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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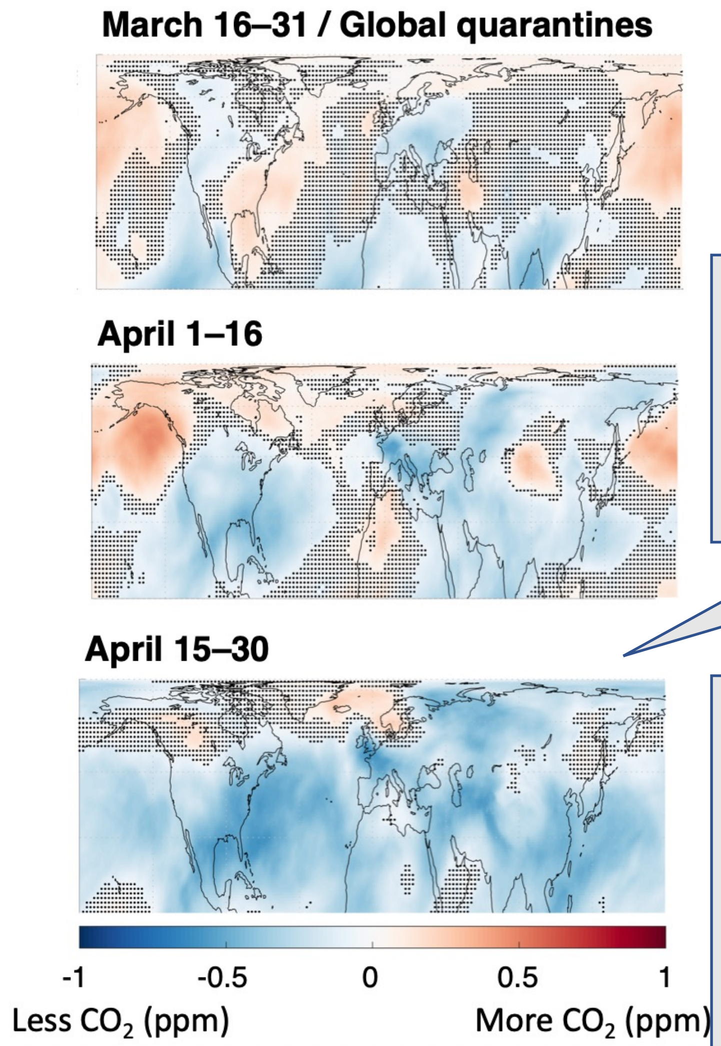
1. CO_2 decreases from COVID-19 were small (< 0.5 ppm), consistent with independent estimates of emissions decreases

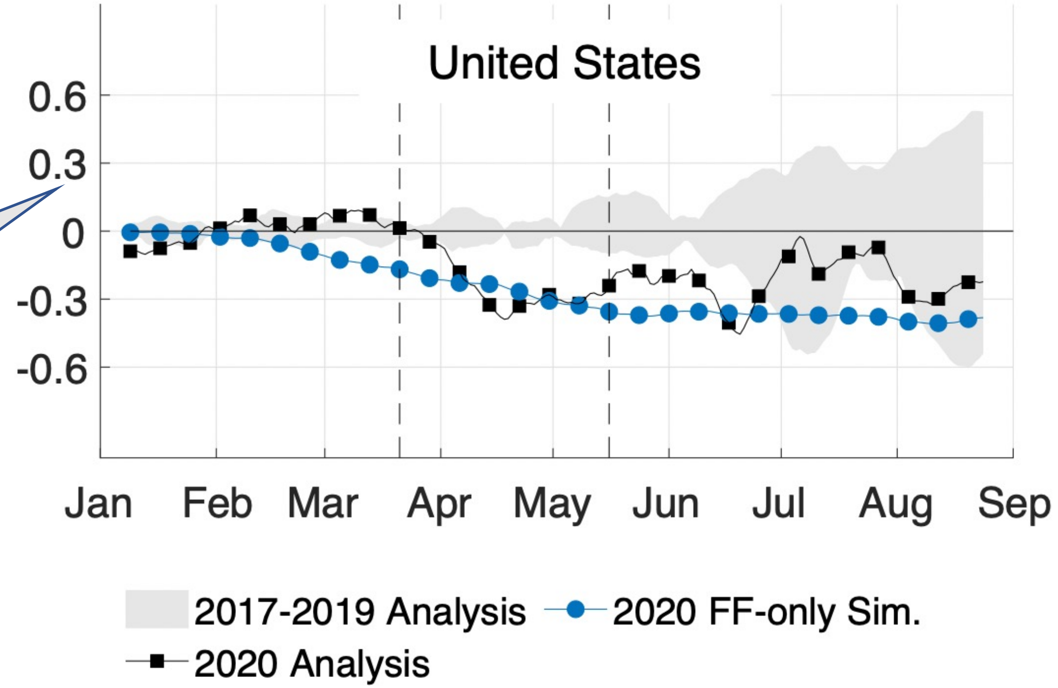


Detailed analysis of OCO-2 L3 data produced by the GEOS Constituent Data Assimilation System (CoDAS) allowed detection of flux-driven anomalies in XCO_2 during COVID-19 pandemic.

Anomaly maps (left) show the change in XCO_2 anomalies as quarantines were imposed throughout much of the world

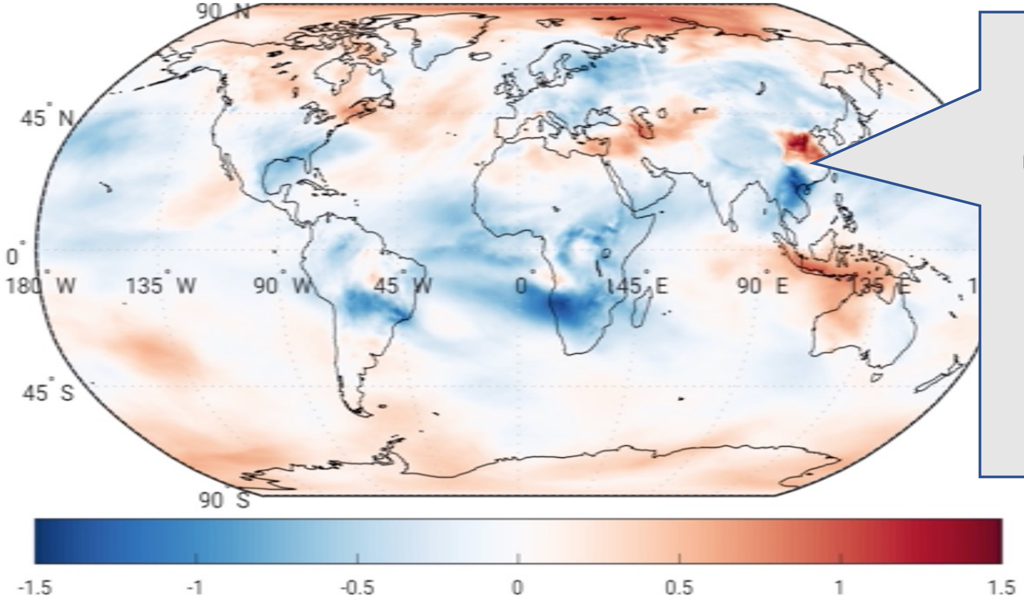
Changes in XCO_2 were small (< 0.5 ppm) even over the world's largest economies, and consistent with independent estimates of global emissions decreases of 8-10%.

XCO_2 anomaly over the U.S. during 2020



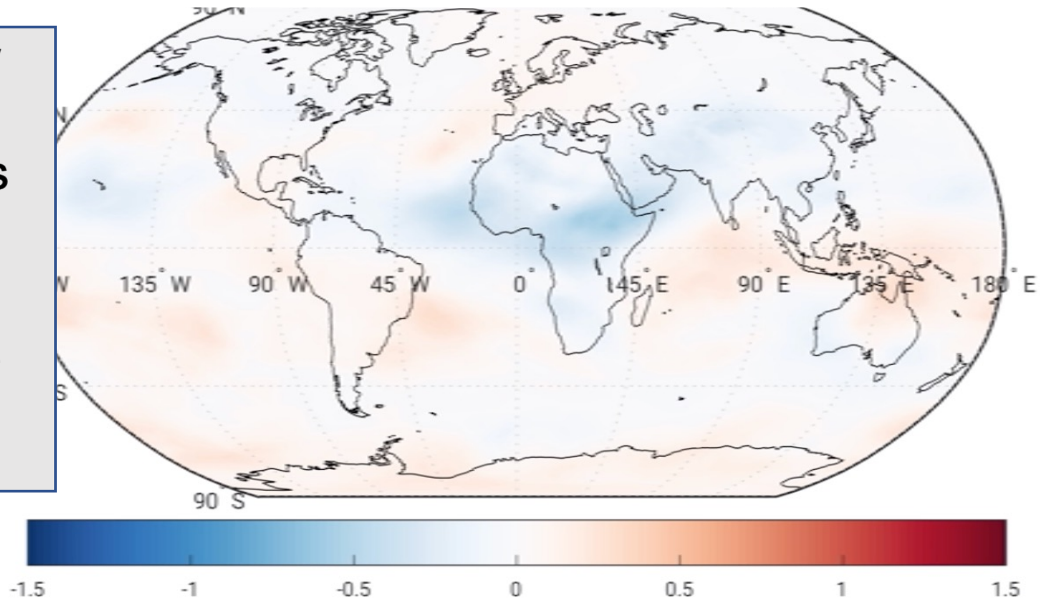
2. Interpretation of emissions decreases requires careful consideration of year-specific circulation changes

Conventional XCO_2 Anomaly
2020 – climatology (2015-2019)
Jan 1-15, 2020



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

Flux-driven XCO_2 Anomaly
Assimilation anomaly – simulation anomaly

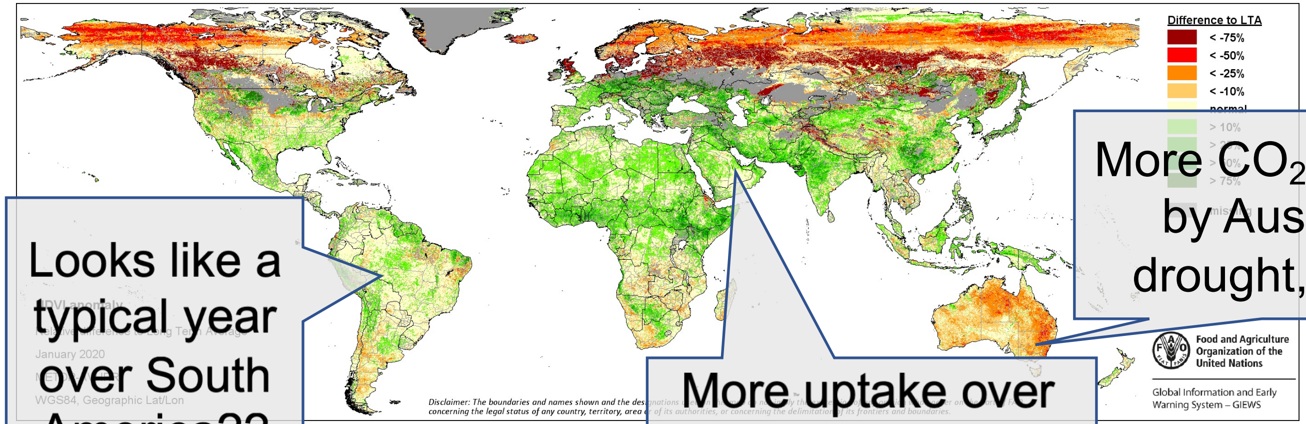


XCO_2 anomalies are strongly influenced by weather. Such influences can be minimized by averaging over larger area/longer time period, but this diminishes the ability to see localized COVID-19 impacts

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

NDVI anomalies – January 2020 (FAO)

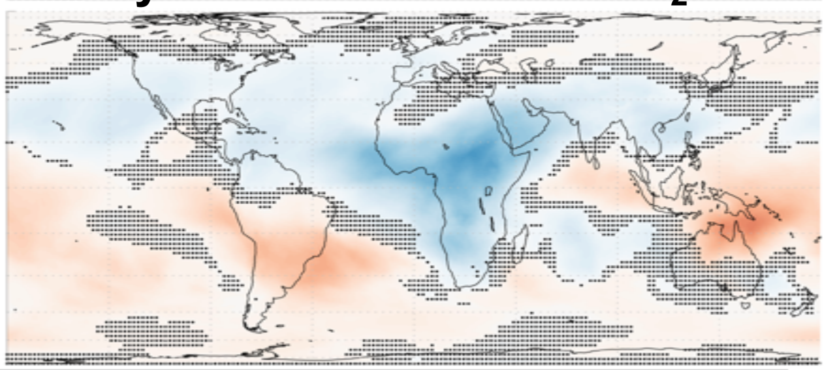


Looks like a typical year over South America??

More uptake over India, Africa??

More CO_2 released by Australian drought, fires??

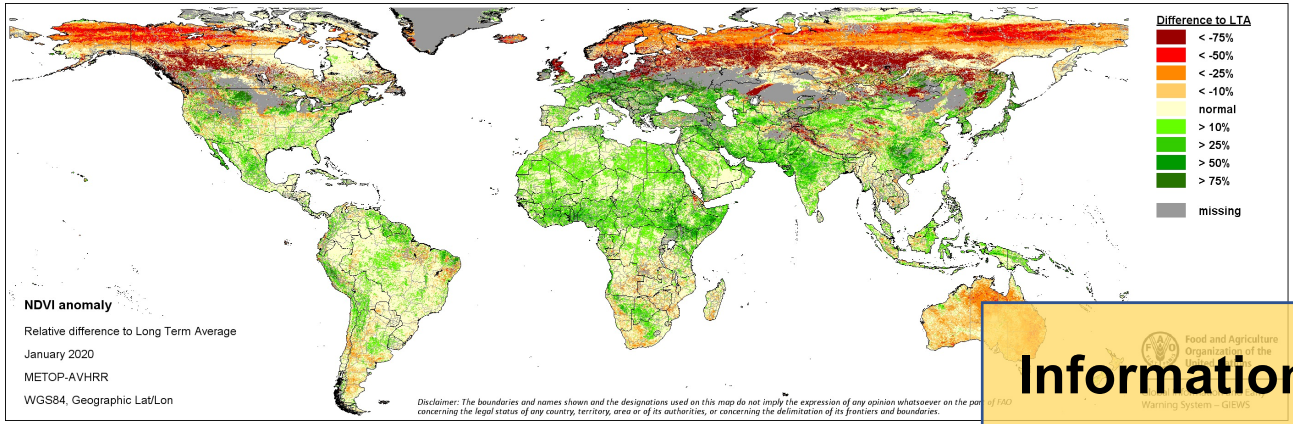
January 2020 Flux-driven XCO_2 anomaly



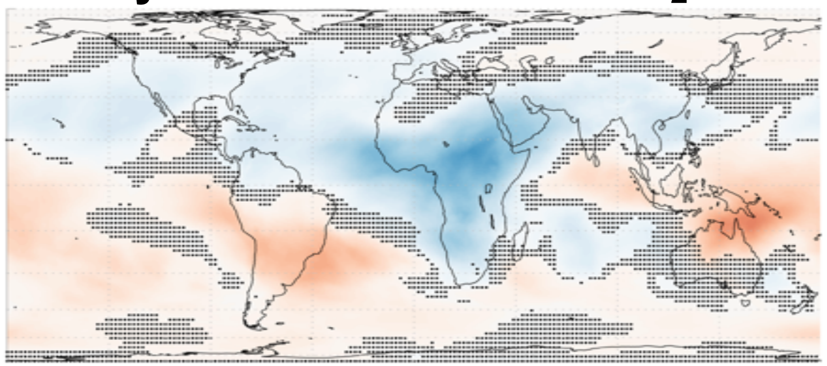
During COVID-19, anomalies in land surface, meteorological conditions provided valuable but non-quantitative indications of changes in land-atmosphere flux in near-real-time

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

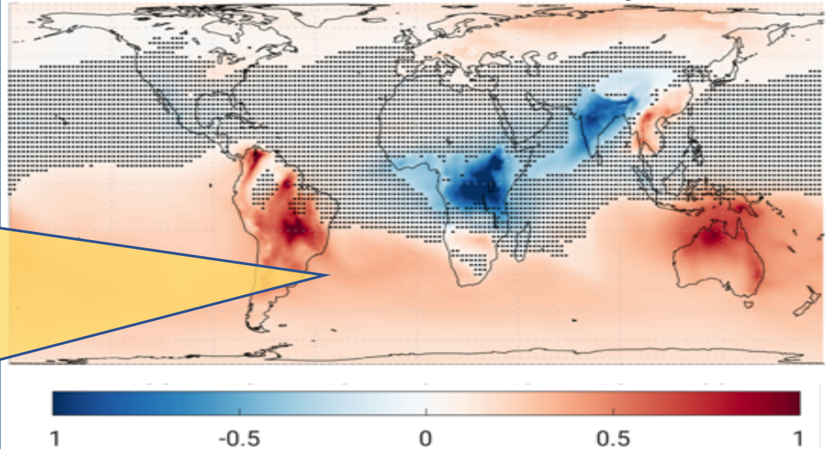
NDVI anomalies – January 2020 (FAO)



January 2020 Flux-driven XCO_2 anomaly



Biosphere anomaly (vegetation model ensemble)



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

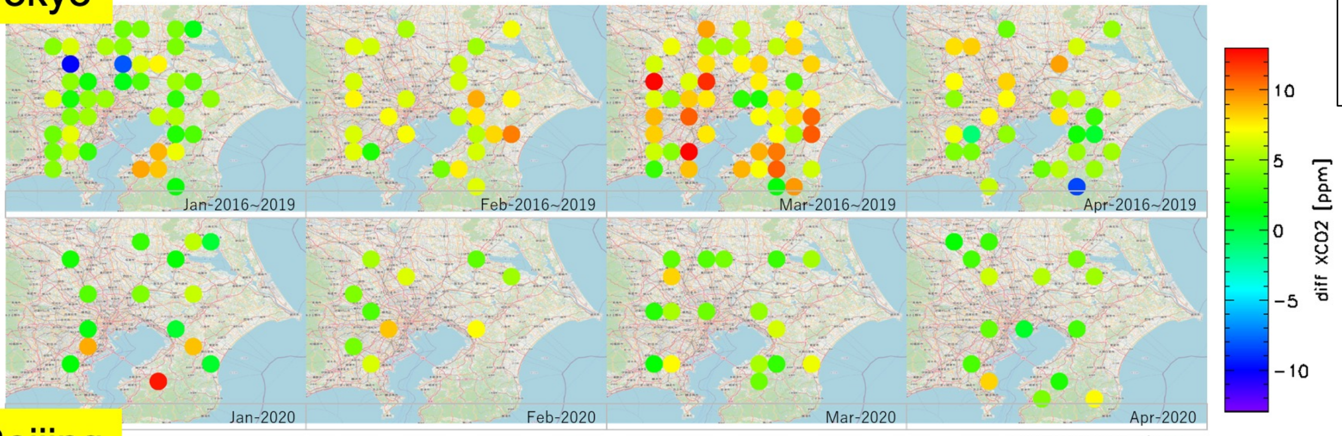
Information from land, ocean models needed to interpret and attribute flux anomalies, but getting timely information is a challenge

4. Targeted GOSAT partial column observations provide more detail over urban regions

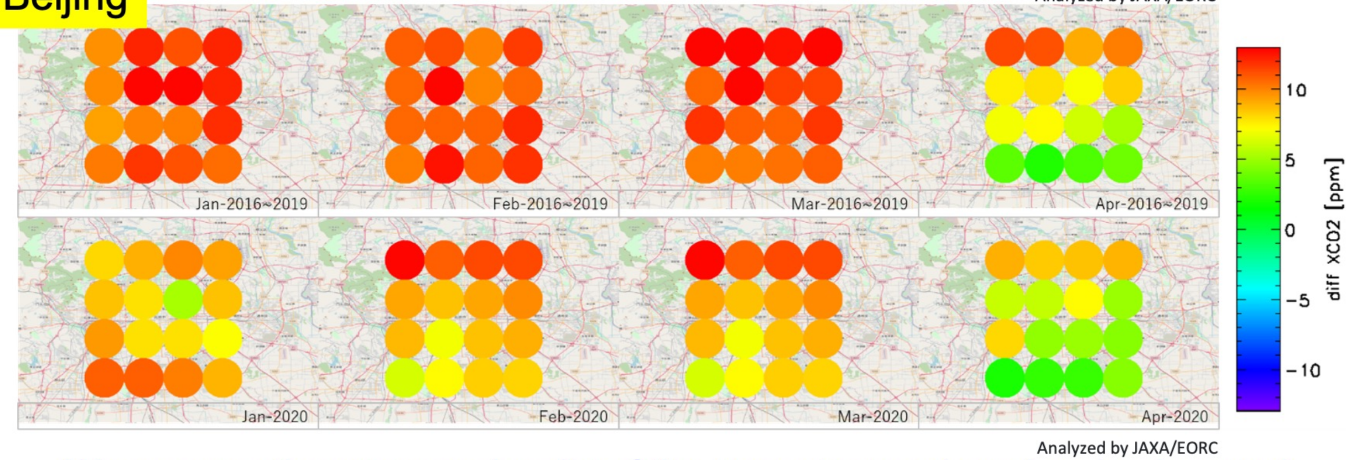
Average monthly abundances of CO_2 in the lower troposphere for the past 4 years (upper, reference) and 2020 (lower) from GOSAT

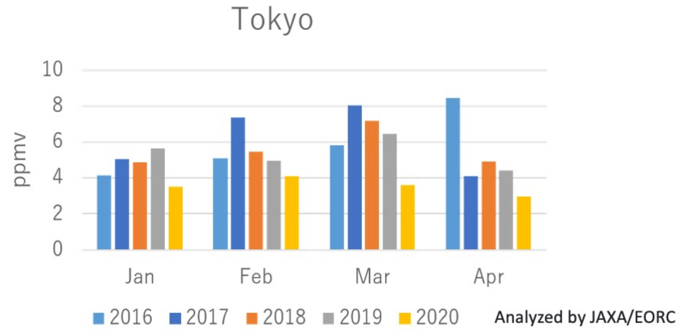
The difference in CO_2 density in the upper and lower troposphere is smaller in 2020 compared to 2016-2019 in Tokyo and Beijing.

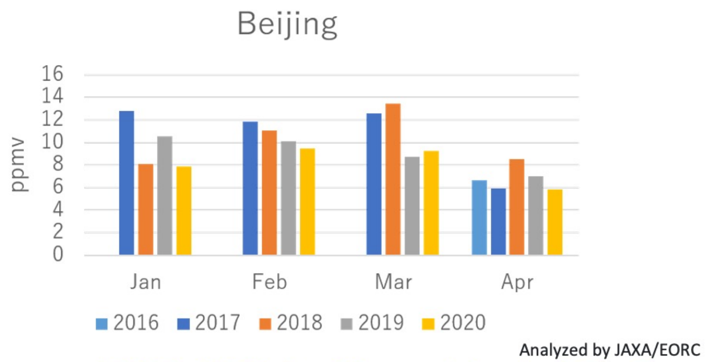
Tokyo



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 △ CO_2 for more than 20 major megacities in the world

Slide from Kuze-san, JAXA

What have we learned so far?

1. CO_2 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