Daily monitoring reveals global CO_2 emission patterns

Monitoring of the daily global CO_2 emissions in 2020 reveals the spatial–temporal pattern of the drop in emissions due to the impact of the COVID-19 pandemic. The daily CO_2 emission changes also reveal different patterns of human activities and fossil CO_2 emissions across countries, sectors and periods.

This is a summary of:
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The question

Fossil fuel combustion and cement production are the major sources of anthropogenic CO_2 emissions[1]. These 'fossil CO_2' emissions are often estimated annually based on energy consumption statistics and emission factors (CO_2 emissions per unit of energy consumed), and track the interannual pattern of global CO_2 emissions. However, given the high latency (more than one year) and coarse temporal resolution (annual) of current CO_2 estimations, the patterns of fossil CO_2 emissions are difficult to capture at a higher temporal resolution, especially the impact of short-term activity changes such as the global lockdowns during the COVID-19 pandemic. Insight into the dynamic nature of CO_2 emissions would reveal the patterns of human activities and provide a basis for assessing the gap to our climate targets.

The solution

We previously described the Carbon Monitor fossil CO_2 emission data set, which estimated daily data for six emission sectors and 12 high-emitting countries or regions, plus the rest of the world as an aggregate[2]. Even acknowledging higher uncertainties, this data set provides more up-to-date information than other inventories, which have a time lag.

We have now gone a step further by using our previously reported methodology[2] and wider sources of activity data to provide daily CO_2 emissions for the whole of 2020, calculated from inventories and Carbon Monitor near-real-time activity data for power generation (29 countries), industry (73 countries), ground transportation (406 cities), aviation and maritime transportation, and residential consumption (206 countries) sectors. These data were used to estimate the daily CO_2 emissions for 40 countries or regions and the global total for 2020. Daily CO_2 emissions in 2019 were used as reference data, and comparison with the 2020 emissions data revealed differences caused by factors such as weather, temperature, industrial development and — importantly — the impact of the COVID-19 pandemic, which started in early 2020. The calculated CO_2 emissions data with a daily temporal resolution, thus, provide a full picture of CO_2 emissions in 2020.

The reductions in the daily CO_2 emissions in 2020 reveal different patterns across countries and sectors (Fig. 1). Our results show that global CO_2 emissions in 2020 dropped by around 6% compared with those in 2019. This reduction in CO_2 emissions was primarily caused by the impact of the COVID-19 pandemic, including a large decrease in emissions from the transportation sector. However, daily CO_2 emissions gradually recovered towards 2019 levels from late April 2020 upon partial reopening of economies. Subsequent waves of lockdowns in late 2020 continued to cause smaller CO_2 reductions, primarily in western countries.

The implications

The reduction in CO_2 emissions in 2020 was approximately five times larger than the annual emissions decline at the peak of the Global Financial Crisis of 2008. This extraordinary decrease in emissions during 2020 is similar in magnitude to the sustained annual emission reductions necessary to limit global warming to 1.5 °C, and underscores the magnitude and speed at which the transition to renewable energy sources needs to advance[3]. However, stimulus packages are still dominated by fossil fuel investments, although they are becoming greener with time. On the basis of our continuous monitoring, global CO_2 emissions may have already rebounded to near 2019 levels in 2021[4].

In the current study, we did not consider the temporal variations in emission factors across sectors, which are mainly caused by changes in the mix of fuel types. For example, the large-scale application of clean energy sources, such as the increasing share of renewable energy in the power sector, and electrification in other sectors, will reduce the emission factors per unit of sectoral activity. Such changes in emission factors need to be considered in future studies and would further reduce the uncertainty of the data set.

To meet the transition to a transparent reporting framework under the Paris Agreement, further monitoring, observation, data collection and improved analysis methods are urgently needed. Monitoring trends in daily emissions in near-real-time, as demonstrated here, could contribute to timely policy actions with implications for climate change mitigation and Earth system management. The remaining global CO_2 budget should be tracked in a timely manner to continually update the gap between our current mitigation efforts and the need to limit global warming to 1.5 or 2 °C.

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EXPERT OPINION

"This paper provides an estimate of CO_2 emissions for 2020 and compares these with 2019 emissions. Data have been gathered by means of an extensive process, and the level of detail enables analysis of the emissions at a global level, at a country level and across six different sectors. The data gathered and presented in this paper are extremely valuable and give unique insight into the evolution of emissions in 2020." **Jan Brusselaers, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands**.

FIGURE

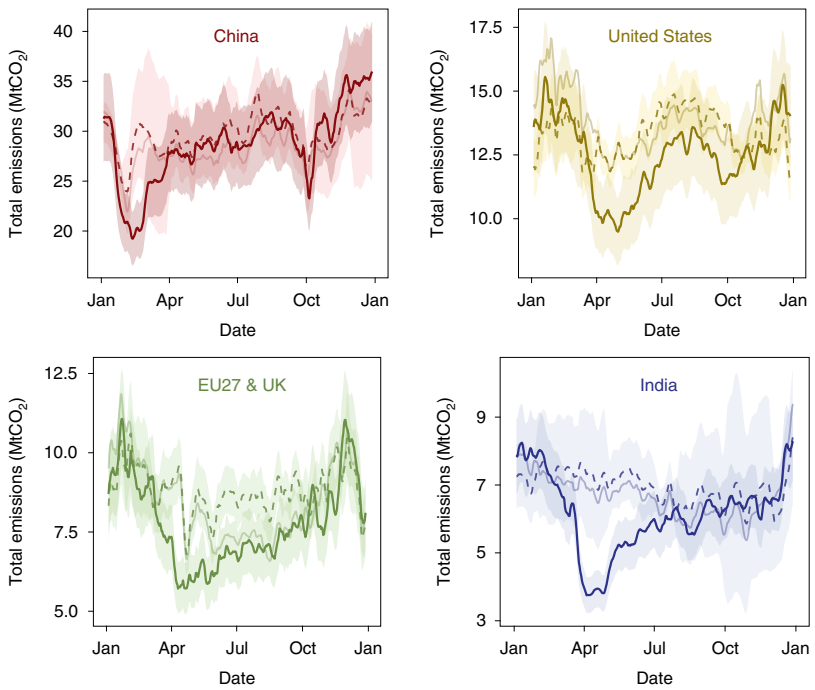

Fig. 1 | Daily CO_2 emissions for the four highest-emitting regions (China, United States, EU27 & UK, India) in 2019 and 2020. The thick and thin solid lines show the seven-day running mean of daily CO_2 emissions in 2020 and in 2019, respectively. The dashed lines are the 2020 baseline emissions, simulated by combining the daily variation from 2019 with historical emission trends. The 2-sigma uncertainty ranges are shown as light and dark shaded areas for the simulated baselines and daily estimates, respectively. Mt, million tonnes.

BEHIND THE PAPER

Monitoring of CO_2 emissions in a timely and accurate manner would provide an important basis for assessing climate change. To achieve this goal, we have been developing a near-real-time data system that can reflect dynamic changes in anthropogenic activities and their CO_2 emissions. This work is being developed by an international academic research team, the Carbon Monitor programme, which comprises over 100 researchers from more than 30 institutions around the world. Multiple data sets that show the daily CO_2 emission variations at multi-scale levels are being published in near-real-time, including global data and data for specific regions and cities, as well as a gridded daily CO_2 emissions map called GRACED[5]. With the ability to monitor CO_2 emissions in near-real-time, we have been trying to clarify whether we are on the pathway towards limiting anthropogenic warming to 1.5 °C. **Z.D.**

REFERENCES

1. Friedlingstein, P. et al. Global Carbon Budget 2021. *Earth Syst. Sci. Data.* **14**, 1917–2005 (2022).
This paper reports an annual estimation of each component in the global carbon cycle.

2. Liu, Z. et al. Near-real-time monitoring of global CO_2 emissions reveals the effects of the COVID-19 pandemic. *Nat. Commun.* **11**, 5172 (2020).
This paper presents the dramatic emission decrease for the first half of 2020.

3. Liu, Z. et al. Monitoring global carbon emissions in 2021. *Nat. Rev. Earth. Environ.* **3**, 217–219 (2022).
This comment article discusses the remaining carbon budget for limiting anthropogenic warming to 1.5 °C based on the latest emission estimations.

4. Davis, S. J. et al. Emissions rebound from the COVID-19 pandemic. *Nat. Clim. Change* **12**, 412–414 (2022).
This paper presents the global CO_2 emission rebound in 2021.

5. Dou, X. et al. Near-real-time global gridded daily CO_2 emissions. *The Innovation* **3**, 100182 (2022).
This paper presents the global gridded daily CO_2 emission map disaggregated from the Carbon Monitor data set.

FROM THE EDITOR

"Big CO_2 emission declines during the early part of the COVID-19 pandemic are well-known, although the study by Liu et al. stands out in how it shows, in impressive granular detail, the specific cause of these dips, which in turn helps in the development of more effective climate change mitigation strategies." **James Super, Senior Editor, *Nature Geoscience***.