Response of atmospheric carbon dioxide to reduced emissions due to the COVID-19 shutdown.

Key messages:

1. Concentrations of greenhouse gases in the atmosphere continue to increase
2. Long-term observations coordinated by the WMO demonstrated substantial interannual variability in the concentration annual growth rate that was largely driven by the natural processes (biosphere).
3. The separation between natural variability and the one influence by lock-down measures will require datasets over longer time and sophisticated model analysis (helped also by use of isotope measurements).
4. The most substantial impact of the shutdown emission reductions on atmospheric GHG concentrations has been observed in urban areas.
5. Continued long-term observations under different conditions combined with comprehensive analysis can serve as a guiding tool to see where we go through the economic recovery process and can guide the corrective actions.

Carbon dioxide (CO_2) is a long-lived gas that accumulates in the atmosphere, so when sources and sinks would come in net balance the concentration will have a small variability, like in the last 14 000 years until the start of the industrial era around 1750 AD. Emissions from burning fossil fuel and land use change have increased CO_2 in the Earth's atmosphere from the pre-industrial level of 280 ppm to currently more than 410 ppm (means 410 CO_2 molecules per million of air molecules or 0.041% of all air molecules).

The latest analysis of observations from the WMO Global Atmosphere Watch (GAW) Programme supported by the Scientific Advisory Group on Greenhouse Gases and the WDCGG shows that globally averaged surface mole fractions(the measure of concentration) calculated from this in-situ network for CO_2, methane (CH_4) and nitrous oxide (N_2O) reached new highs in 2018, with CO_2 at 407.8±0.1 ppm, CH_4 at 1869±2 ppb and N_2O at 331.1±0.1 ppb. These values constitute, respectively, 147%, 259% and 123% of pre-industrial (before 1750) levels [WMO2019]. Concentrations of these main greenhouse gases continued to rise in 2019 and 2020.

Despite efforts to reduce per capita emissions as agreed in the Kyoto Protocol and the 2015 Paris Climate Agreement, emissions of CO_2 have increased globally year by year with about 1% in the last decade [GCP2019]. The additional CO_2 emissions have resulted in an increase in atmospheric CO_2 of between 2 and 3 ppm per year [WMO2019] in that period. This variability of about 1 ppm in the atmospheric growth rate is almost entirely due to variability in the uptake of CO_2 by ecosystems and oceans, that together take up roughly 50% of human emissions [GCP2019].

[GCP2020] has analysed the reduction of economic activities due to the COVID-19 shutdown in the major economies of the world and estimated that during the height of the shutdown daily emissions may have been reduced by up to 17% globally due to the confinement of the population. As the duration and severity of lockdown measures remain unclear, prediction of the total annual emission reduction over 2020 is very uncertain. [GCP2020] estimates this annual reduction at between 4.2% and 7.5%. This is also the kind of emission reduction rate needed from year to year in the coming 30 years to reach the Paris agreement target of limiting climate warming to 1.5 °C. This implies that the annual global increase in CO_2 (typically 2-3 ppm) will shrink by 4.2-7.5% (finally 0.08-0.23 ppm and transient up to a factor of two higher), well within the 1 ppm natural interannual variability. A similar conclusion was drawn by [CB2020] and [ICOS2020a].

The global atmospheric CO_2 signal is the integration of all natural and anthropogenic fluxes into and out of the atmosphere that have been well mixed by turbulent mixing and atmospheric transport. The GAW global network of surface stations can resolve global changes of atmospheric CO_2 over a year within 0.1 ppm of precision. Satellite observations cannot reach this precision for the global mean at the moment. When in-situ measurements are made closer to particular sources and sinks, individual signals can be stronger but are also entangled, and in most cases the natural signal shows the highest variability with strong diurnal and seasonal variations, while fossil fuel emissions are relatively consistent, which makes it hard to detect changes on the order of 10-20% on the timescales of a year or less. Measurements of the stable isotope Carbon-14 in CO_2 are now being made in several cities and regions around the world and will enable us to separate fossil sources of CO_2 from ecosystem sources and sinks regardless of how variable the latter are. However, these Carbon-14 measurements are still rare and it takes time to analyse the discrete samples in the lab, while high precision CO_2 measurements nowadays are mostly performed by continuously measuring in-situ instruments in networks that are designed to receive the integrated signal of all sources and sinks.

To determine changes in the fossil fuel signal amongst high natural CO_2 variability requires long time series to determine robust statistics and complex data modelling using data assimilation techniques. Emissions changes of the order of 10-20% are hard to quantify with certainty unless one measures within about 10 km of the fossil fuel emission sources. An example of the significant changes that can be measured within cities (such as proposed in the WMO IG^{3}IS program framework) is shown in [ICOS2020b] where reductions in emissions of up to 75% were measured in the city centres of Helsinki, Florence, Heraklion, Pesaro, London and Basel, using so called eddy covariance techniques that directly measure vertical exchange fluxes within a several kilometre circumference of the measurement point.

To conclude: we have shown that a reduction of emissions in the order of 4-7% globally does not mean that CO_2 in the atmosphere will go down, in fact the CO_2 will continue to accumulate and the level will just increase a little less than without this reduction. Discerning the change will be difficult because the superimposed and larger natural variability.

Only when the net emission of CO_2 comes close to zero, will the net uptake by ecosystems and ocean start to slightly reduce the CO_2 levels in the atmosphere. Even then most of the CO_2 already added to the atmosphere will remain there for several centuries and take part in the warming of our climate.

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[GCP2019] Friedlingstein, P. et al. Global Carbon Budget 2019. Earth Syst. Sci. Data 11, 1783–1838 (2019). https://doi.org/10.5194/essd-11-1783-2019

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[ICOS2020a] Kutsch W. et al. Finding a hair in the swimming pool: The signal of changed fossil emissions in the atmosphere. https://www.icos-cp.eu/event/917, accessed at 2 June 2020.

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[WMO2019] WMO Greenhouse Gas Bulletin (GHG Bulletin) - No. 15: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2018. https://library.wmo.int/index.php?lvl=notice_display&id=21620