

The state of greenhouse gases in the atmosphere using global observations through 2019

Oksana A. Tarasova (#), Alex Vermeulen, Yousuke Sawa, Sander Houweling, Ed Dlugokencky (#) WMO, Geneva, Switzerland (otarasova@wmo.int)

Global averaged annual mean mole fractions of key GHG in 2019

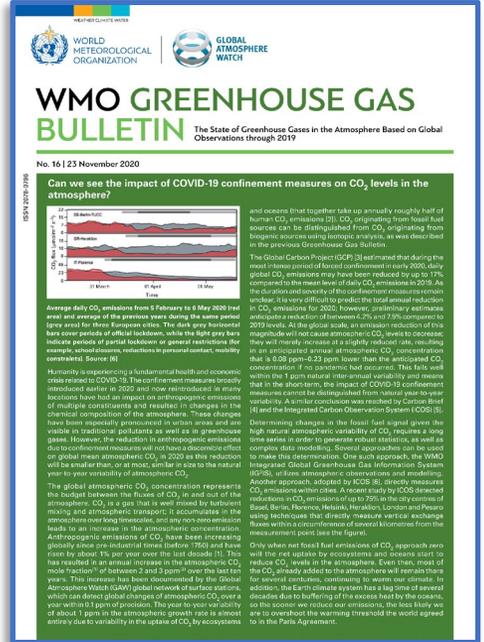
CO₂=410.5 ppm

CH₄=1877 ppb

N₂O=332.0 ppb

CO₂-eq=500 ppm

The GAW global network for carbon dioxide in the last decade. The network for methane is similar.



WMO GREENHOUSE GAS BULLETIN
The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2019
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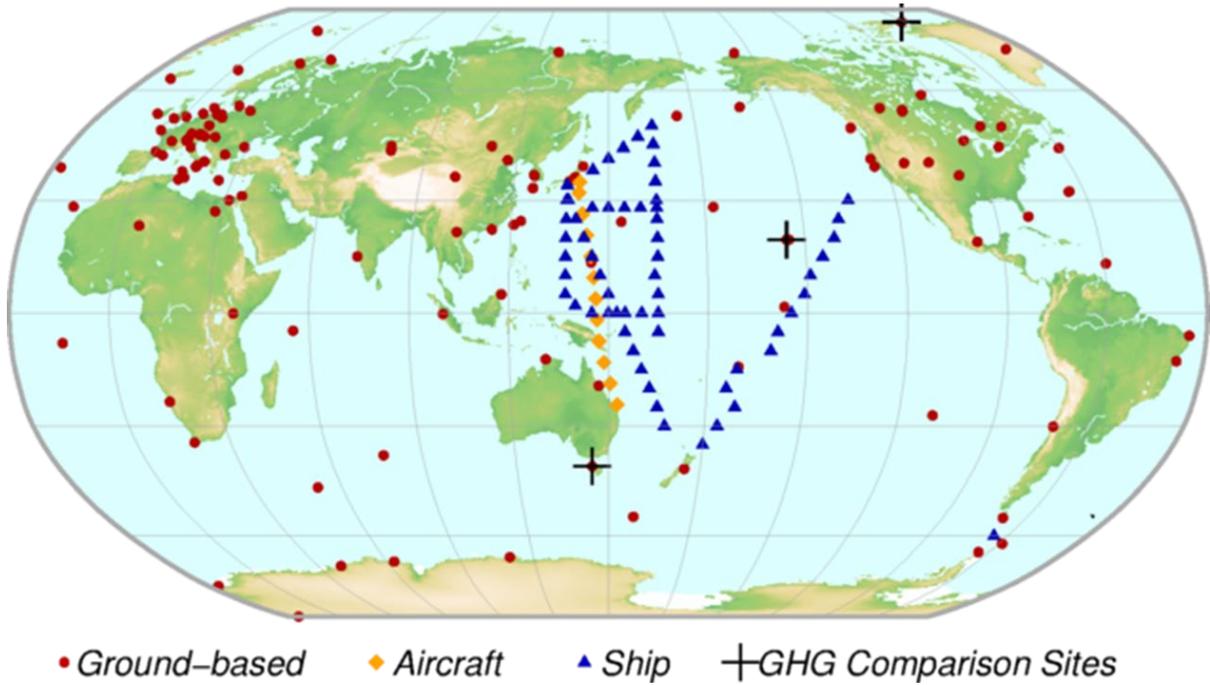
Can we see the impact of COVID-19 confinement measures on CO₂ levels in the atmosphere?

and oceans that together take up annually roughly half of human CO₂ emissions [2]. CO₂ originating from fossil fuel sources can be distinguished from CO₂ originating from biogenic sources using isotopic analysis, as was described in the previous Greenhouse Gas Bulletin.

The Global Carbon Project (GCP) [3] estimated that during the most intense period of forced confinement in early 2020, daily global CO₂ emissions may have been reduced by up to 17% compared to the mean level of daily CO₂ emissions in 2018. As the duration and severity of the confinement measures remains unclear, it is very difficult to predict the total annual reduction in CO₂ emissions for 2020. However, preliminary estimates anticipate a reduction of between 4.2% and 7.9% compared to 2019 levels. At the global scale, an emissions reduction of this magnitude will not cause atmospheric CO₂ levels to decrease; they will merely increase at a slightly reduced rate, resulting in an anticipated annual atmospheric CO₂ concentration that is 8.20 ppm±0.23 ppm lower than the anticipated CO₂ concentration if no pandemic had occurred. This falls well within the 1 ppm natural inter-annual variability and means that in the short term, the impact of COVID-19 confinement measures cannot be distinguished from natural year-to-year variability. A similar conclusion was reached by Carbon Brief [4] and the Integrated Carbon Observation System (ICOS) [5].

Determining changes in the fossil fuel signal given the high natural atmospheric variability of CO₂ requires a long time series in order to generate robust statistics, as well as complete data resolution. Several approaches can be used to make this determination. One such approach, the WMO Integrated Global Greenhouse Gas Information System (IGG3), utilizes atmospheric observations and modelling. Another approach, adopted by ICOS [5], directly measures CO₂ emissions within cities. A recent study by ICOS selected locations in CO₂ concentrations up to 7.2% in the vicinity of Basel, Berlin, Florence, Helsinki, Houston, London and Poznań using mobile flux towers that directly measure vehicle exchange fluxes within a circumference of several kilometres from the measurement point, see Fig. 10(a).

Only when net fossil fuel emissions of CO₂ approach zero will the net uptake by ecosystems and oceans start to reduce CO₂ levels in the atmosphere. Even then, most of the CO₂ already added to the atmosphere will remain there for several centuries, centuries to years for methane. In addition, the Earth climate system has a lag time of several decades due to buffering of the excess heat by the oceans, so the sooner we reduce our emissions, the less likely we are to overshoot the warming threshold the world agreed to in the Paris Agreement.



133 (CO₂), 134 (CH₄) and 100 (N₂O) stations used for the 2019 analyses



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Global annual mean abundances (2019) and trends of key greenhouse gases from the WMO/GAW global greenhouse gas observational network

	CO ₂	CH ₄	N ₂ O
2019 global mean abundance	410.5±0.2 ppm	1877±2 ppb	332.0±0.1 ppb
2019 abundance relative to 1750 ^a	148%	260%	123%
2018–19 absolute increase	2.6 ppm	8 ppb	0.9 ppb
2018–19 relative increase	0.64%	0.43%	0.27%
Mean annual absolute increase over the past 10 years	2.37 ppm yr ⁻¹	7.3 ppb yr ⁻¹	0.96 ppb yr ⁻¹

* Units are dry-air mole fractions, and uncertainties are 68% confidence limits

** Assuming a pre-industrial mole fraction of 278 ppm for CO₂, 722 ppb for CH₄ and 270 ppb for N₂O. The number of stations used for the analyses was 133 for CO₂, 134 for CH₄ and 100 for N₂O.



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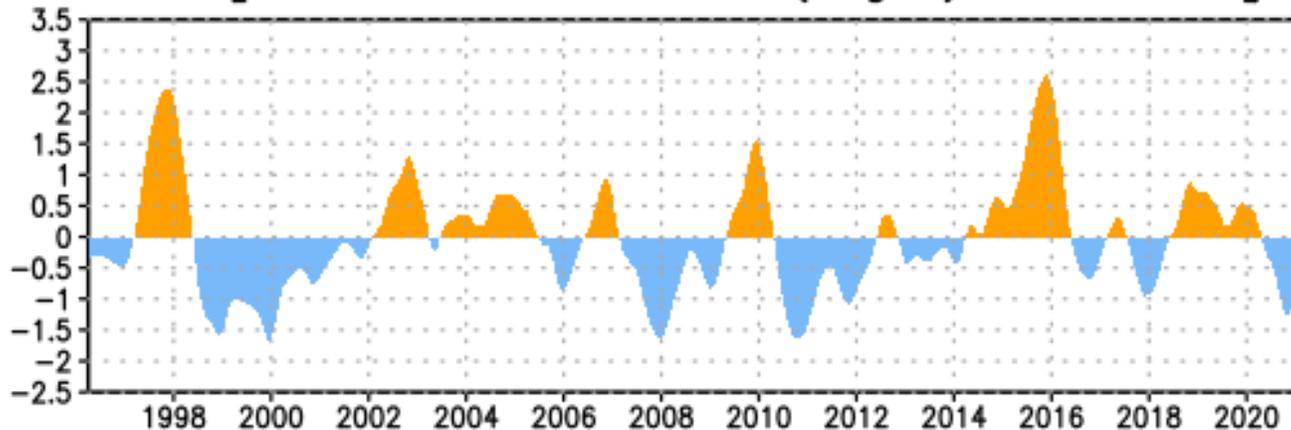
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(#) WMO, Geneva, Switzerland (otarasova@wmo.int)



Decadal variability of the annual growth rates

	CO ₂	CH ₄	N ₂ O
2018–19 absolute increase	2.6 ppm	8 ppb	0.9 ppb
Previous year increase	2.3 ppm	9 ppb	1.2 ppb
Max increase over the past 10 years	3.2 ppm (2016)	10 ppb (2015)	1.2 ppb (2018)
Min increase over the past 10 years	1.9 ppm (2014)	5 ppb (2010-2012)	0.8 ppb (2016-2017)
Mean increase over the past 10 years	2.37 ppm yr ⁻¹	7.3 ppb yr ⁻¹	0.96 ppb yr ⁻¹

ONI [3–mrm SST anomalies (deg C) in Nino 3.4]



Climate Prediction Center / NCEP

An annual increase in the atmospheric CO₂ mole fraction was between 1.9 and 3.2 ppm per year over the last ten years. This increase has been documented by the Global Atmosphere Watch (GAW) global network of surface stations, which can detect global changes of atmospheric CO₂ over a year **within 0.1 ppm** of precision. The year-to-year variability of about 1 ppm in the atmospheric growth rate is almost entirely **due to variability in the uptake of CO₂ by ecosystems and oceans** (that together take up annually roughly half of human CO₂ emissions).



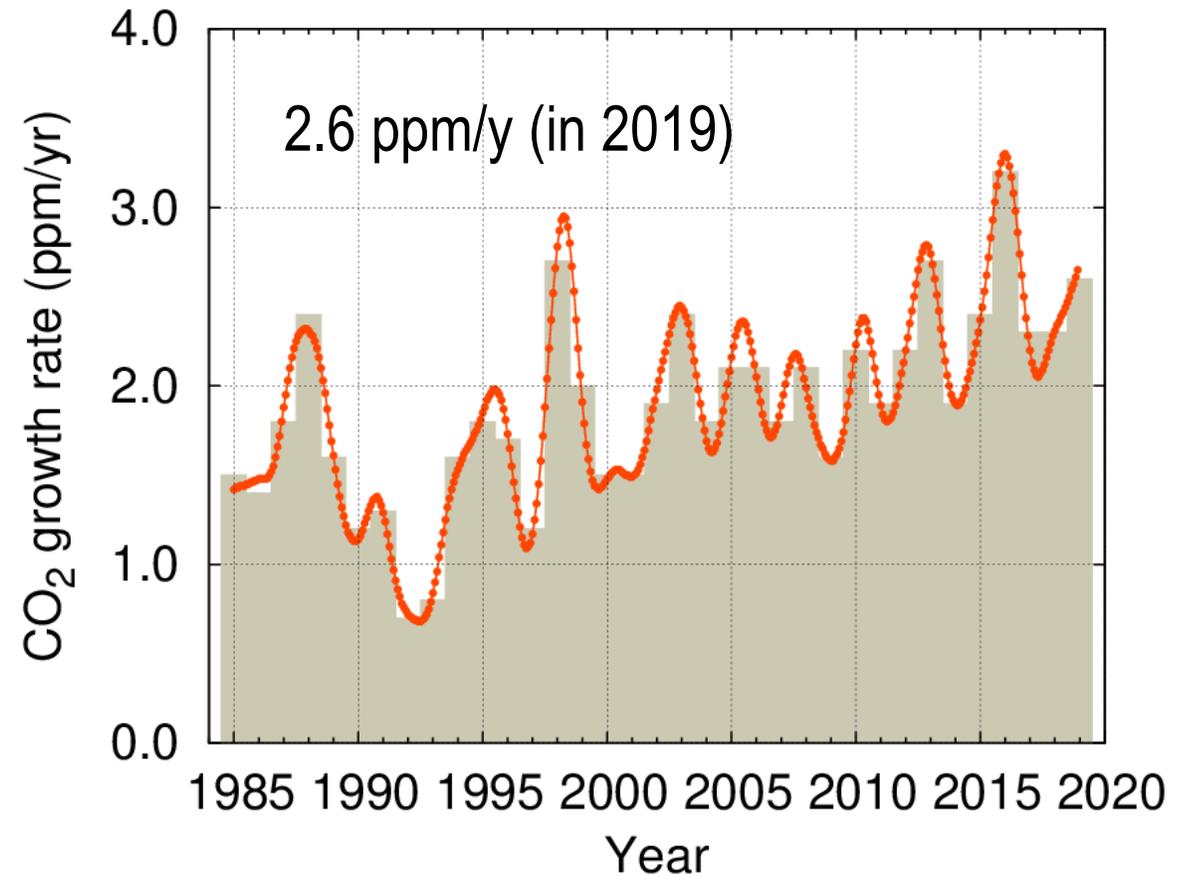
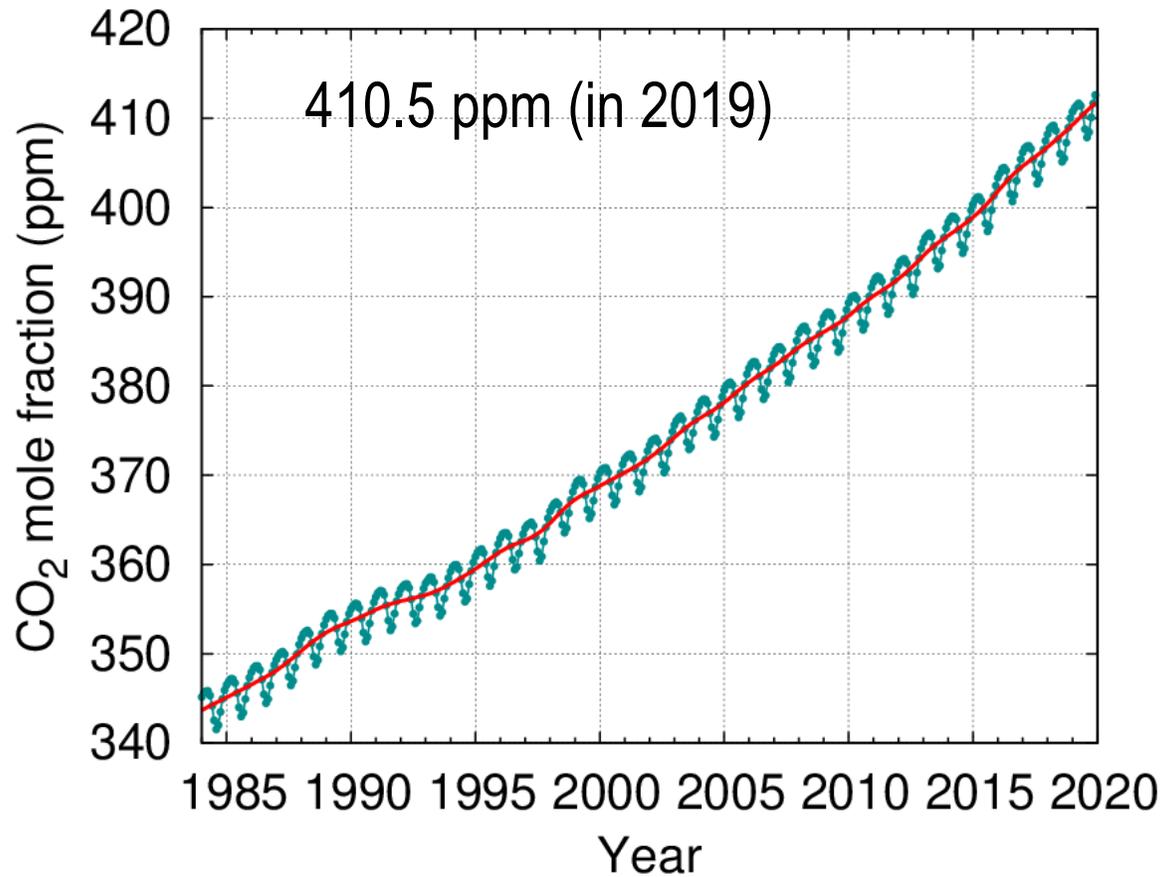
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Carbon dioxide



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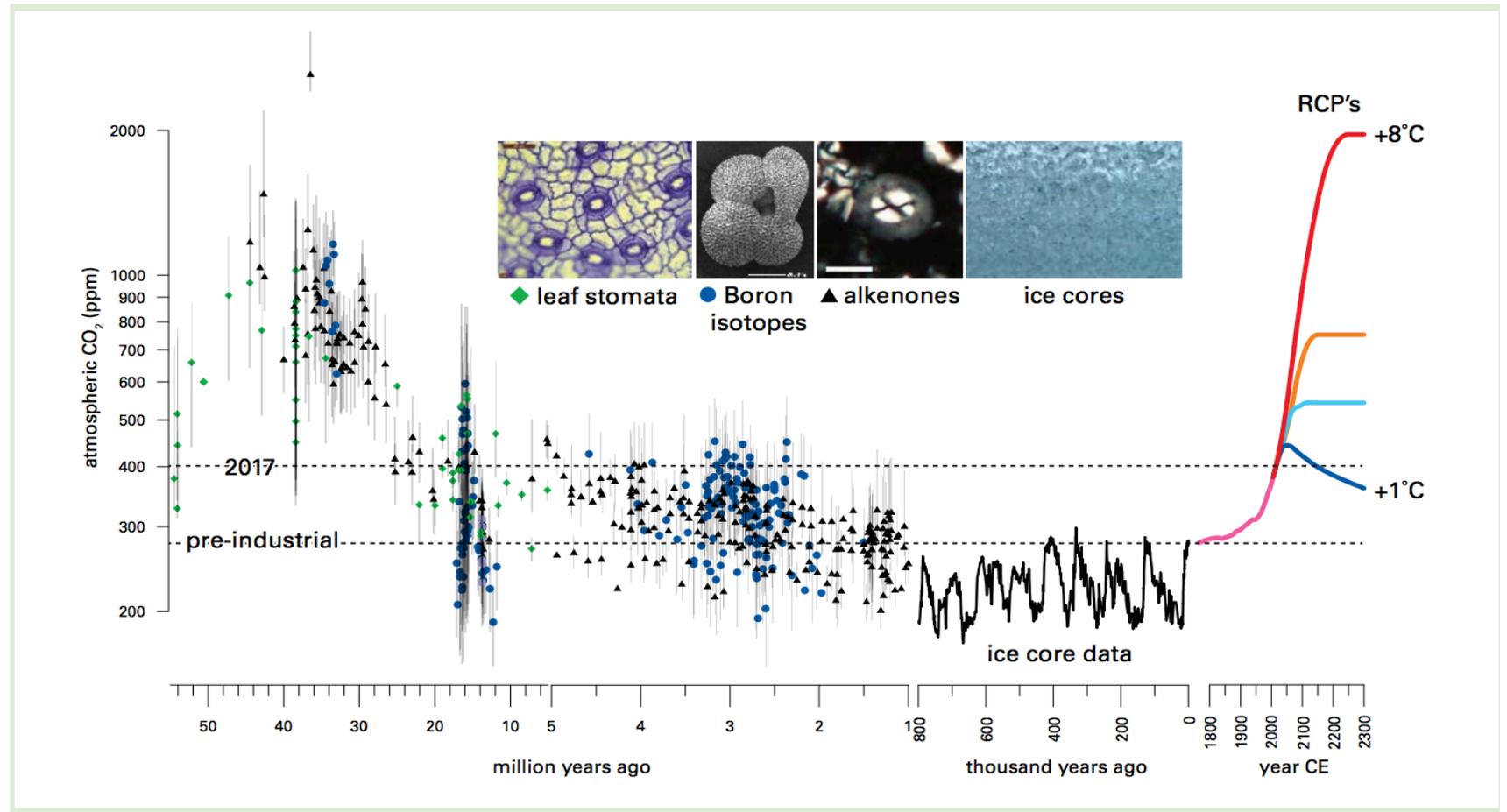
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Time periods of interest include the mid-Pliocene, 3–5 million years ago, in which was the last time Earth’s atmosphere contained 400 ppm CO₂. During that period, global mean surface temperatures were 2–3 °C warmer than today, ice sheets in Greenland and West Antarctica melted and even parts of East Antarctica’s ice retreated, causing the sea level to rise 10–20 m higher than that today.



Carbon dioxide



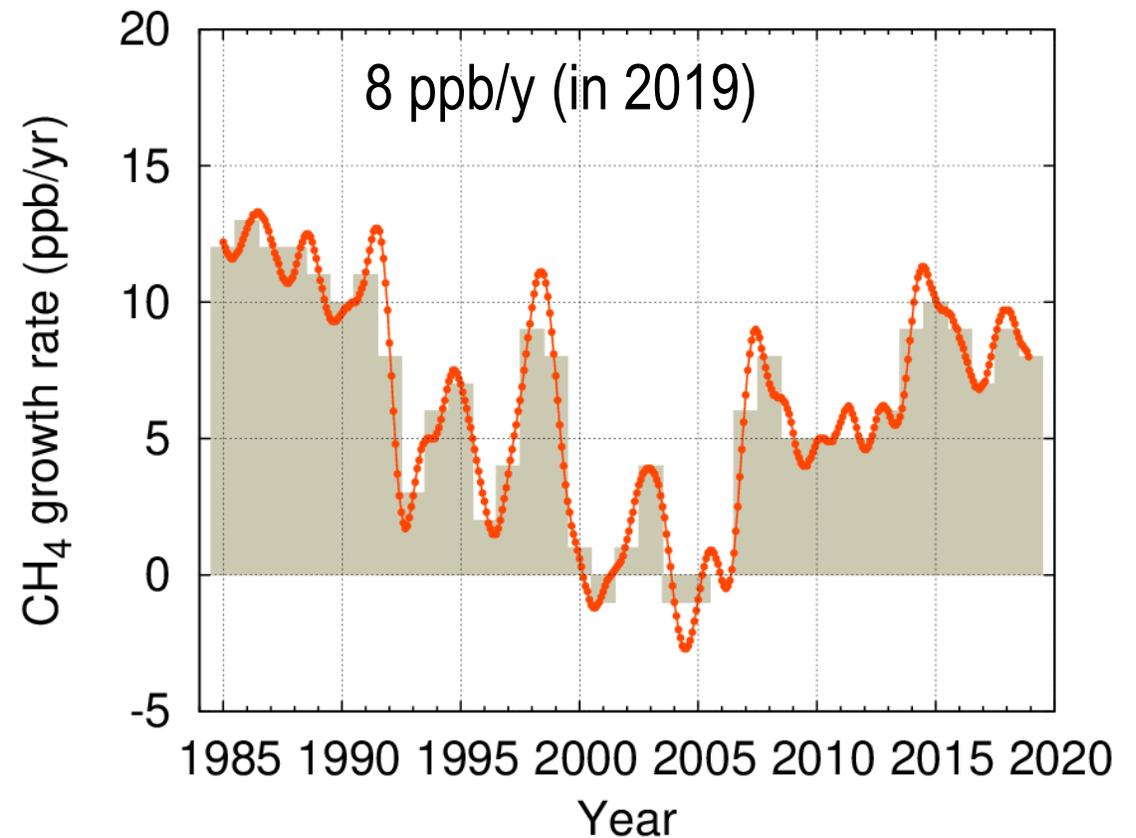
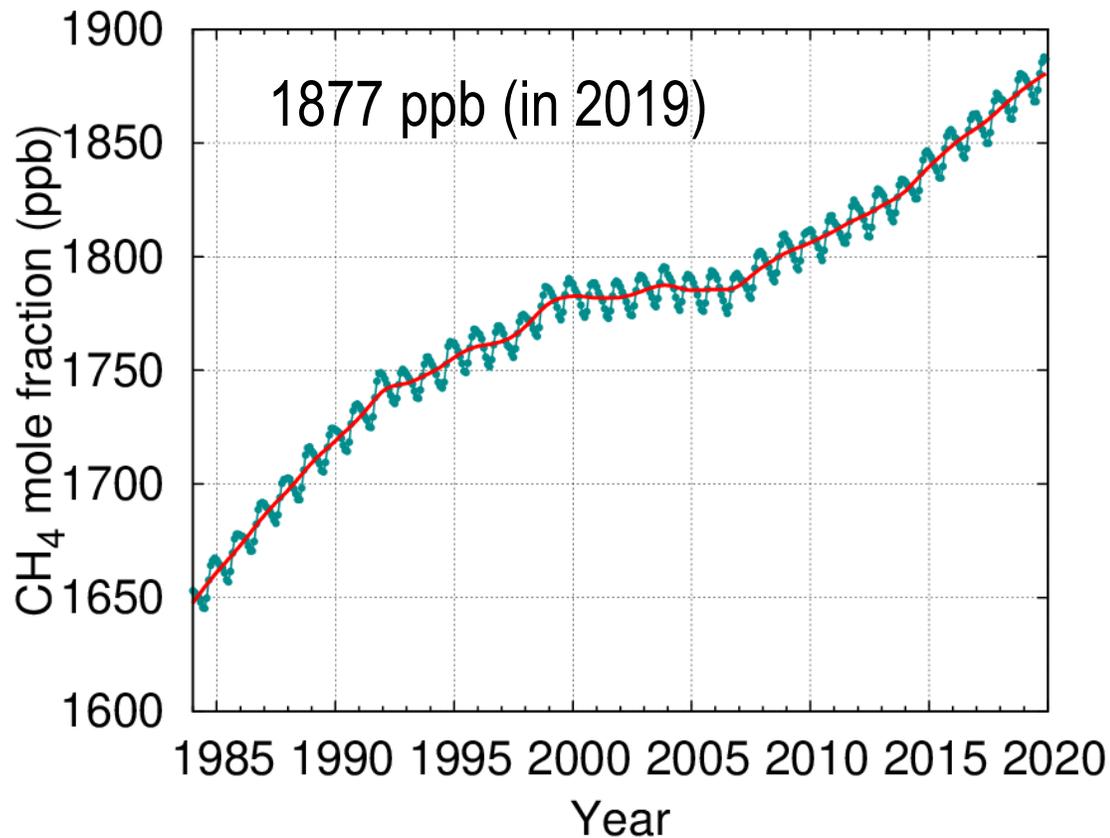
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Methane

Studies using GAW CH₄ measurements indicate that increased CH₄ emissions from wetlands in the tropics and from anthropogenic sources at mid-latitudes of the northern hemisphere are likely causes of the renewed growth.



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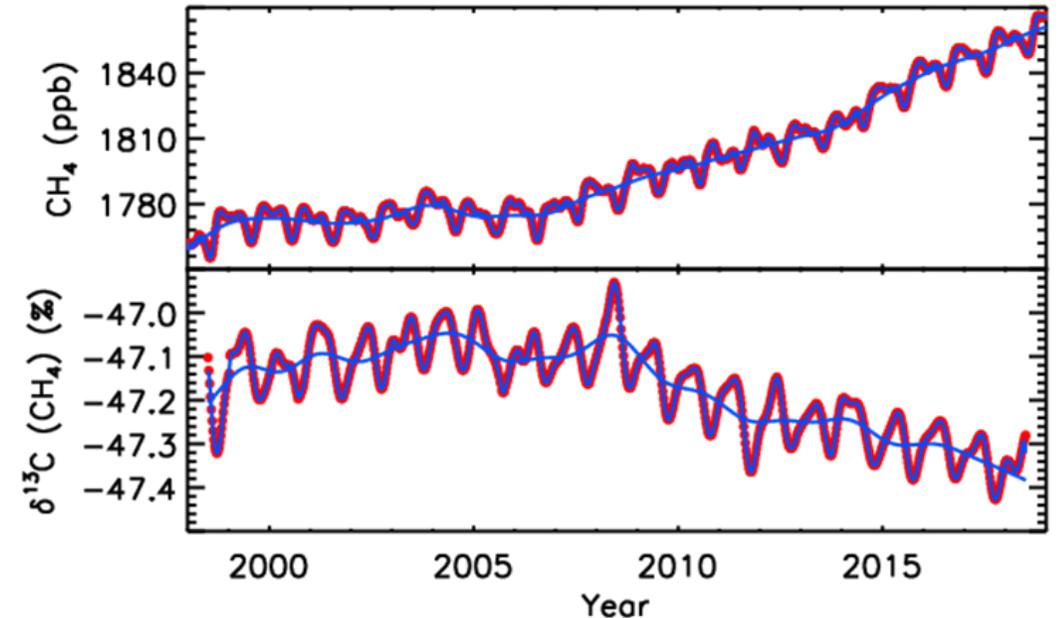
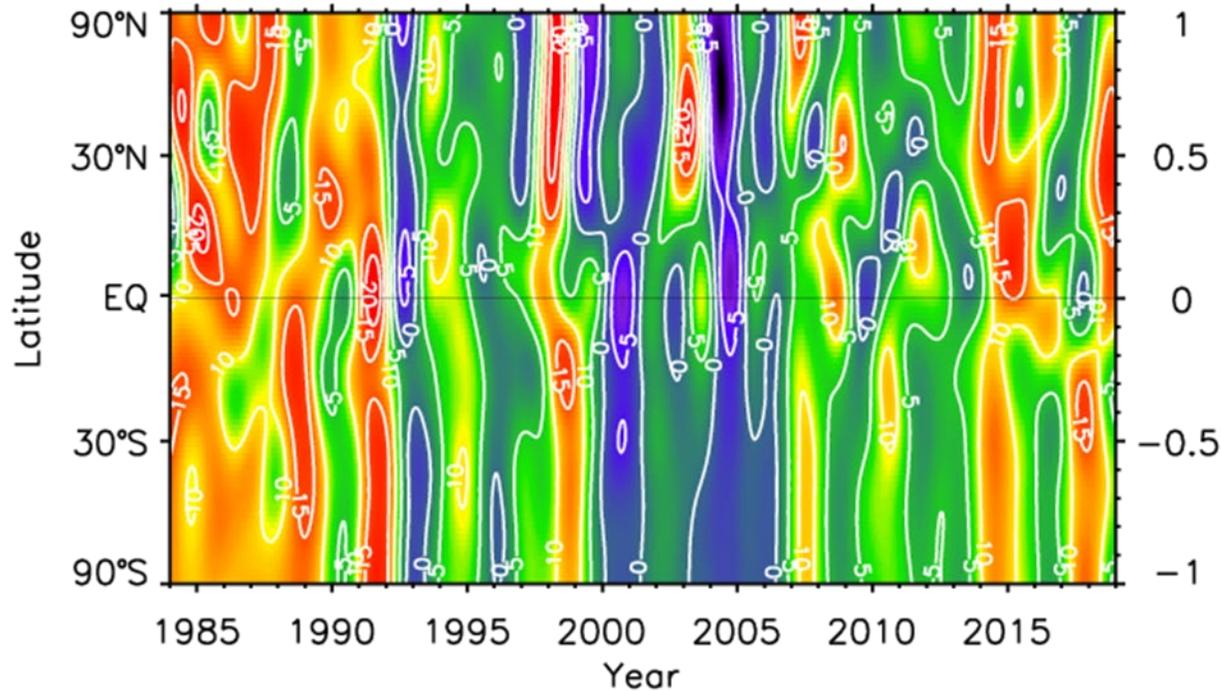
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Where methane changes happen



Though there are several hypotheses for the renewed CH₄ increase, the most plausible one is that an increase has occurred in some or all sources of biogenic (wetlands, ruminants or waste) emissions, which contain relatively little ¹³C.



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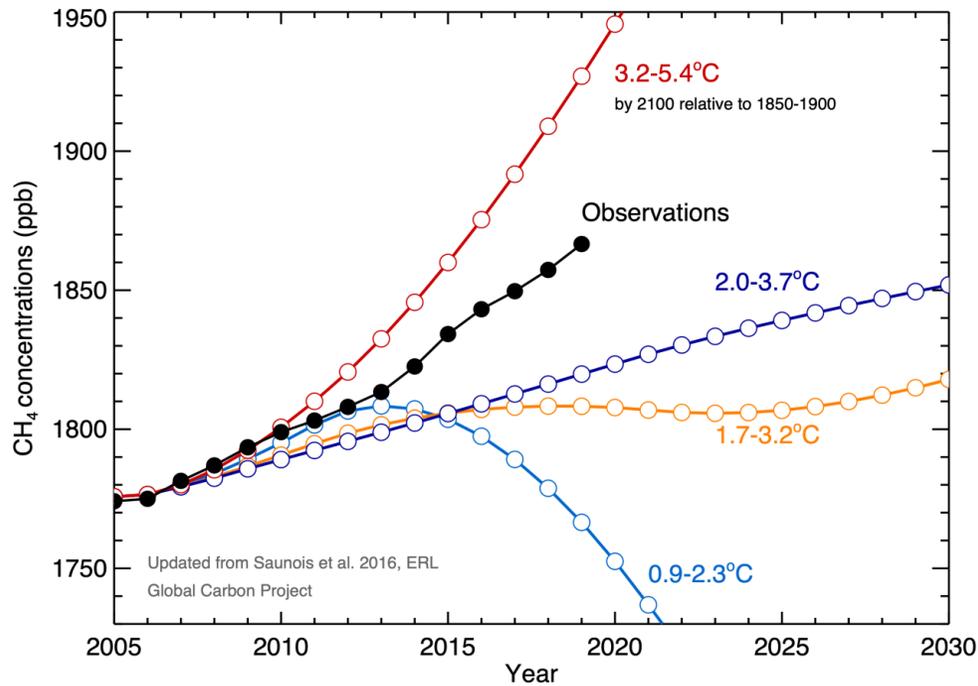
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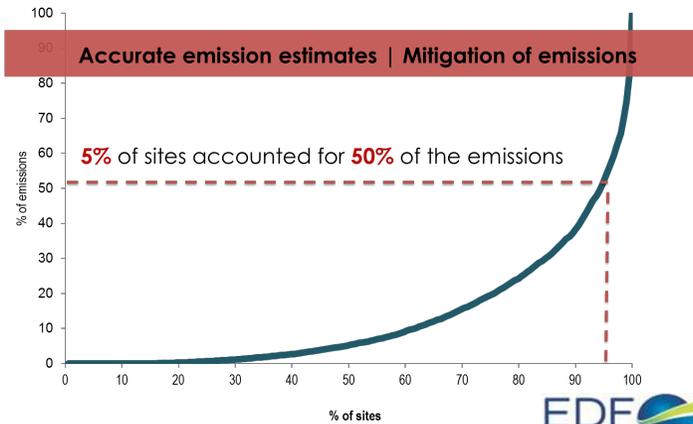
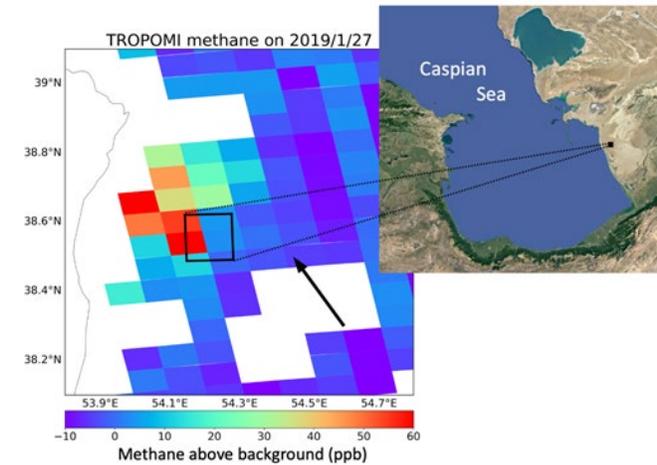
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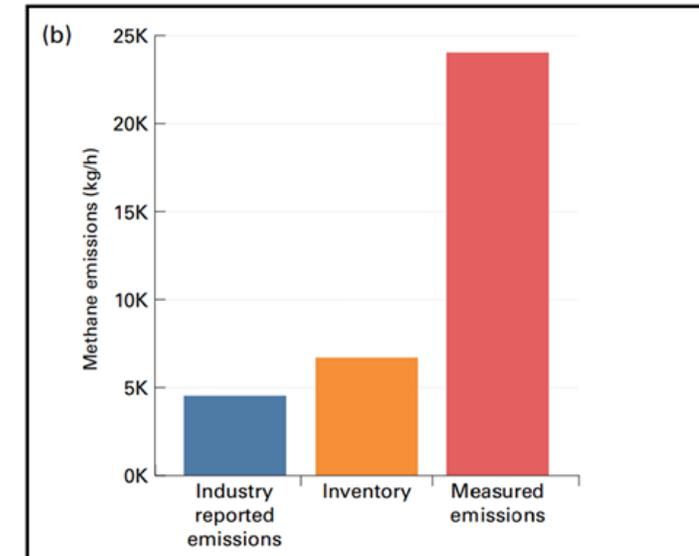
Methane emission reduction opportunities



Fixing leakages from super emitters represents a cost-efficient emission reduction opportunity that has not been fully utilized.



Comparison between measured CH₄ emissions and “bottom-up” estimates based on inventory and industry reports (Canada).





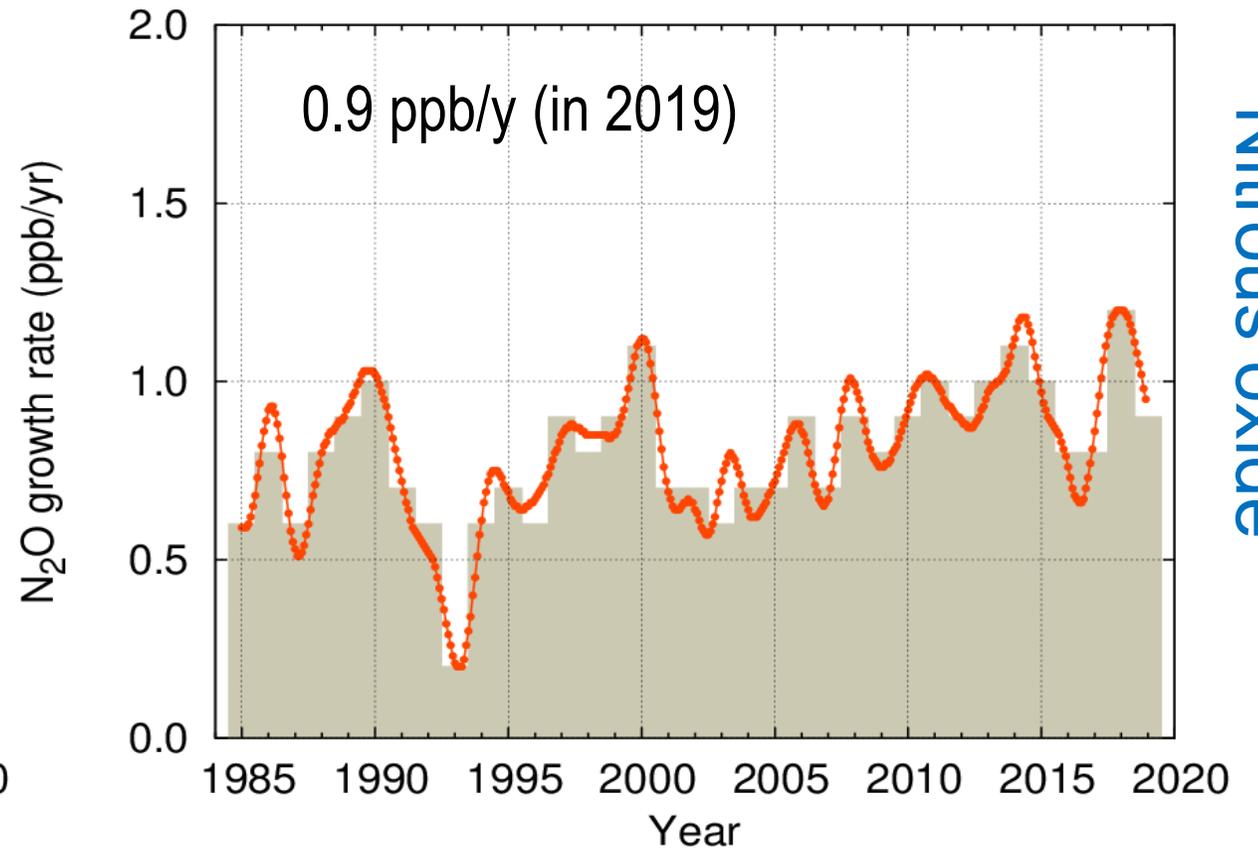
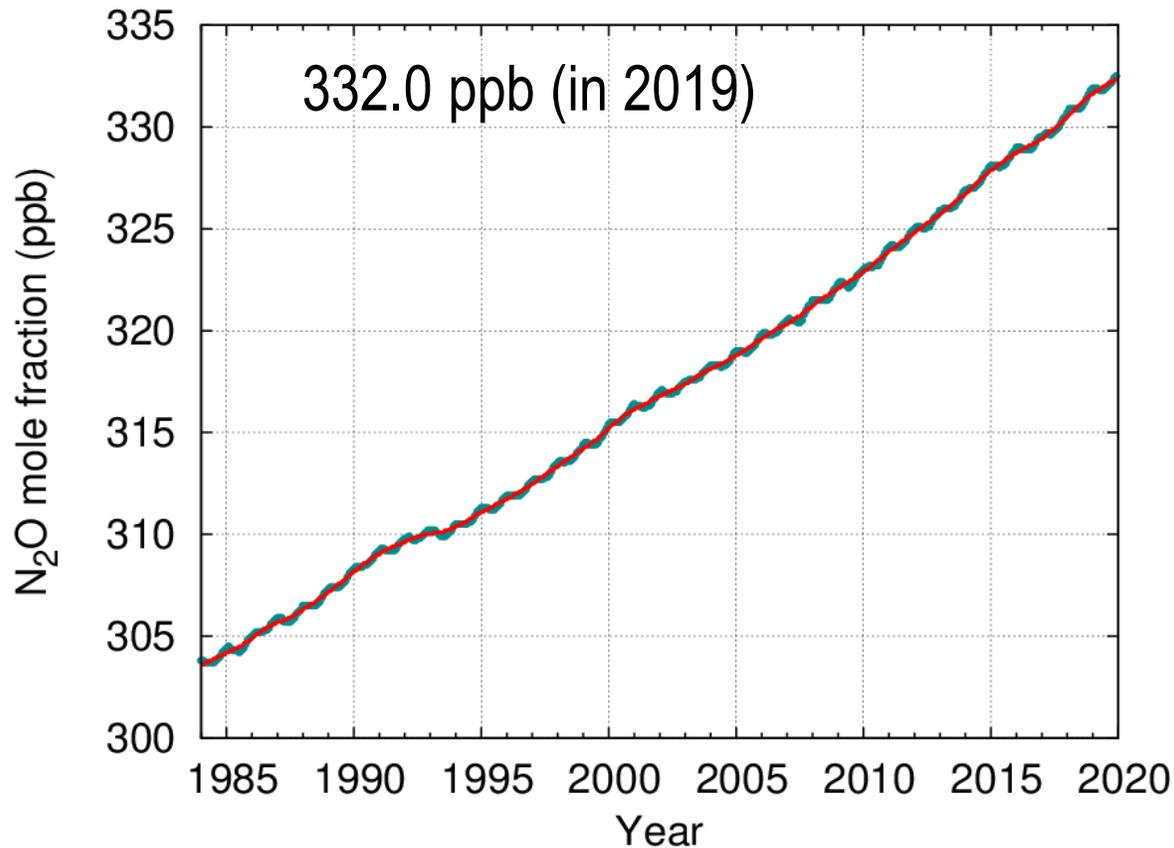
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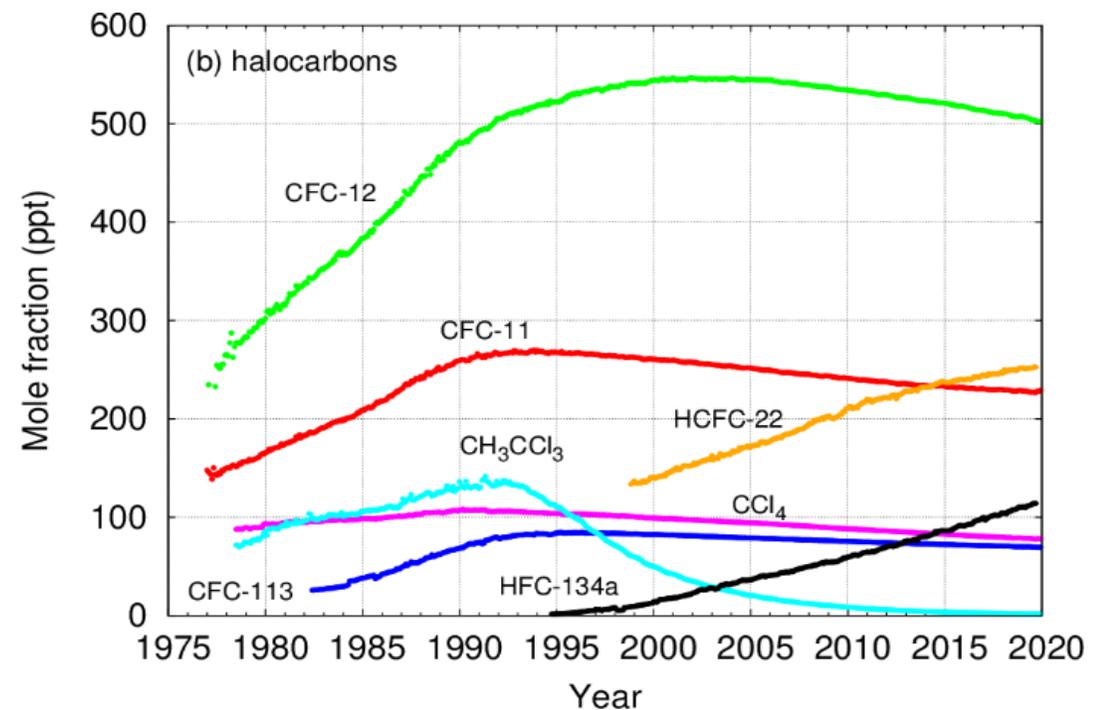
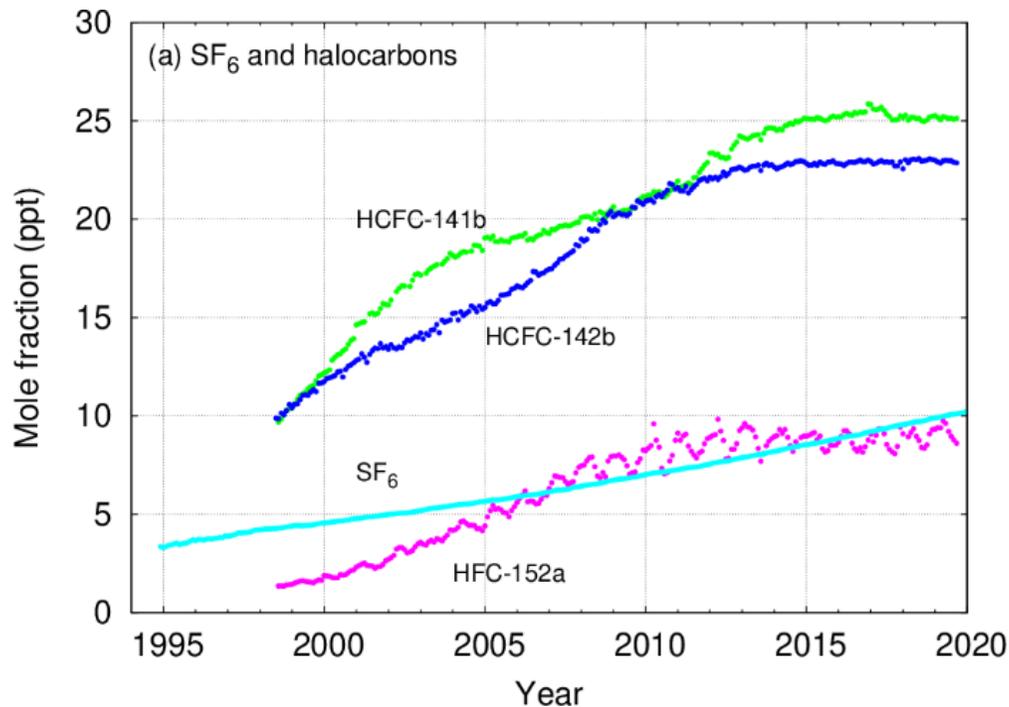
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Monthly mean mole fractions of sulfur hexafluoride (SF₆) and the most important halocarbons: (a) SF₆ and lower mole fractions of halocarbons and (b) higher halocarbon mole fractions. For each gas, the numbers of stations used for the analysis was as follows: SF₆ (87), CFC-11 (23), CFC-12 (25), CFC-113 (22), CCl₄ (21), CH₃CCl₃ (25), HCFC-141b (10), HCFC-142b (15), HCFC-22 (14), HFC-134a (11), HFC-152a (10).

Other greenhouse gases



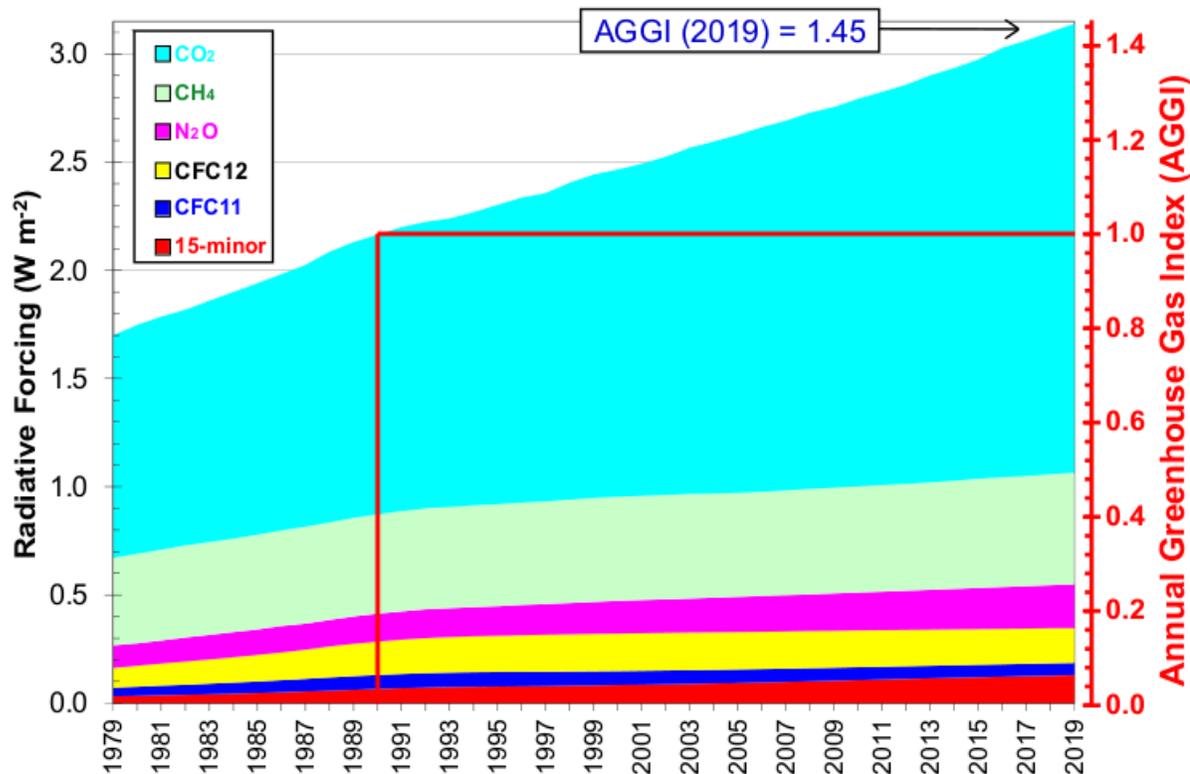
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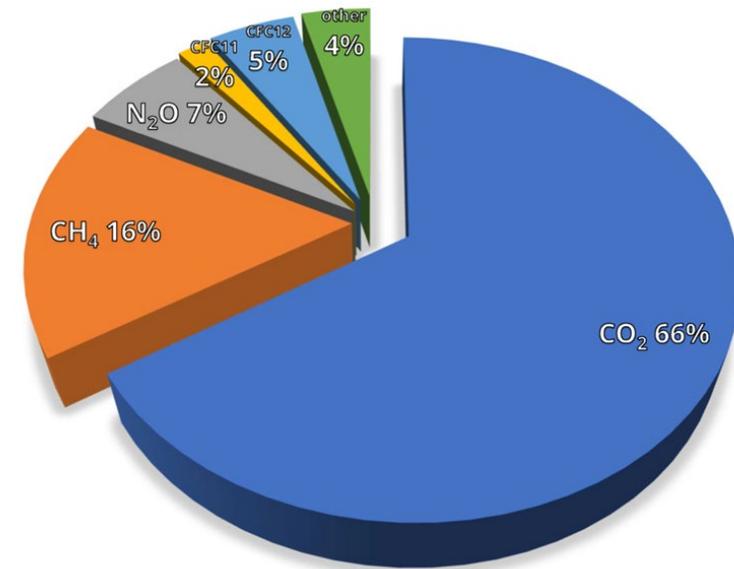
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(<http://www.esrl.noaa.gov/gmd/aggi>).

2019 increase since pre-industrial times



Total radiative forcing in 2019 was 3.14 W m^{-2}
This corresponds to equivalent CO₂ mole fraction
of **500 ppm**
CO₂ alone contributes 82%



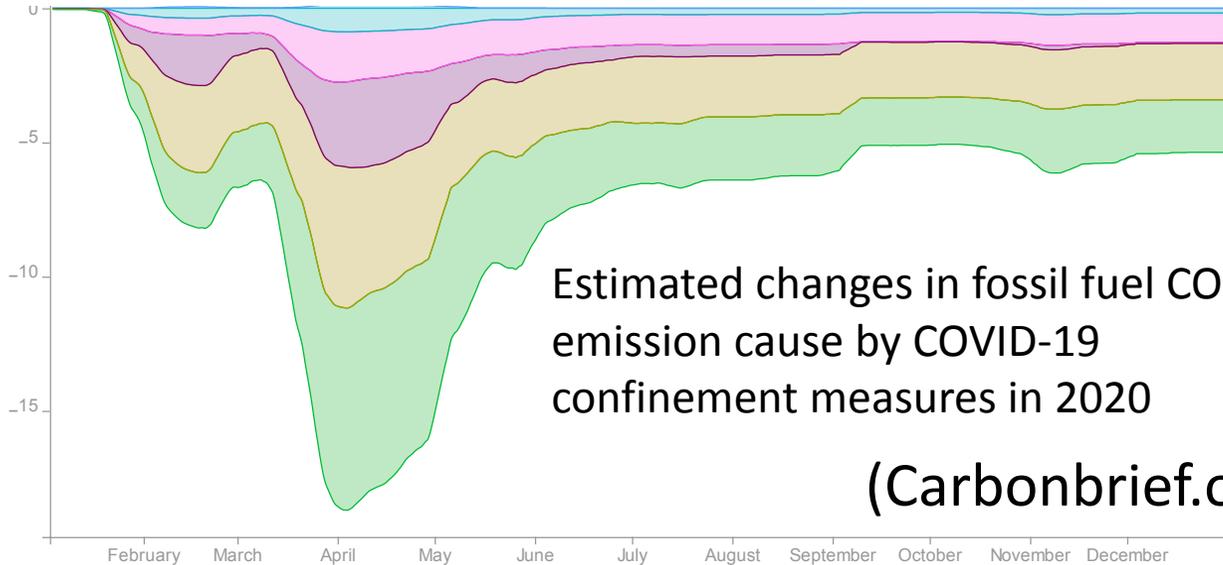
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Updated from Le Quéré et al. Nature Climate Change (2020), excluding international aviation and shipping for country emissions

Power

Industry

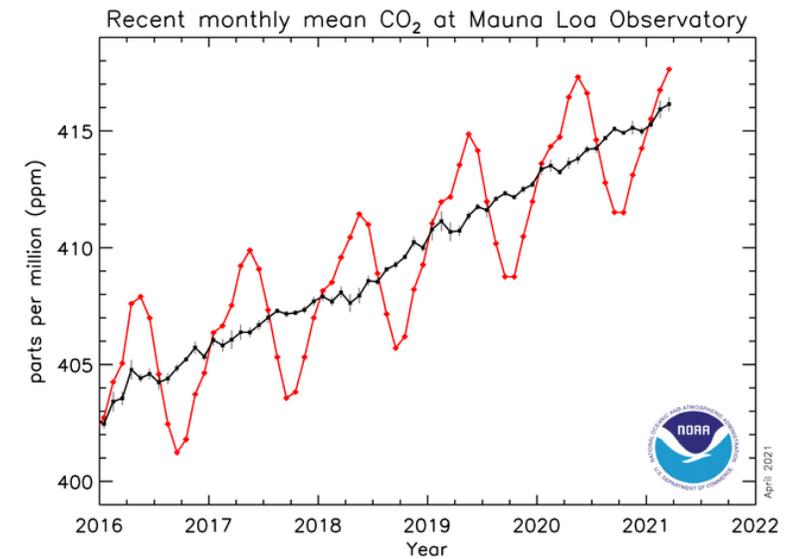
Surface Transport

Public

Residential

Aviation

Impact of COVID-19 lockdown measures on the levels of atmospheric CO₂



Global fossil CO₂ emissions have decreased by 7% in 2020 (Le Quéré, C., Peters, G.P., Friedlingstein, P. et al. Nat. Clim. Chang. 11, 197–199 (2021). <https://doi.org/10.1038/s41558-021-01001-0>).

At the global scale, an emission reduction of this magnitude will not cause atmospheric CO₂ levels to decrease; they will merely increase at a slightly reduced rate, resulting in an anticipated annual atmospheric CO₂ concentration that is 0.08 ppm–0.23 ppm lower than the anticipated CO₂ concentration if no pandemic had occurred. This falls **well within the 1 ppm natural inter-annual variability** and means that in the short-term, the impact of COVID-19 confinement measures cannot be distinguished from natural year-to-year variability.



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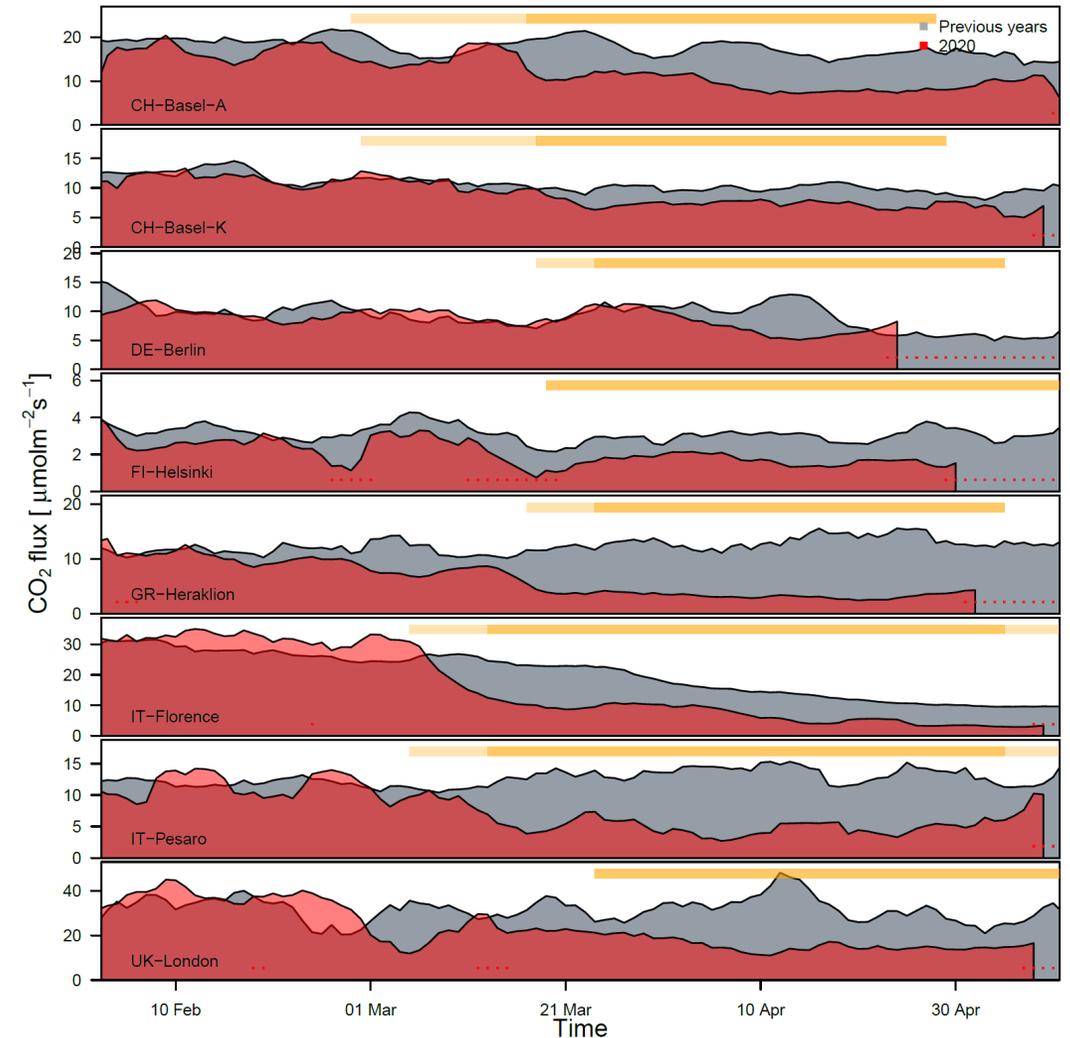
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The WMO Integrated Global Greenhouse Gas Information System (IG³IS), utilizes atmospheric observations and modelling to quantify changes in emission of greenhouse gases (please follow session [AS3.8 on Friday, 30 April](#))

Another approach, adopted the Integrated Carbon Observation System (ICOS), directly measures CO₂ emissions within cities. A recent study by ICOS detected reductions in CO₂ emissions of up to 75% in centres of various cities, including Helsinki, Florence, Heraklion, Pesaro, London, Basel and Berlin, using techniques that directly measure vertical exchange fluxes within a circumference of several kilometres from the measurement point.





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The full version of the Greenhouse Gas Bulletin is available at https://library.wmo.int/doc_num.php?explnum_id=10437

The full Data Summary by the World Data Center is available at <https://gaw.kishou.go.jp/publications/summary>

Fifty-five WMO Members have contributed CO₂ and other greenhouse gas data to the GAW WDCGG. Approximately 40% of the measurement records submitted to WDCGG were obtained at sites of the NOAA Earth System Research Laboratory cooperative air-sampling network. For other networks and stations, see GAW Report No. 255. The Advanced Global Atmospheric Gases Experiment also contributed observations to the Bulletin. The GAW observational stations that contributed data to the Bulletin are included in the list of contributors on the WDCGG web page (<https://gaw.kishou.go.jp/>). They are also described in the GAW Station Information System, GAWSIS (<http://gawsis.meteoswiss.ch>), supported by MeteoSwiss, Switzerland.

Macquarie Island (MQA)



Photo: Barry Becker

American Samoa (SMO)



Photo: NOAA ESRL