

Supplementary Information

The fingerprint of the summer 2018 drought in Europe on ground-based atmospheric CO₂ measurements

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Figure S1. Standardized mean temperature (above) and precipitation (below) anomalies in summer (JJA) 2003, 2015, 2017 and 2018. The dotted areas indicate anomalies ranking as the highest or second highest (95th %-tile) over the period 1979-2018.

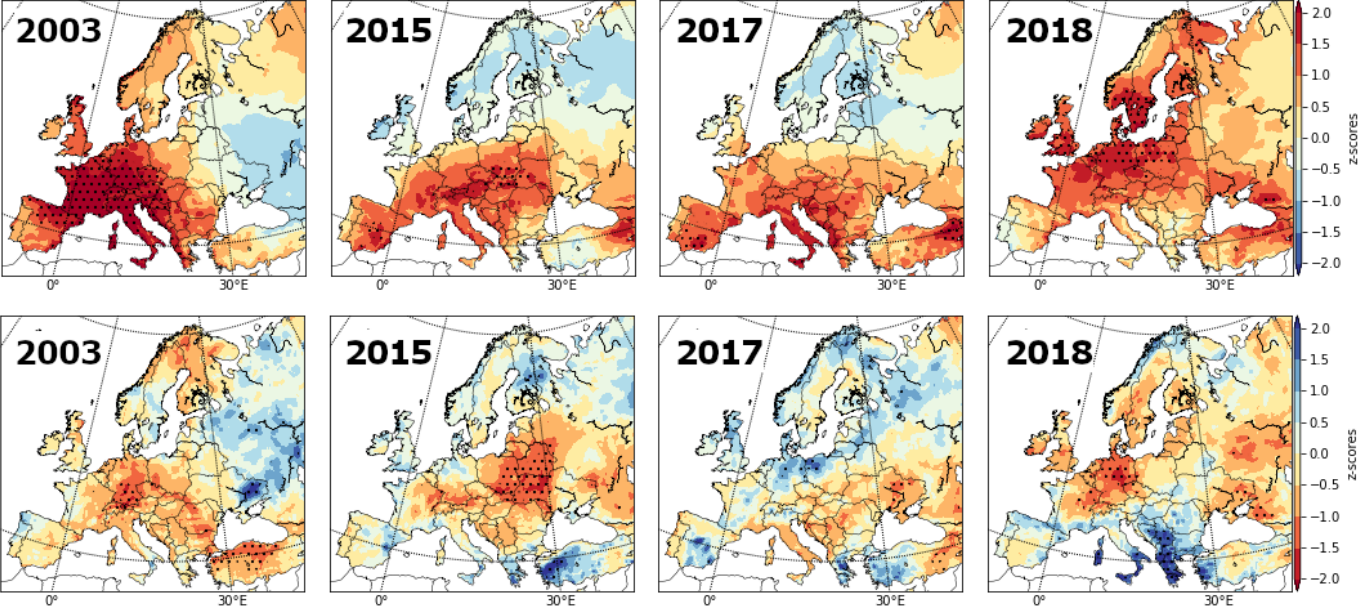
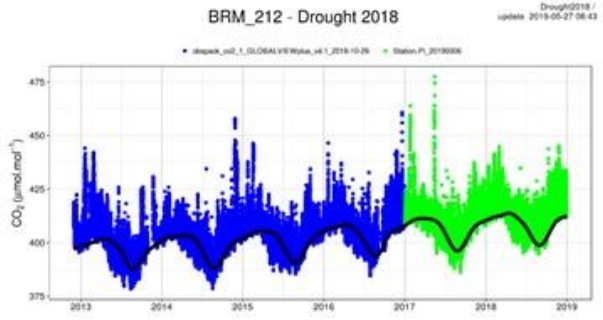
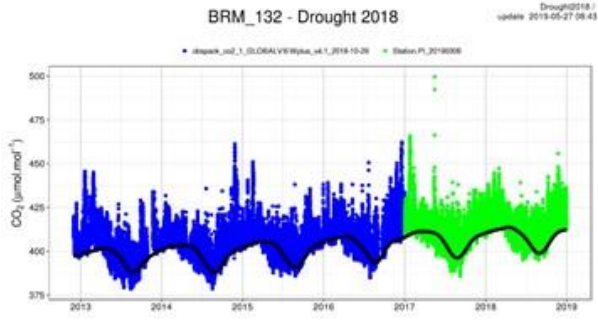
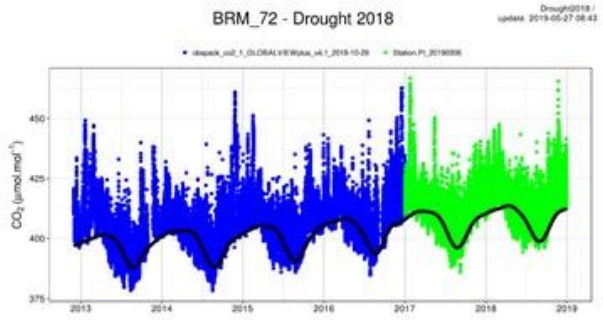
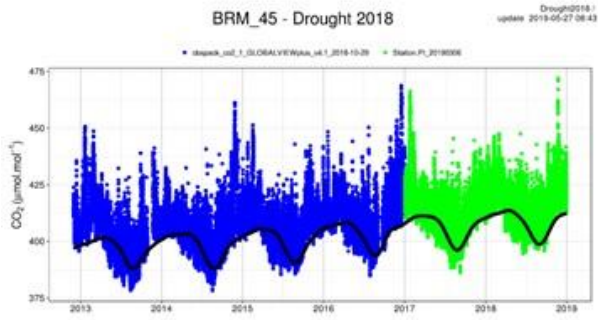
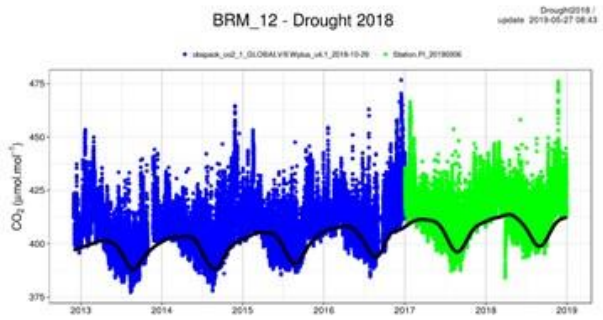
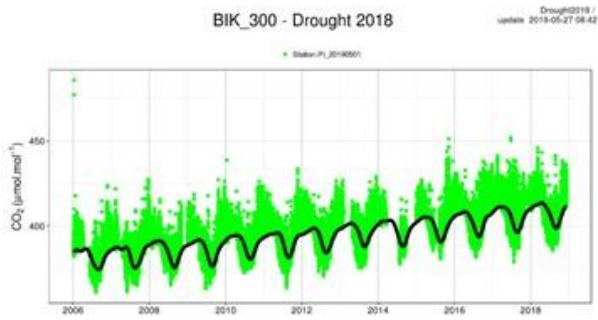
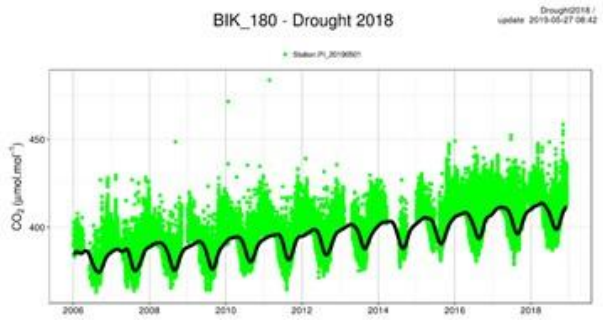
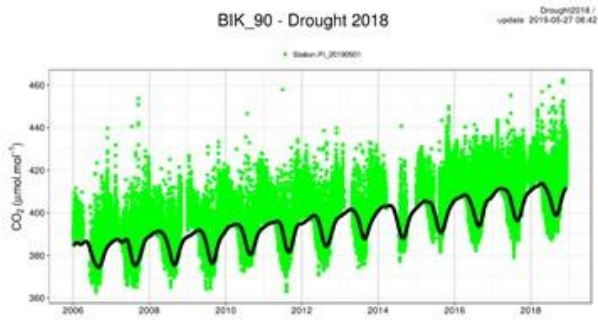
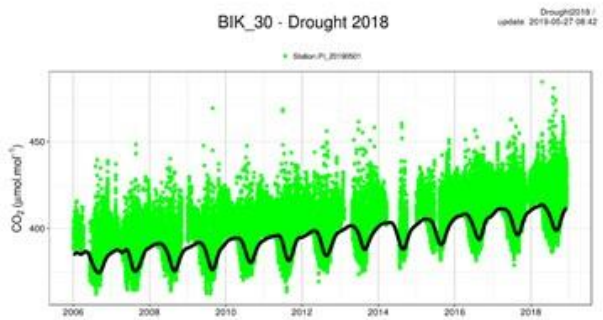
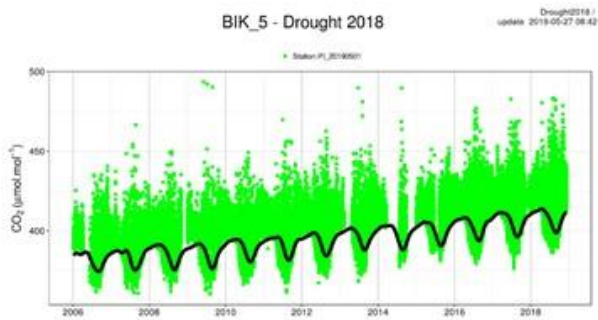
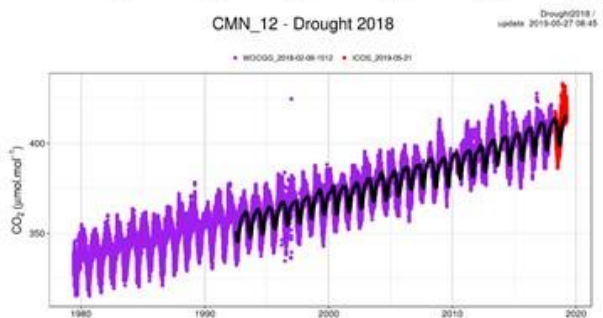
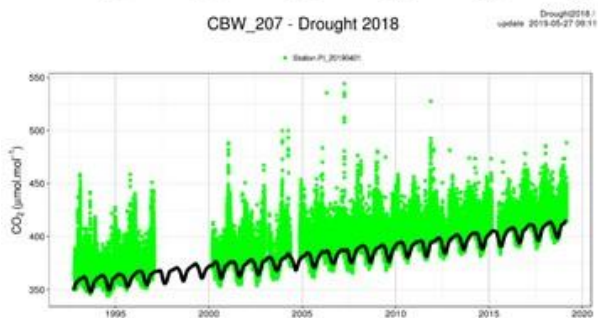
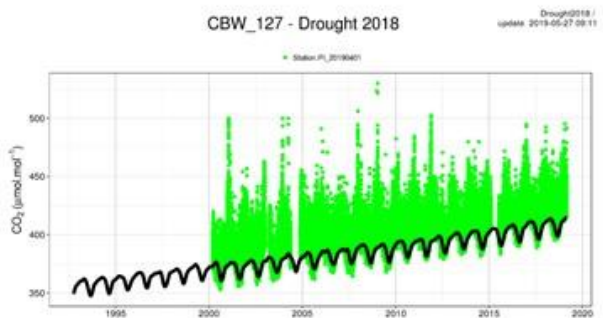
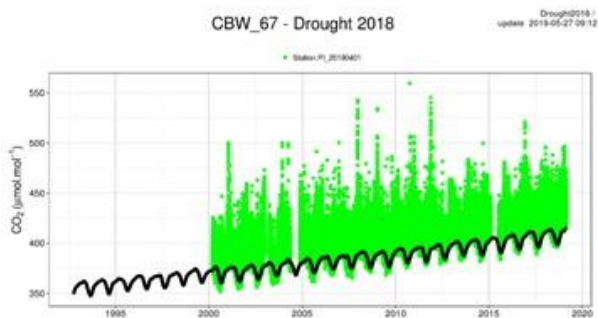
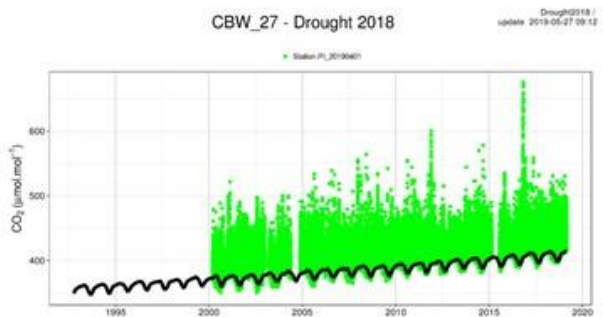
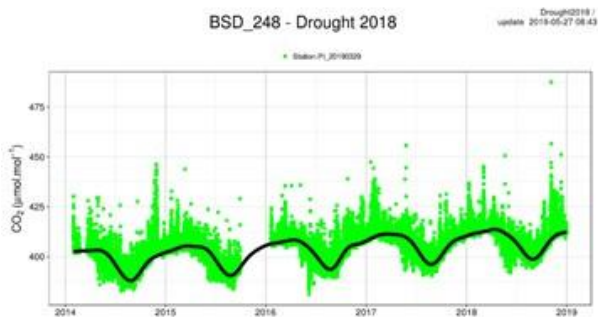
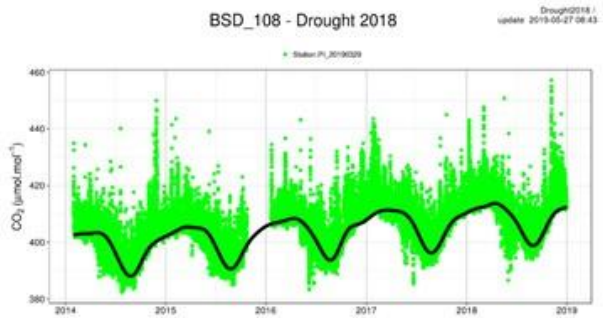
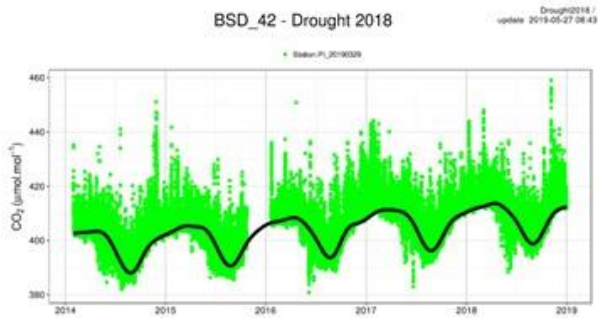
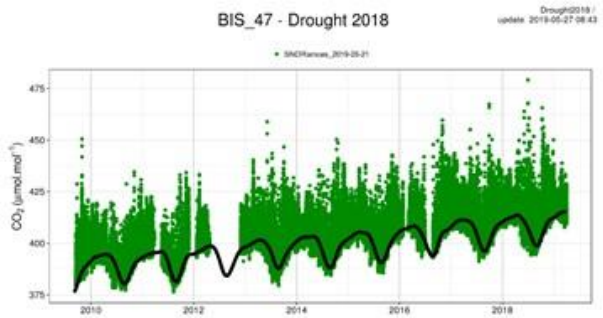
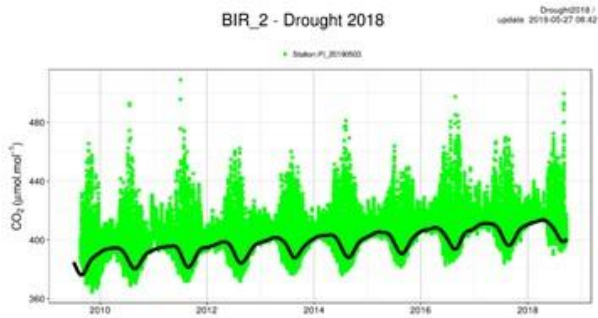
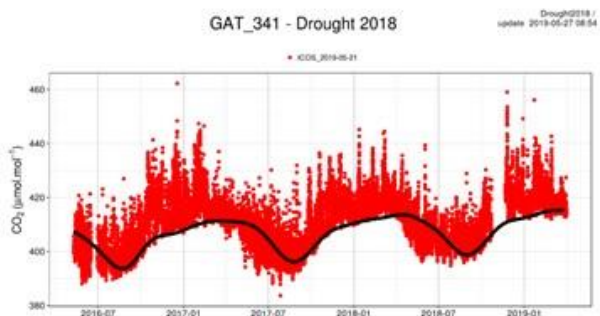
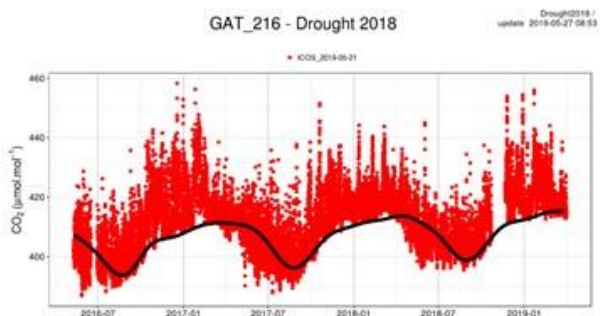
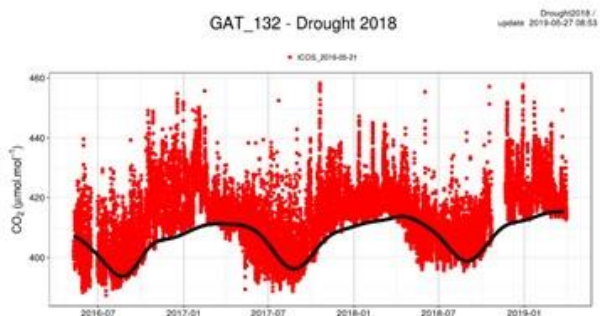
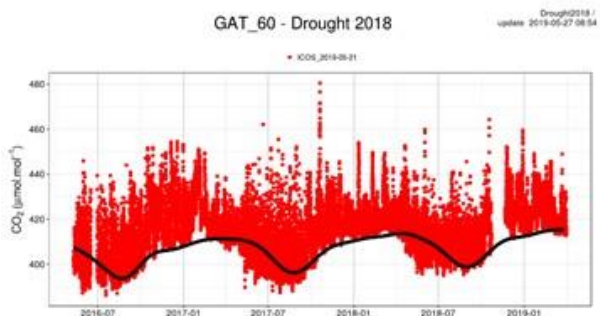
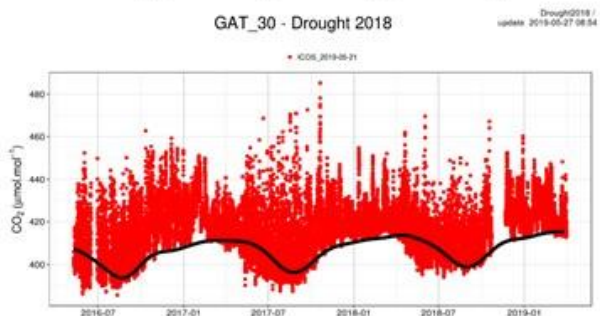
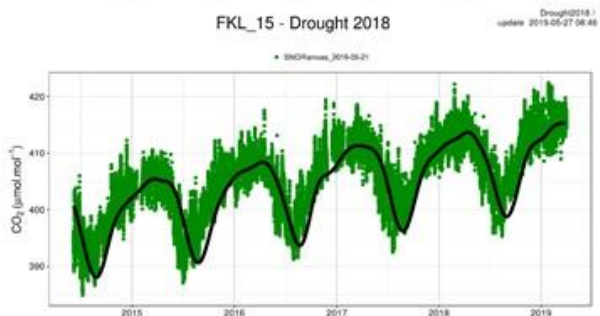
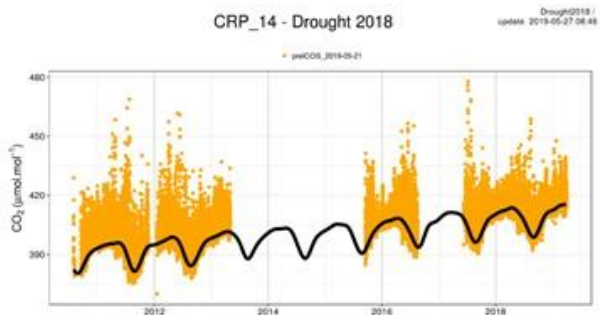
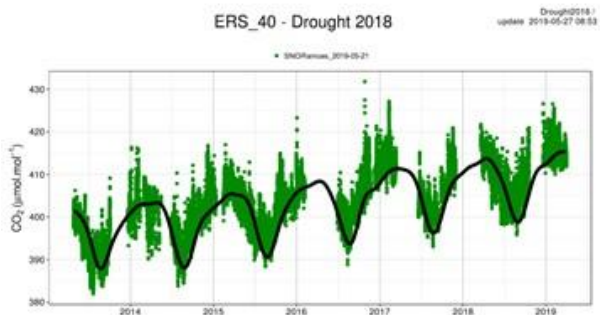
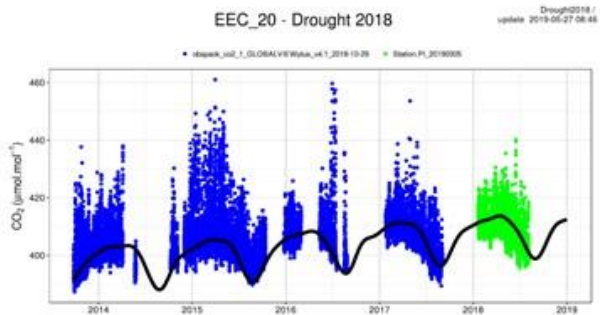
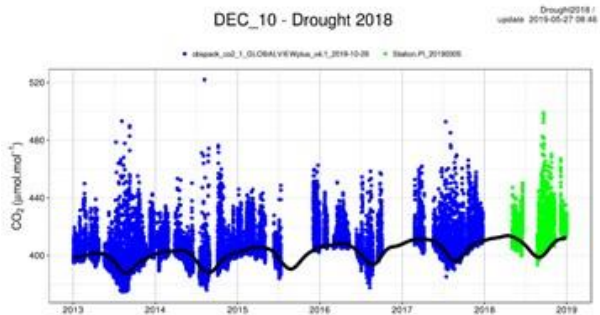
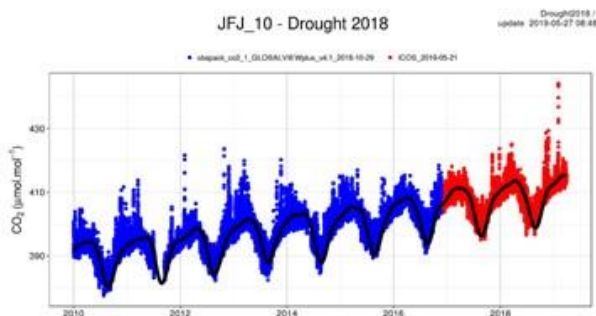
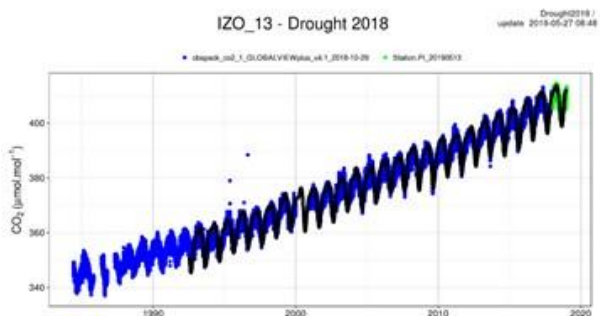
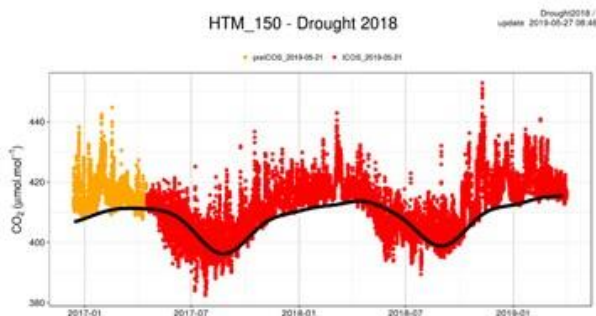
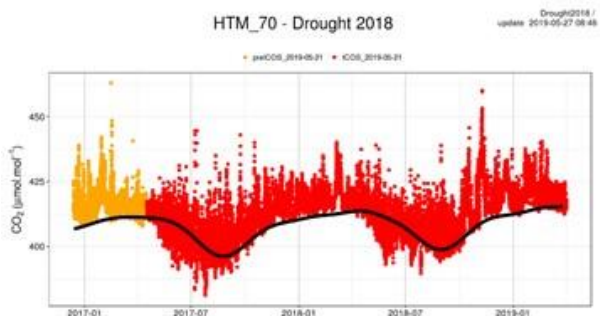
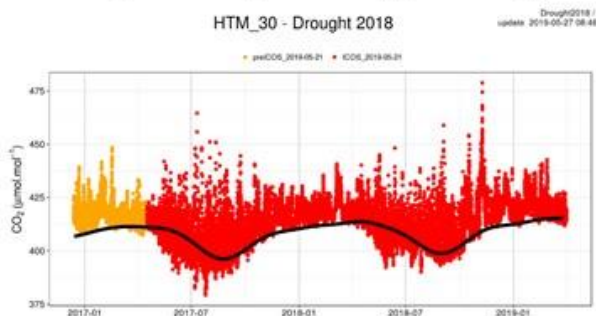
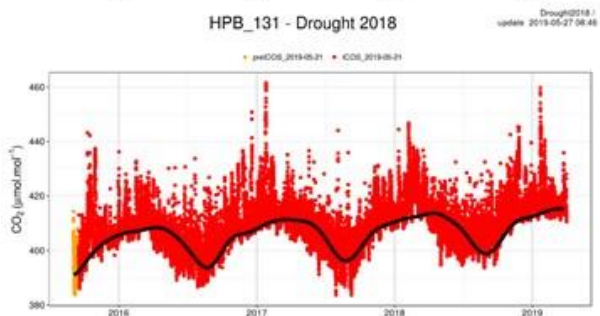
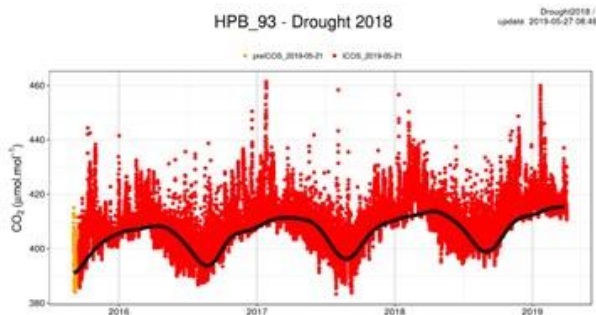
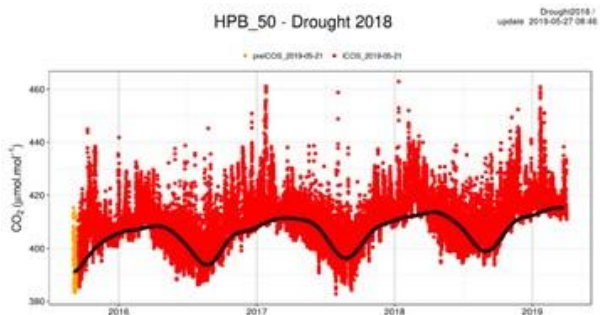
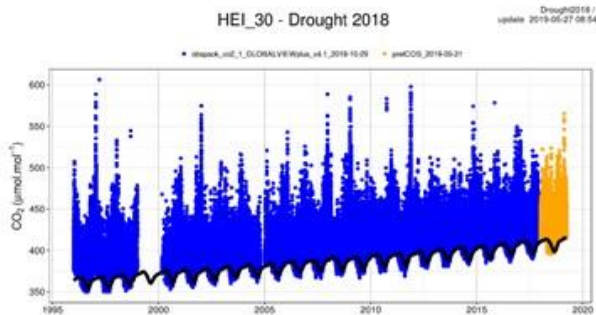
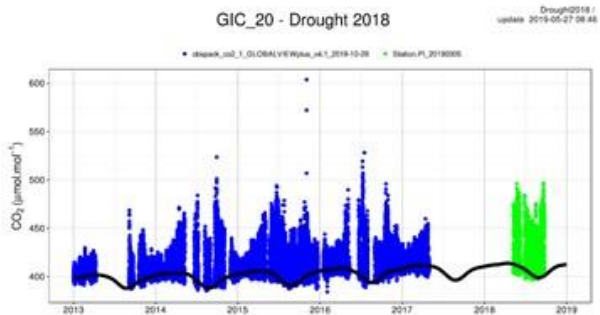


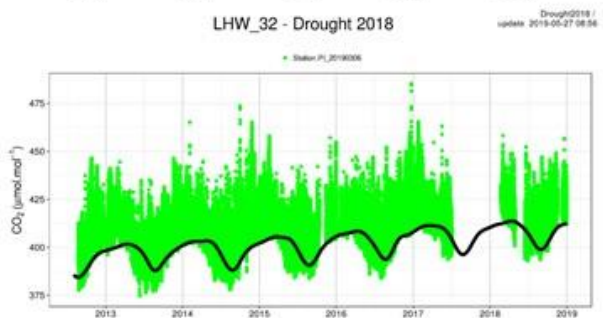
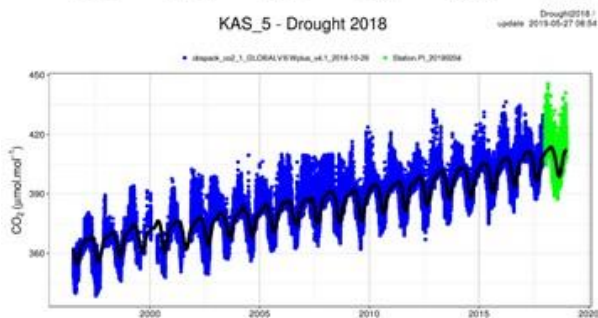
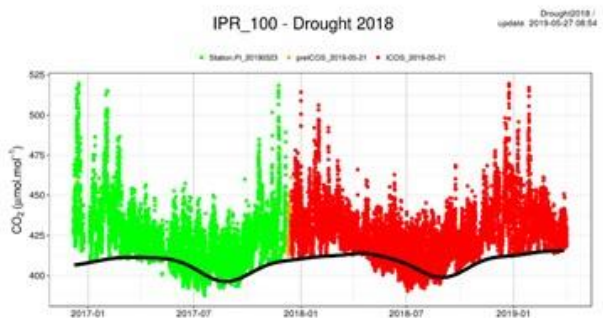
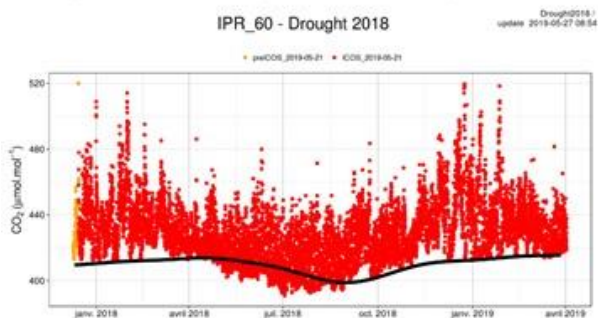
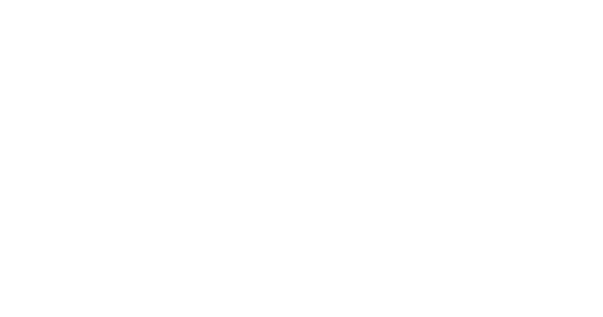
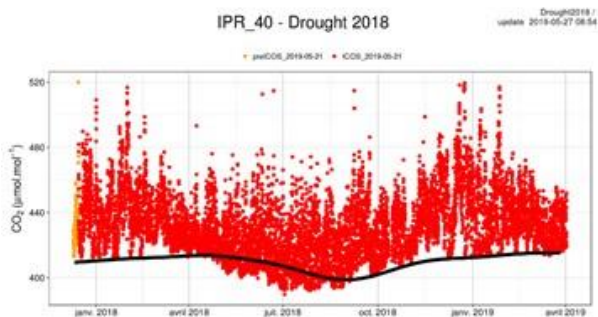
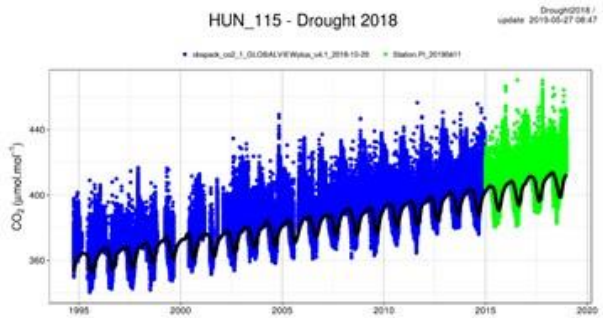
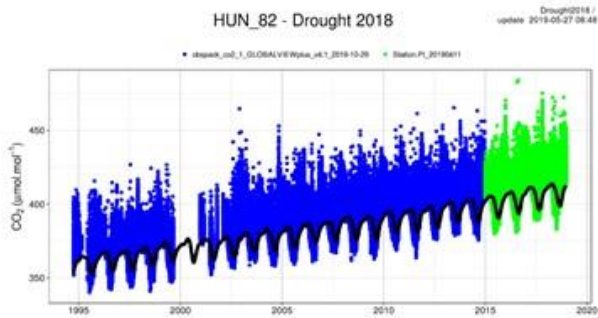
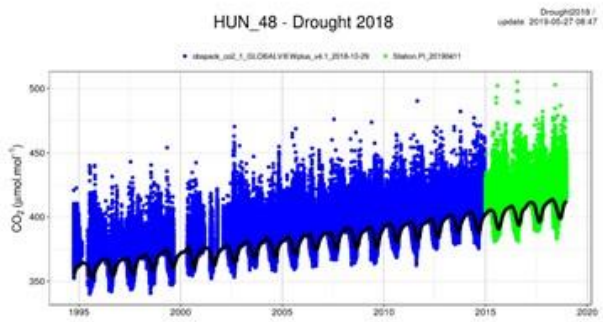
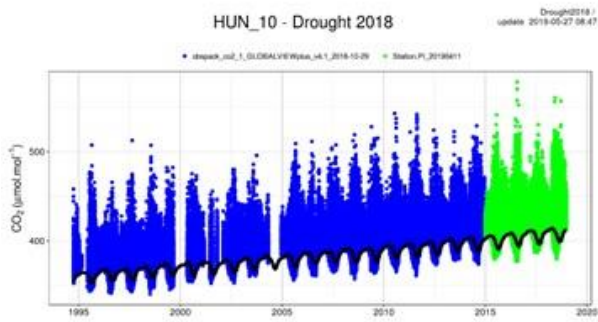
Figure S2. The 96 atmospheric CO₂ time series collected from 48 measurement stations. The network includes 20 tall towers providing time series from few sampling levels. Each point represents an hourly mean, with the colors indicating the origin of the dataset. The black line corresponds to the smooth curve from the selected dataset at mace Head, Ireland.

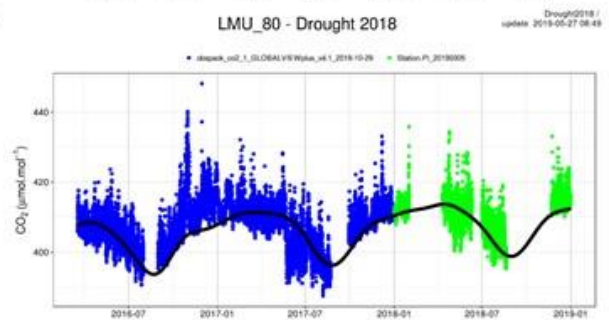
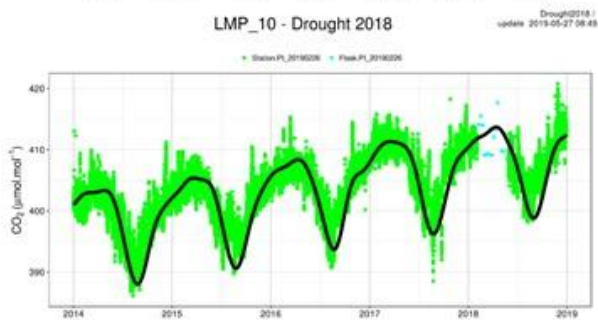
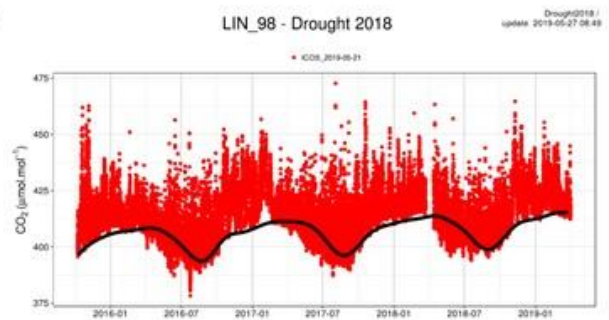
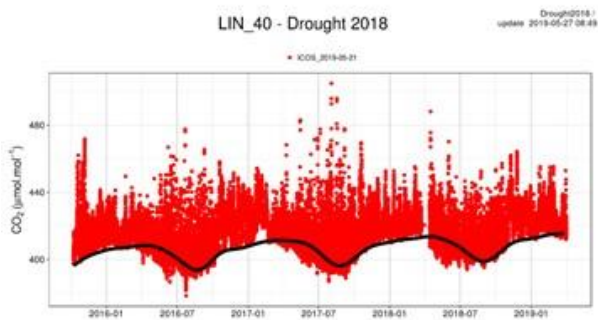
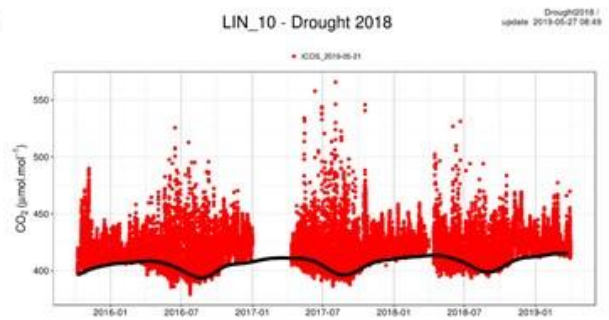
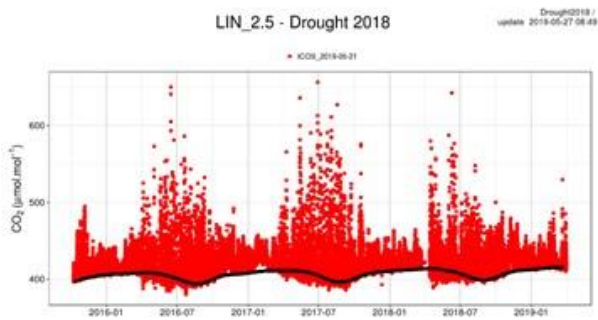
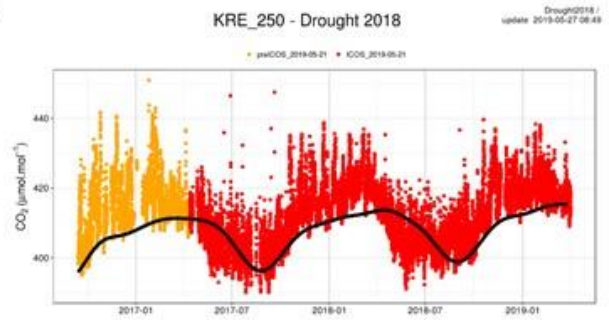
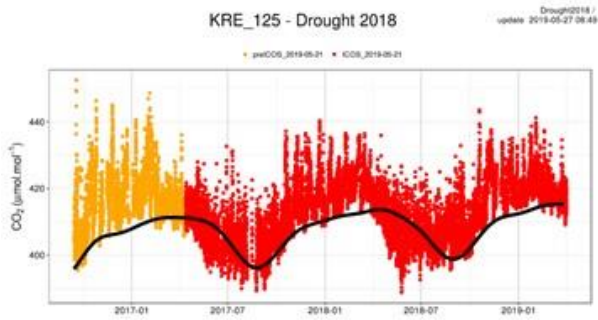
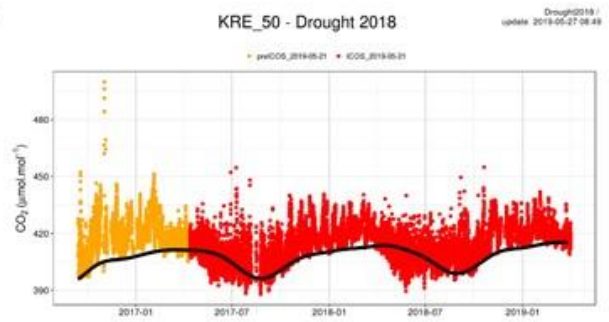
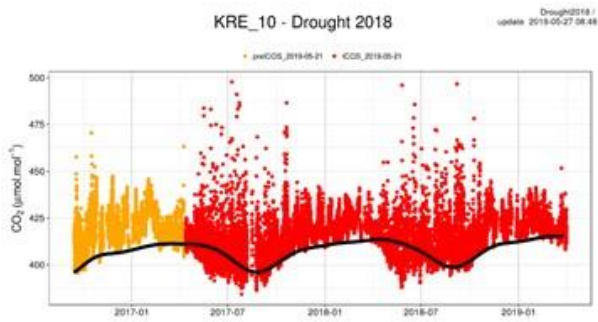


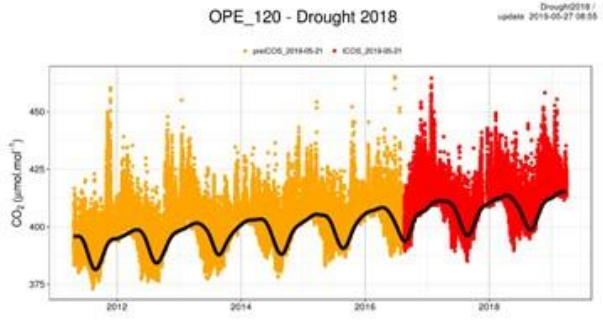
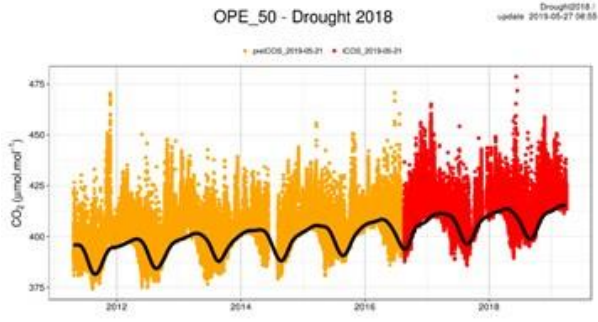
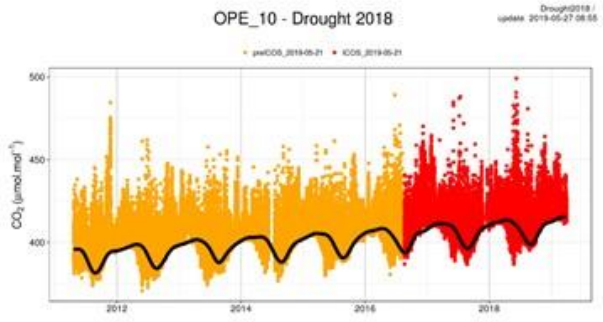
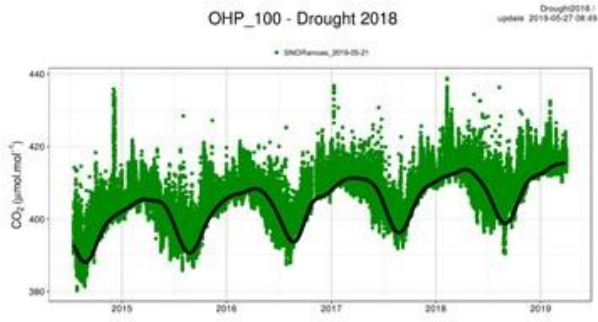
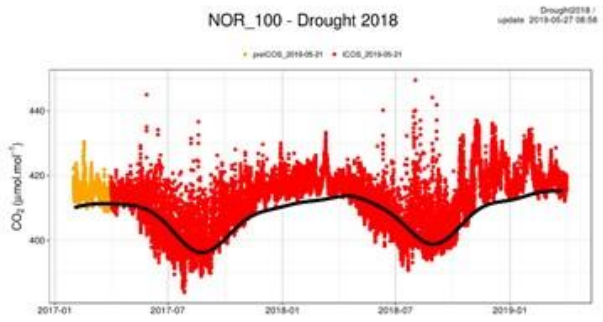
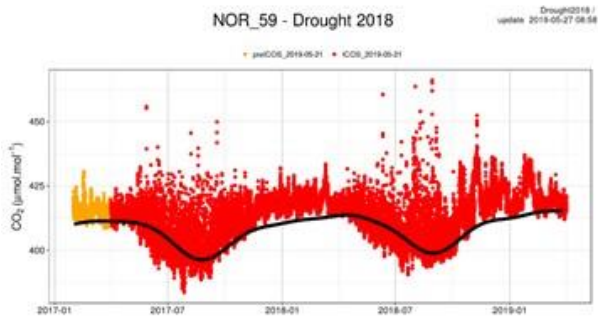
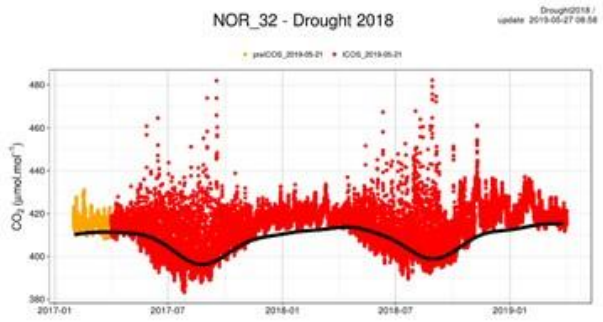
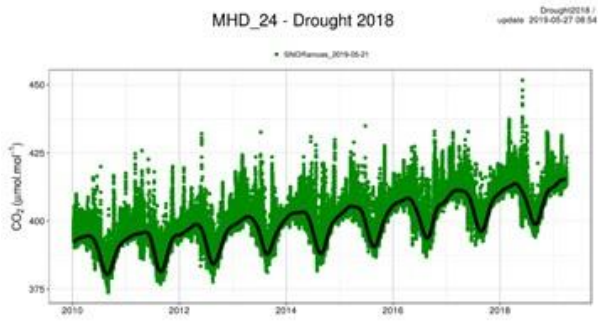
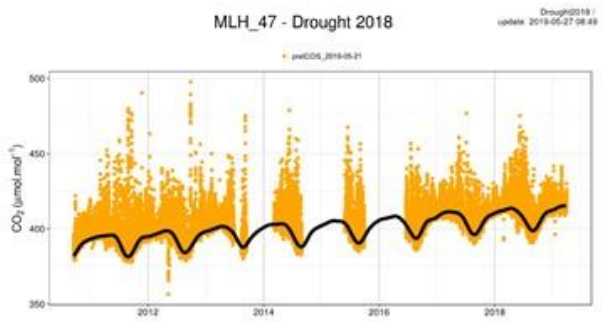
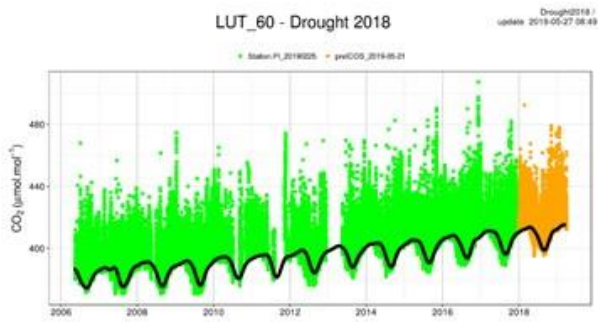


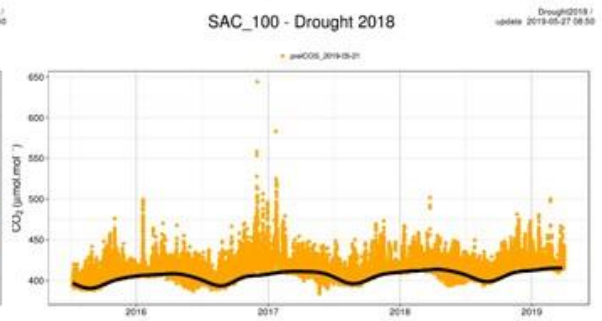
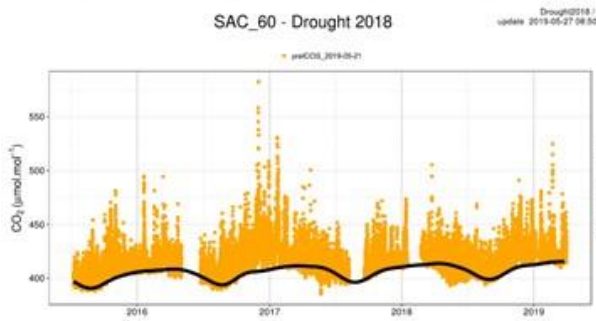
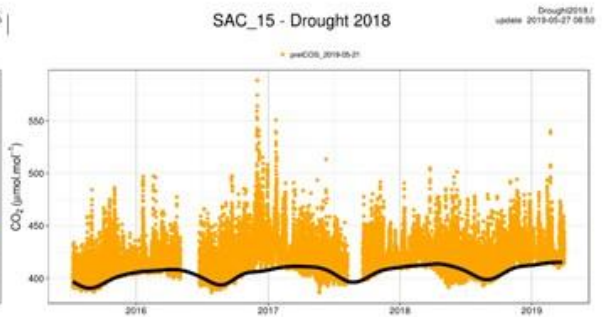
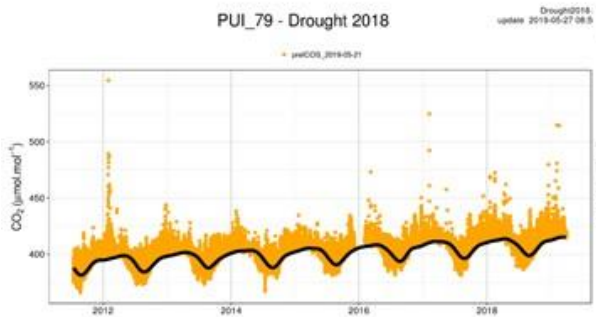
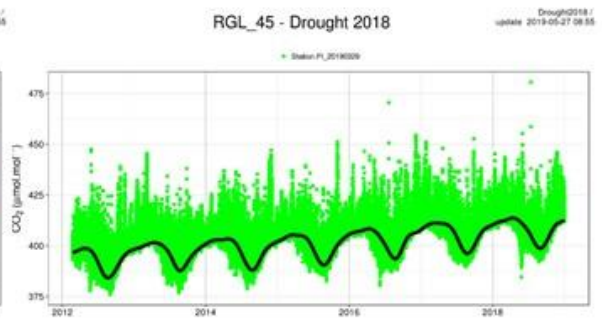
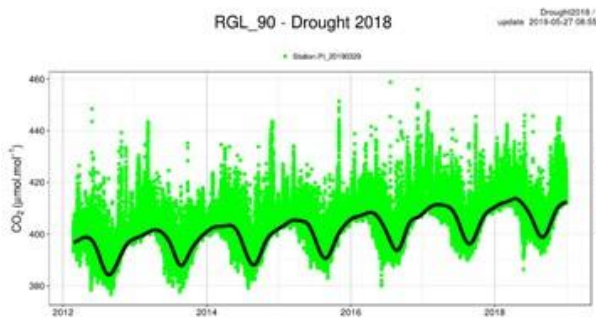
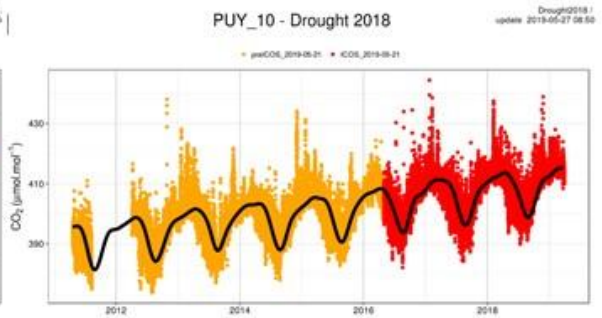
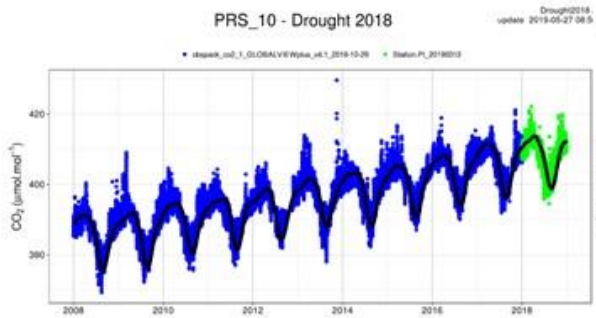
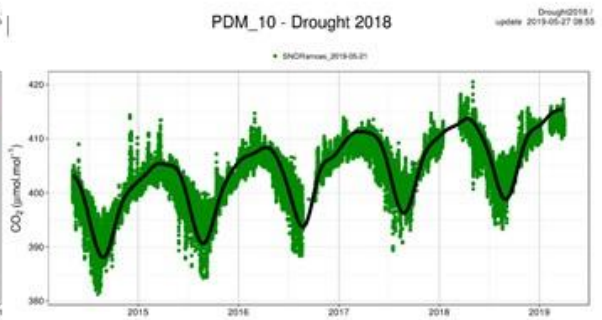
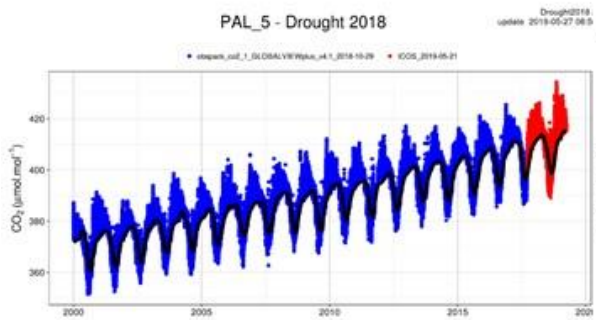


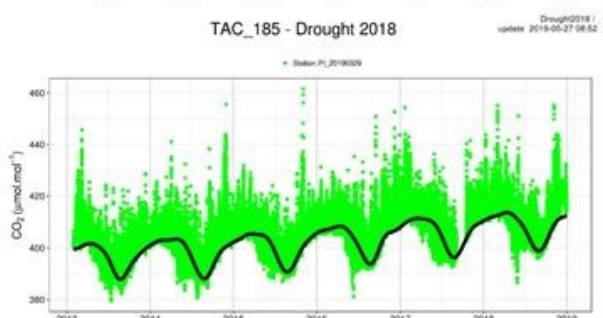
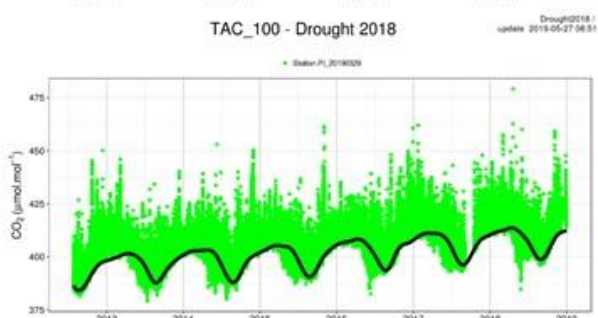
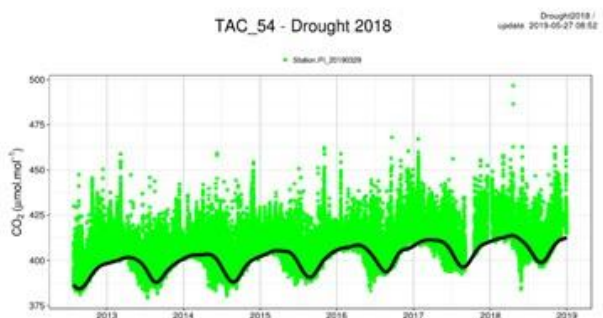
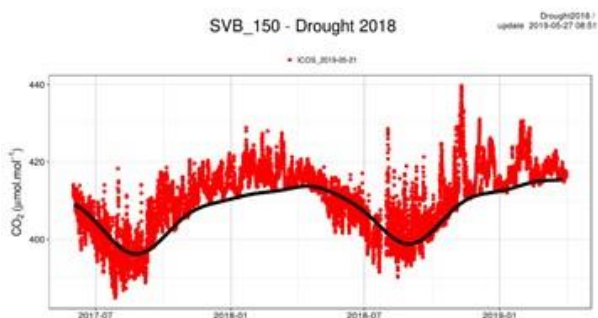
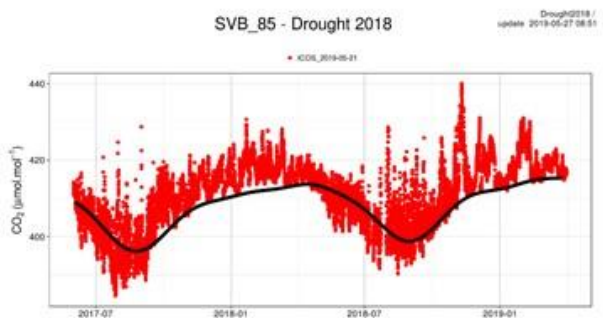
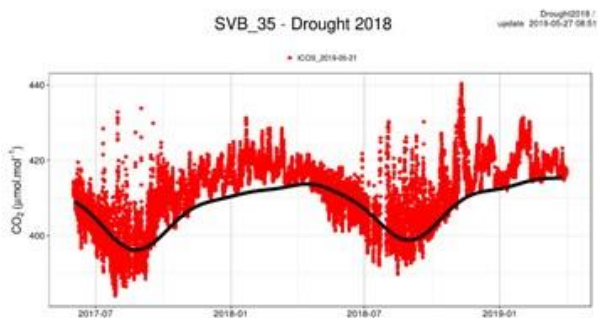
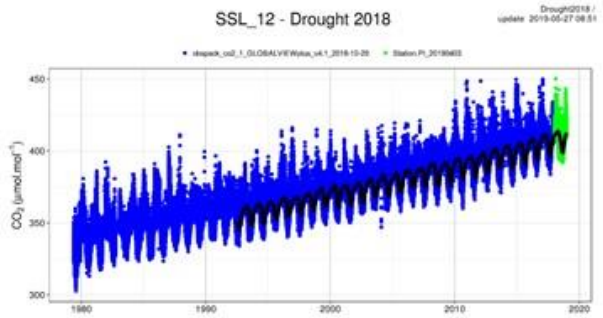
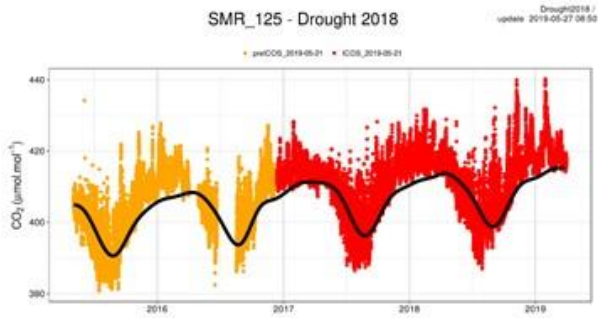
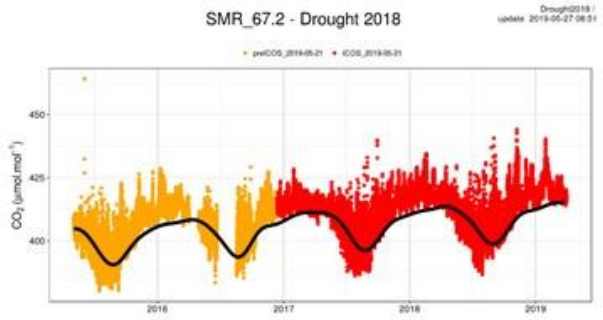
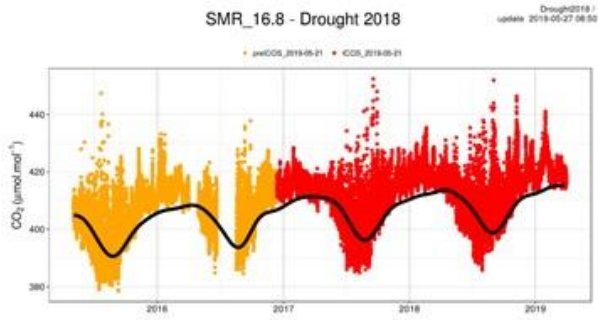












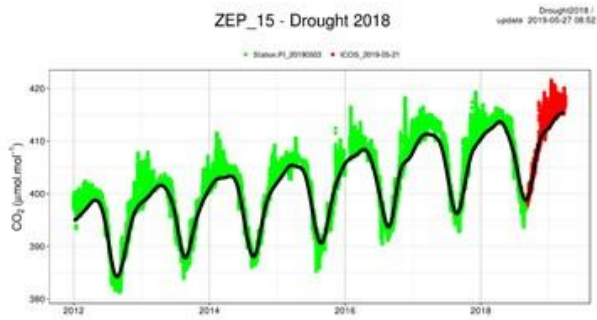
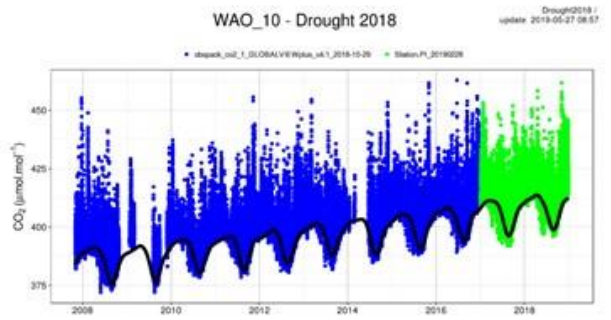
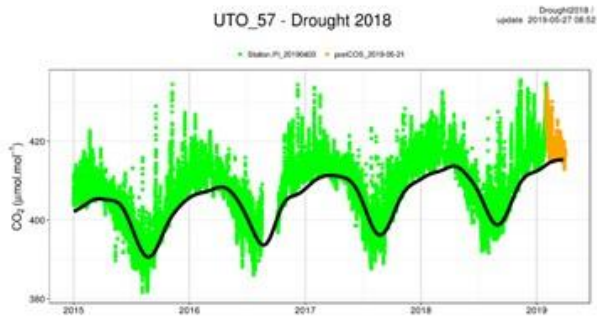
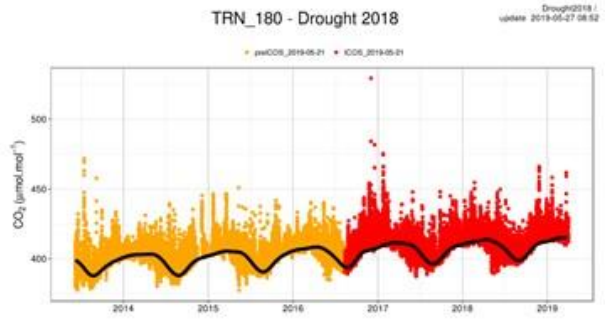
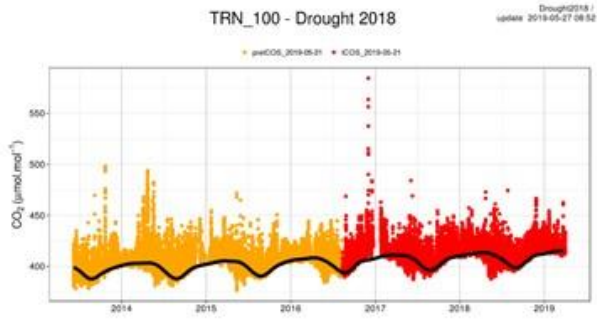
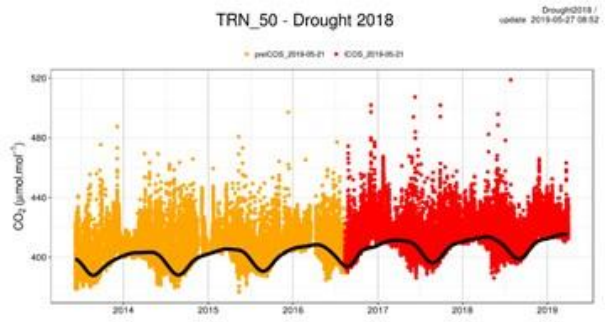
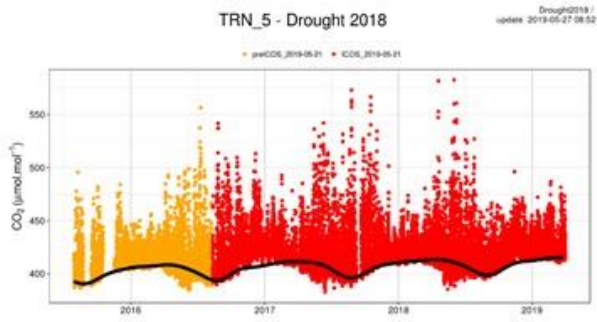
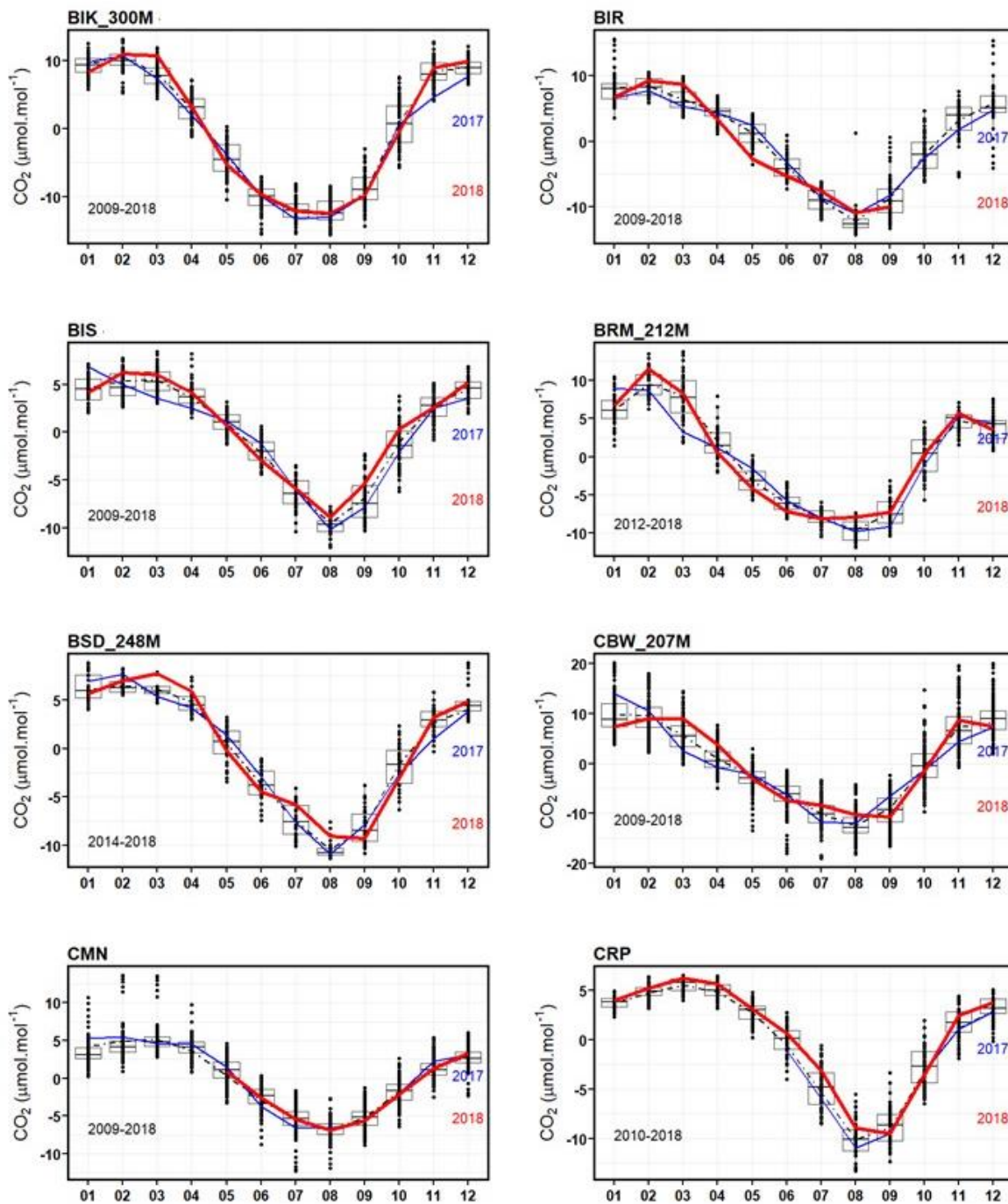
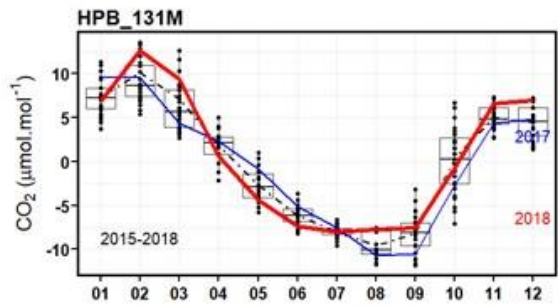
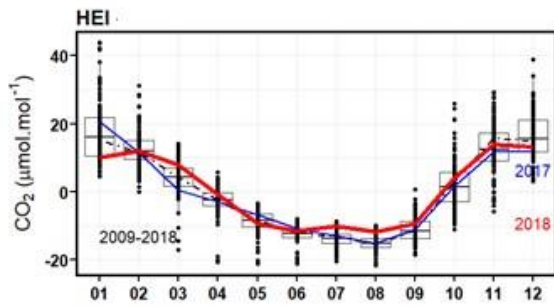
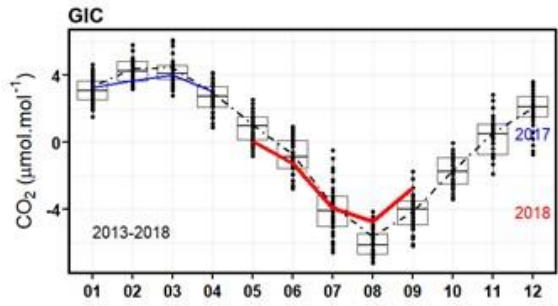
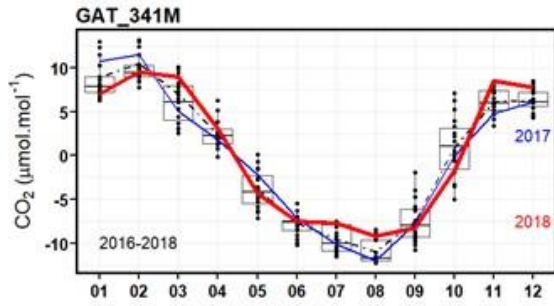
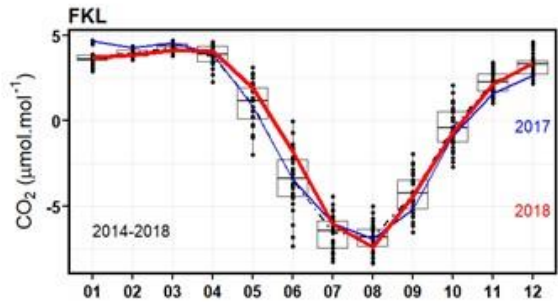
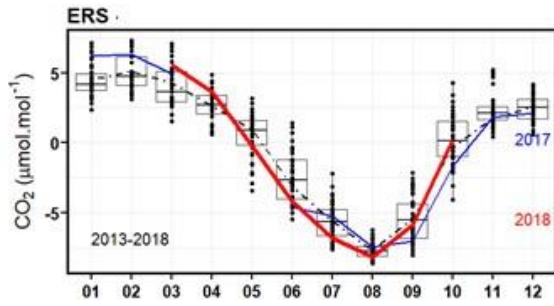
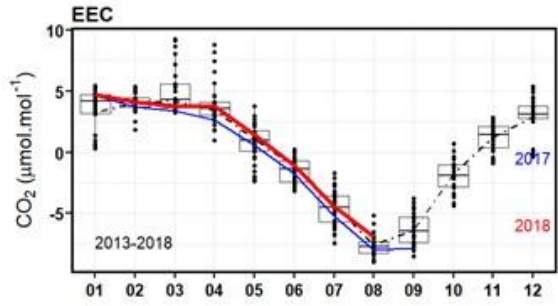
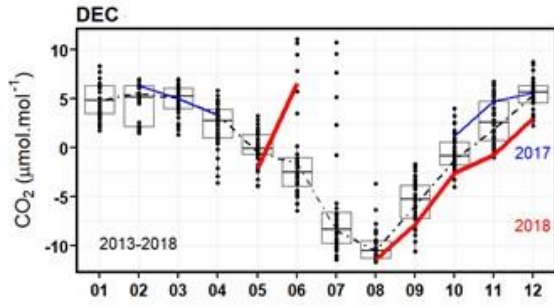
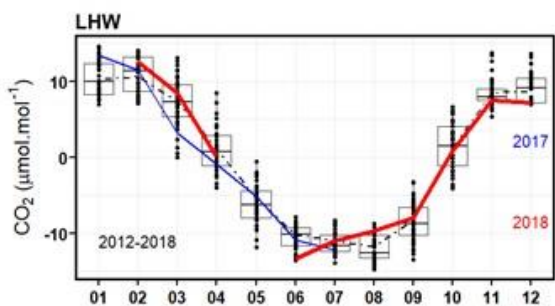
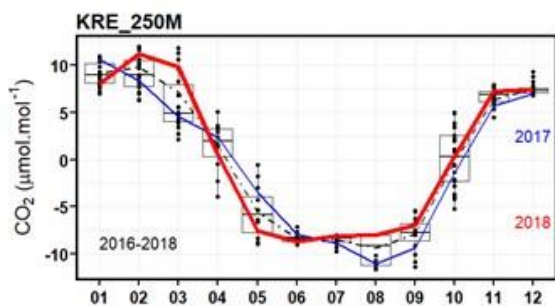
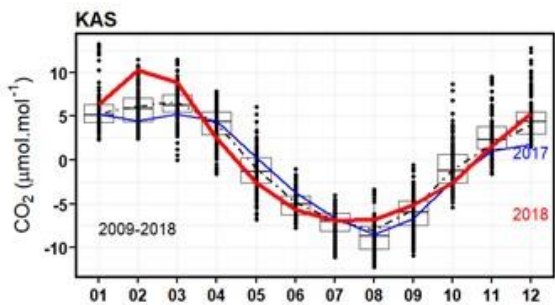
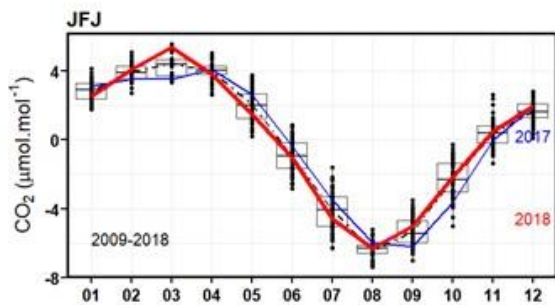
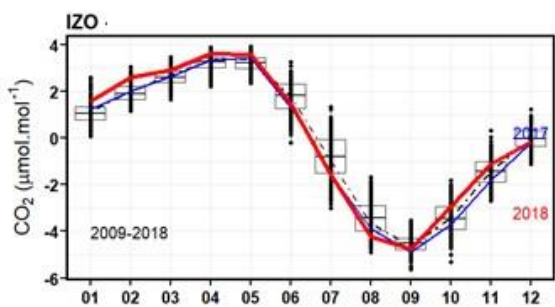
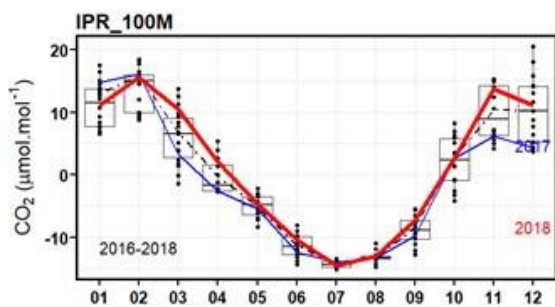
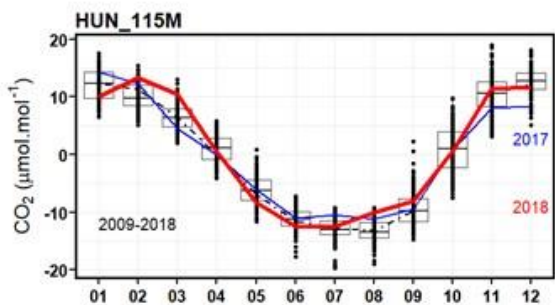
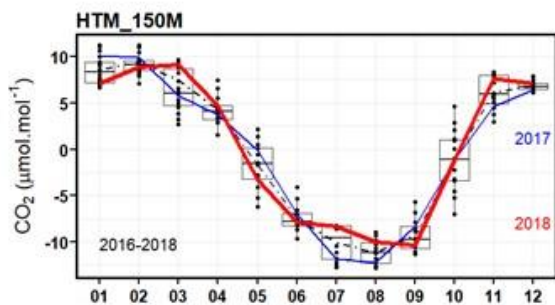
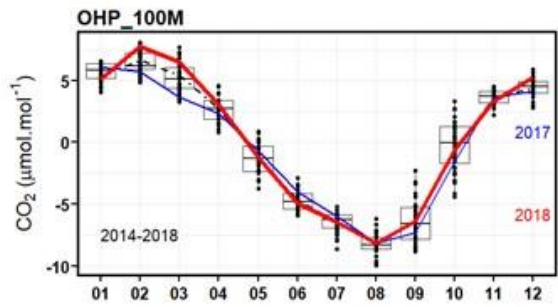
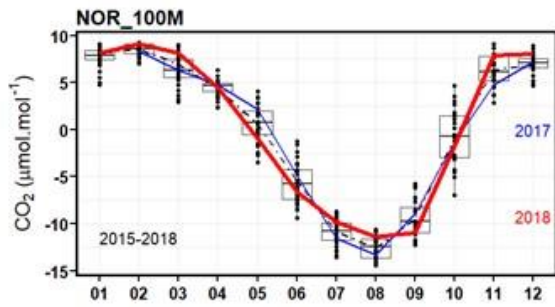
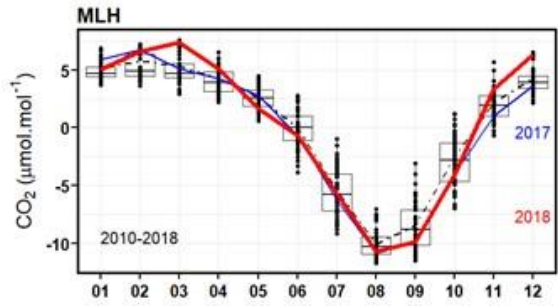
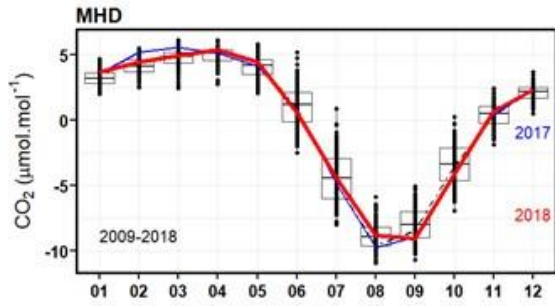
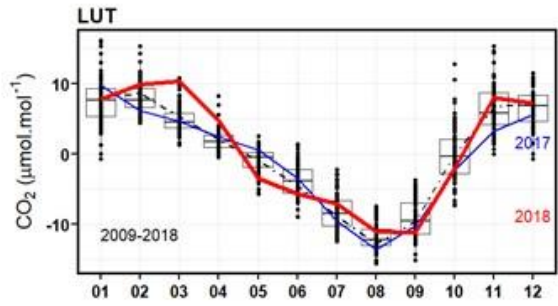
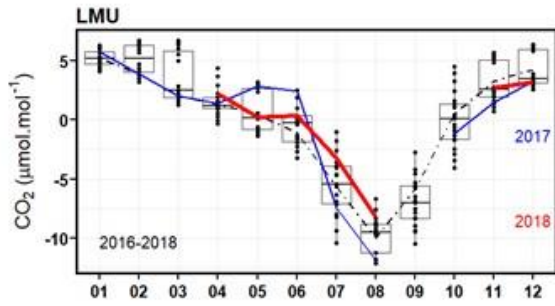
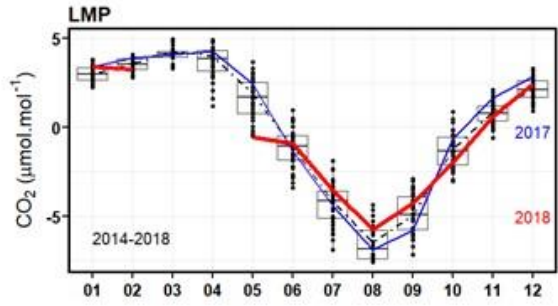
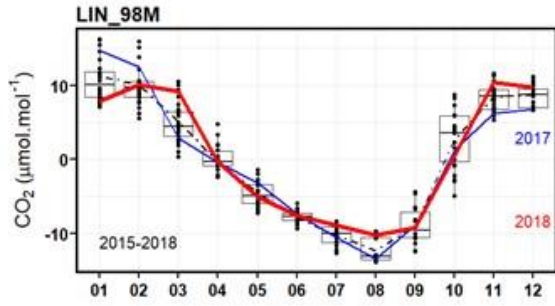


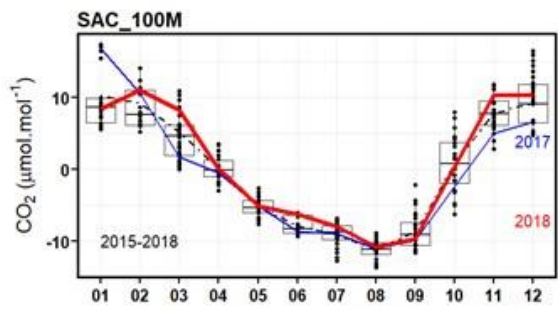
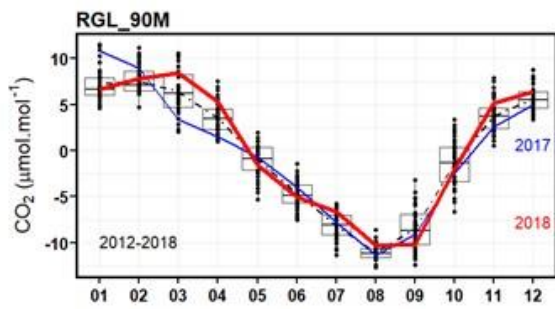
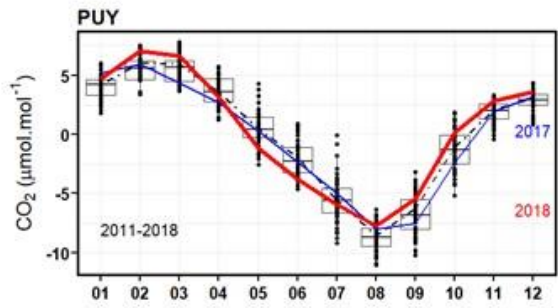
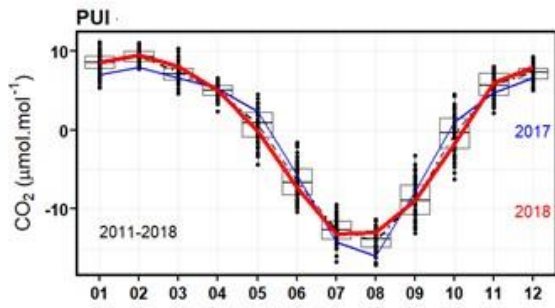
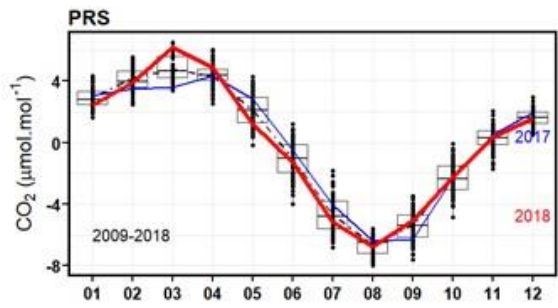
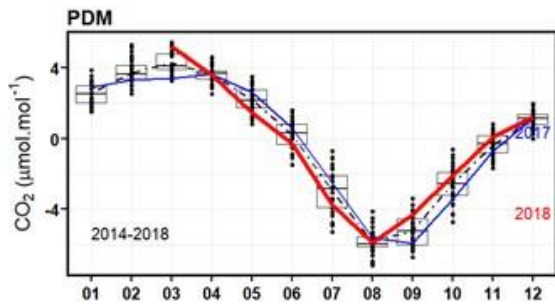
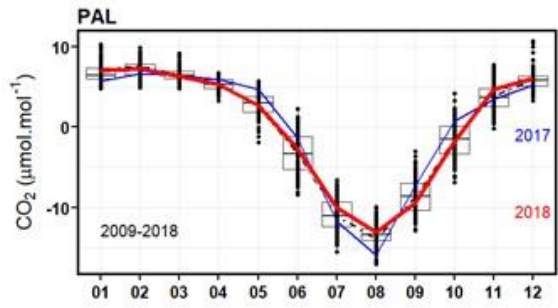
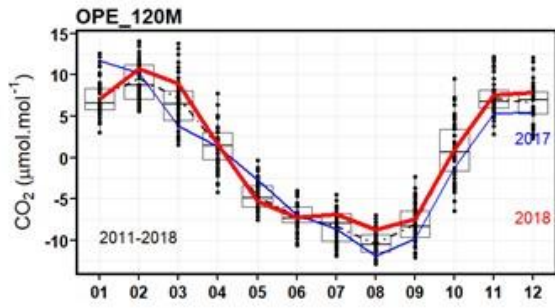
Figure S3. CO₂ seasonal cycles. The 2018 cycle is shown in red, 2017 in blue, and the average of the full measurement period in black. The boxes show the median, first and third quartiles over the entire measurement period of each station, indicated in the bottom left corners. For the 20 tall towers only the highest sampling levels are shown (elevation in m. a.g.l. is given in the title).











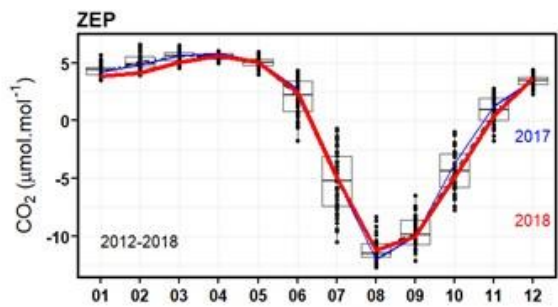
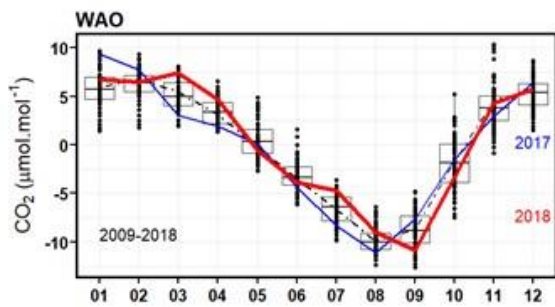
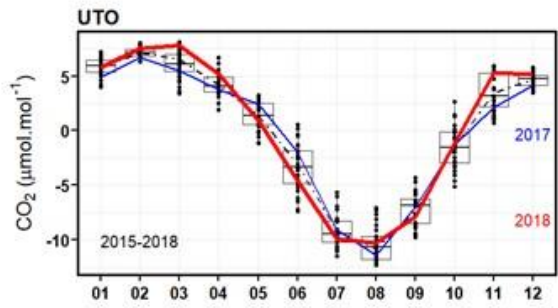
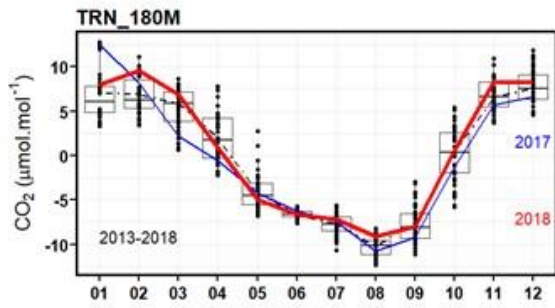
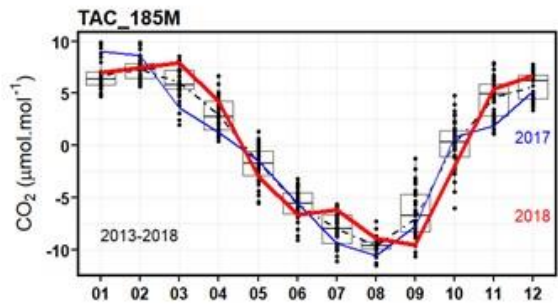
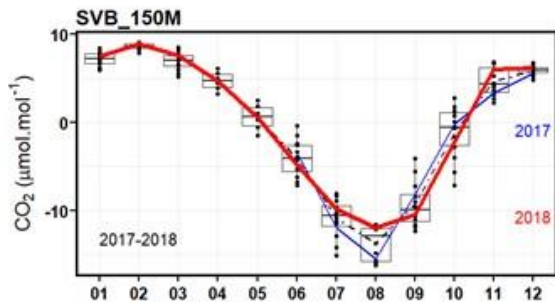
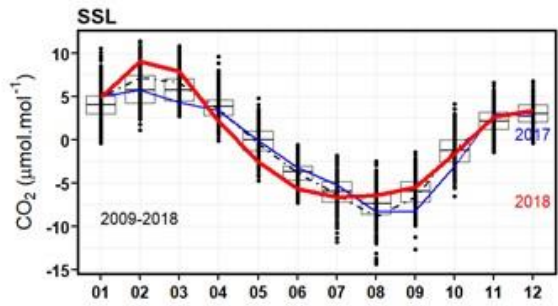
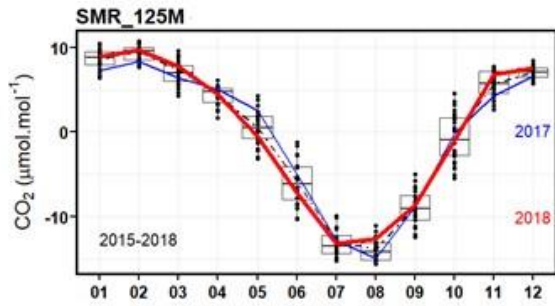
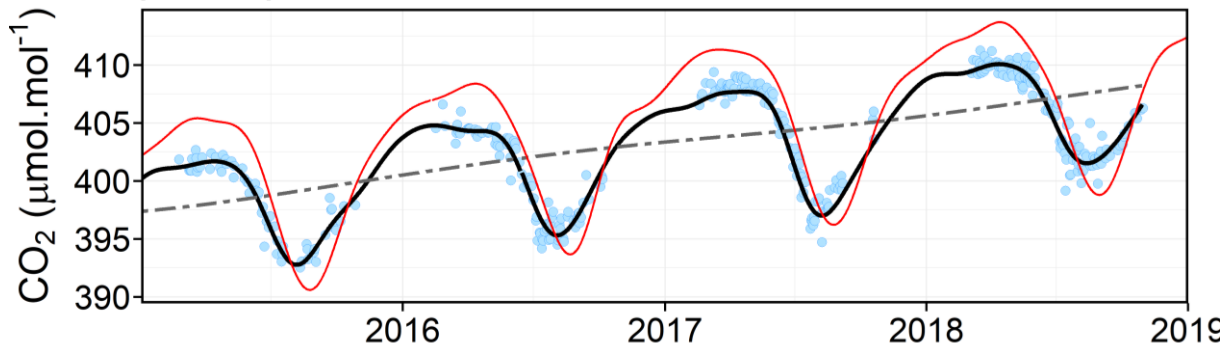


Figure S4. Same as Figure 3 but for the column-averaged dry air mole fraction of CO₂ (XCO₂) observed at Sodankylä TCCON site (SOD, Finland). The red curve represents the smooth curve of the CO₂ time series at Mace Head, Ireland in the marine sector.



Description of the Sodankylä TCCON data:

Detector non-linearity effect was identified for the measurements performed during 2017 as part of the Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG) campaign funded by the European Space Agency. This was overcome in 2018 by performing an instrument modification such as to reduce the signal level on the detector and avoid data acquisition close to the saturation level of the detector. A correction method was tested and applied to the 2017 data which was successful in reducing the non-linearity effects on the measurements (detailed description in Sha et al. (2019)) [47]. A closer inspection of the historical data earlier than 2017 is still needed to be done to check on the non-linearity effect. As a result the SOD time series has been analysed in three ways. We calculated (i) the difference of the 2018 minus the average of the previous years (2009 – 2018) which is discussed in the main section of the paper, (ii) the difference of the 2018 minus the average of 2009 – 2016 period such as to exclude the data from 2017 and 2018 and (iii) the difference of the 2018 minus the 2017 non-linearity corrected data to see the difference relative to the last year. Note that the amplitude of the anomalies for the case i and ii with longer time averaged datasets is very similar and that for last year has higher signal levels.

Figure S5. Monthly mean CO₂ differences anomalies for each month during April to October 2018, compared to the same month during the previous years. Blue: 2018 minus the average of 2009:2018; Red: 2018 minus the average of 2009:2016; and Green: 2018 minus 2017.

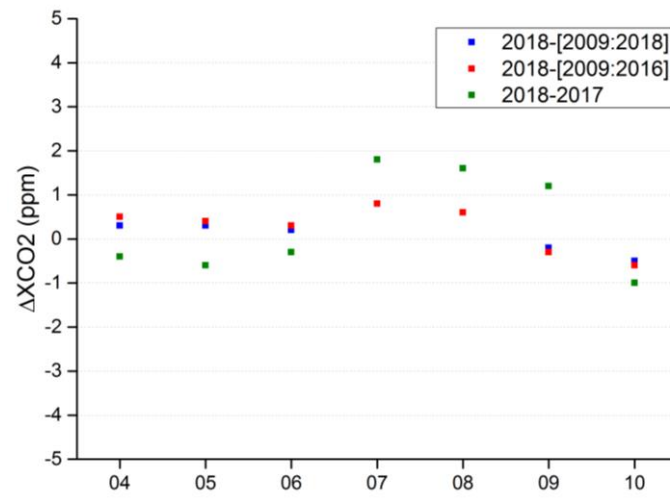


Figure S6. Map of the monthly mean CO₂ differences between 2003 (top panels) or 2015 (bottom panels), and the average of available data over the period 2010–2018, from July (left) to October (right). Circles represent surface stations in flat terrain. Triangles show the mountain site, and the square shows total column measurement station (TCCON).

