Regional impacts of COVID-19 on carbon dioxide detected worldwide from space – what has COVID-19 taught us about carbon monitoring?

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1. CO\textsubscript{2} decreases from COVID-19 were small (< 0.5 ppm), consistent with independent estimates of emissions decreases.

Detailed analysis of OCO-2 L3 data produced by the GEOS Constituent Data Assimilation System (CoDAS) allowed detection of flux-driven anomalies in XCO\textsubscript{2} during COVID-19 pandemic.

Anomaly maps (left) show the change in XCO\textsubscript{2} anomalies as quarantines were imposed throughout much of the world.

Changes in XCO\textsubscript{2} were small (< 0.5 ppm) even over the world’s largest economies, and consistent with independent estimates of global emissions decreases of 8-10%.
2. Interpretation of emissions decreases requires careful consideration of year-specific circulation changes

Conventional $\text{XCO}_2$ Anomaly
Jan 1-15, 2020

Flux-driven $\text{XCO}_2$ Anomaly
Assimilation anomaly – simulation anomaly

Failure to properly account for circulation patterns could result in incorrect conclusions about changes over China

$\text{XCO}_2$ anomalies are strongly influenced by weather. Such influences can be minimized by averaging over larger area/longer time period, but this diminishes the ability to see localized COVID-19 impacts.

To ‘remove’ weather effects, we compare the conventional analysis anomaly (left) with an anomaly computed from GEOS simulations identical to the model used for the assimilation, except that no OCO-2 data are assimilated.
3. Modern data assimilation systems can contribute to low latency carbon monitoring, but availability of up-to-date emissions and flux datasets is a major challenge.

During COVID-19, anomalies in land surface, meteorological conditions provided valuable but non-quantitative indications of changes in land-atmosphere flux in near-real-time.

More CO₂ released by Australian drought, fires??

More uptake over India, Africa??

Looks like a typical year over South America??

NDVI anomalies – January 2020 (FAO)

January 2020 Flux-driven XCO₂ anomaly
3. Modern data assimilation systems can contribute to low latency carbon monitoring, but availability of up-to-date emissions and flux datasets is a major challenge.

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NDVI anomalies – January 2020 (FAO)

January 2020 Flux-driven XCO₂ anomaly

Information from land, ocean models needed to interpret and attribute flux anomalies, but getting timely information is a challenge.

Biosphere anomaly (vegetation model ensemble)
4. Targeted GOSAT partial column observations provide more detail over urban regions

Average monthly abundances of CO$_2$ in the lower troposphere for the past 4 years (upper, reference) and 2020 (lower) from GOSAT

The difference in CO$_2$ density in the upper and lower troposphere is smaller in 2020 compared to 2016-2019 in Tokyo and Beijing.

We assume the average density of the upper troposphere is a background.

XCO$_2$ anomaly: XCO$_2$(LT)-XCO$_2$(UT$_{average}$), LT (0-4 km), UT (4-12 km)

JAXA EORC will provide $\Delta$CO$_2$ for more than 20 major megacities in the world.
What have we learned so far?

1. CO₂ decreases from COVID-19 were small (< 0.5 ppm), consistent with independent estimates of emissions decreases
2. Interpretation of emissions decreases requires careful consideration of year-specific circulation changes
   - *We can detect fraction of a ppm changes in fluxes using a combination of space-based data and assimilation systems*
3. These systems can contribute to low latency carbon monitoring by detecting changes in total flux, but availability of up-to-date emissions and flux datasets is a major challenge for attribution and interpretation
   - *Overhauling the processing chain can improve latencies from 6-18 months to ~3 months, but still much room for improvement*
4. The spatial scale of emissions reductions detected by current generation sensors is limited by coverage, but targeted observations over cities provide a glimpse of what may be possible more broadly in the future