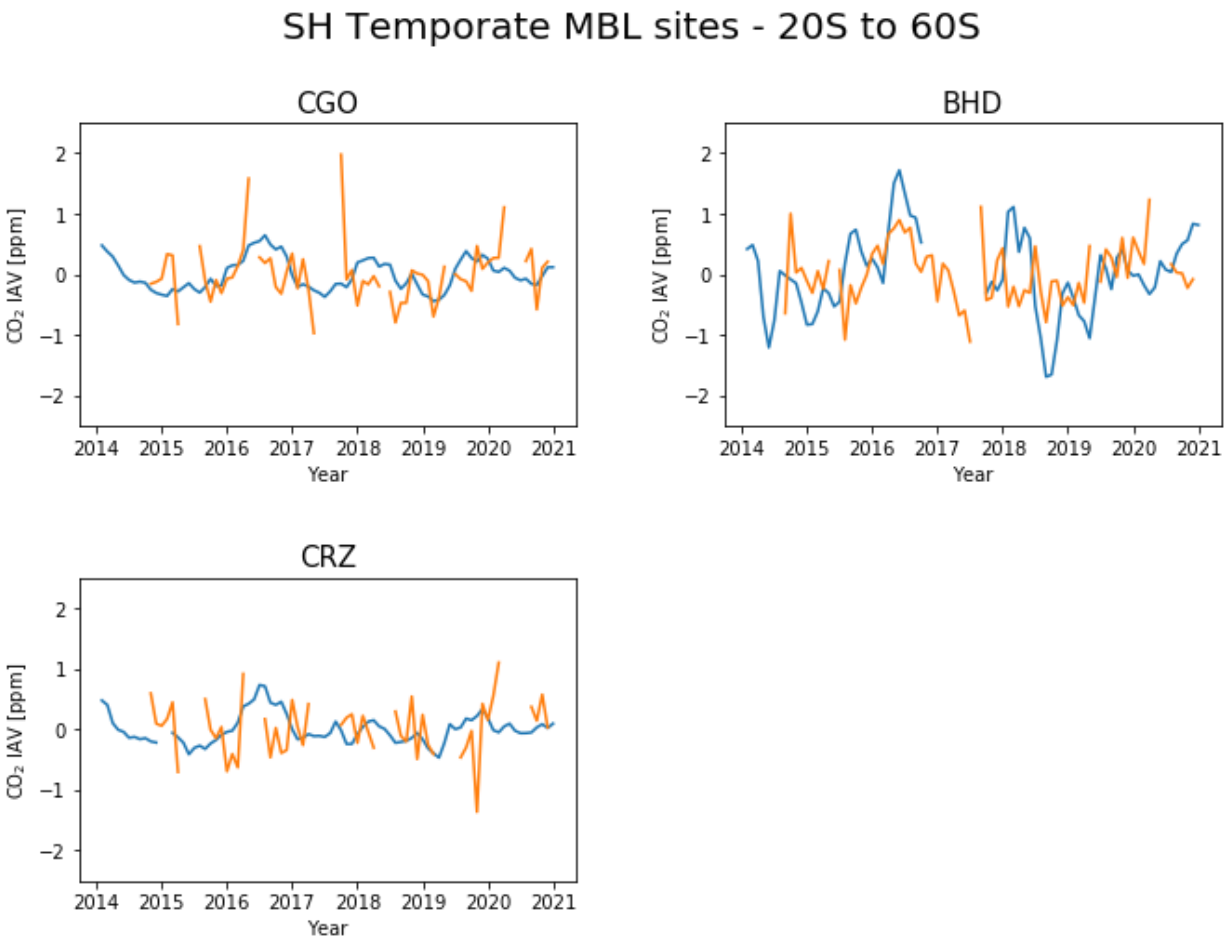




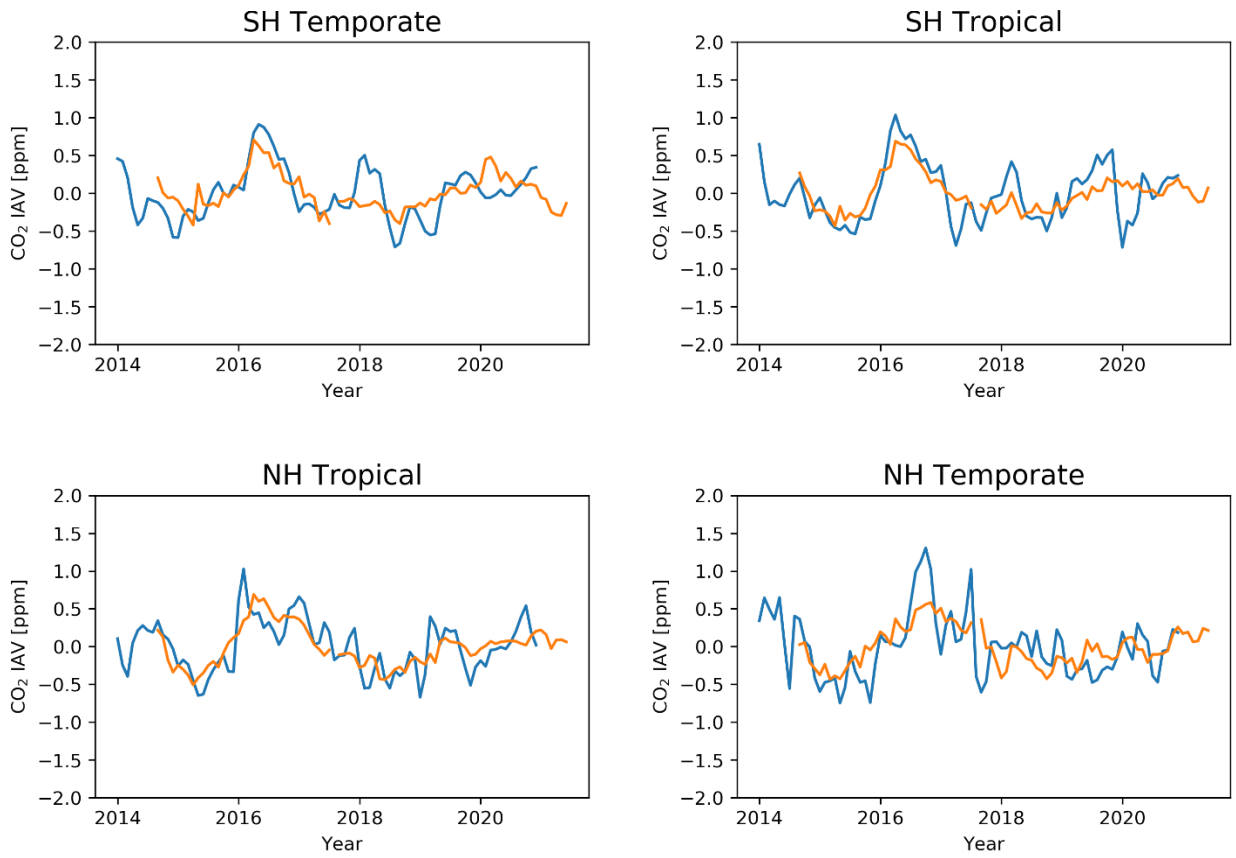








Supplementary Figure 12. Timeseries comparison between surface CO_2 MBL IAV and the co-located OCO-2 XCO_2 and. Orange lines based on OCO-2 observations while blue lines based on MBL sites.



Supplementary Figure 13. Timeseries comparison between the zonal mean OCO-2 XCO_2 and zonal mean MBL surface CO_2 IAV.

	Temperate Northern Hemisphere (20-60°N)	Northern hemisphere tropical (0 - 20°S)	Southern hemisphere tropical (0 - 20°S)	Temperate Southern Hemisphere (20-60°S)
Averaged R in a zonal band	0.280	0.173	0.501	0.423
R of the averaged zonal mean IAV timeseries	0.546	0.335	0.711	0.509

Supplementary Table 1. Comparison between the averaged R value for all TCCON sites IAV timeseries in a latitude band and the R value of the averaged TCCON IAV timeseries within the zonal band.