Impact of COVID-19 lockdown on secondary pollutants (Ozone for a start) across the world

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NCAR

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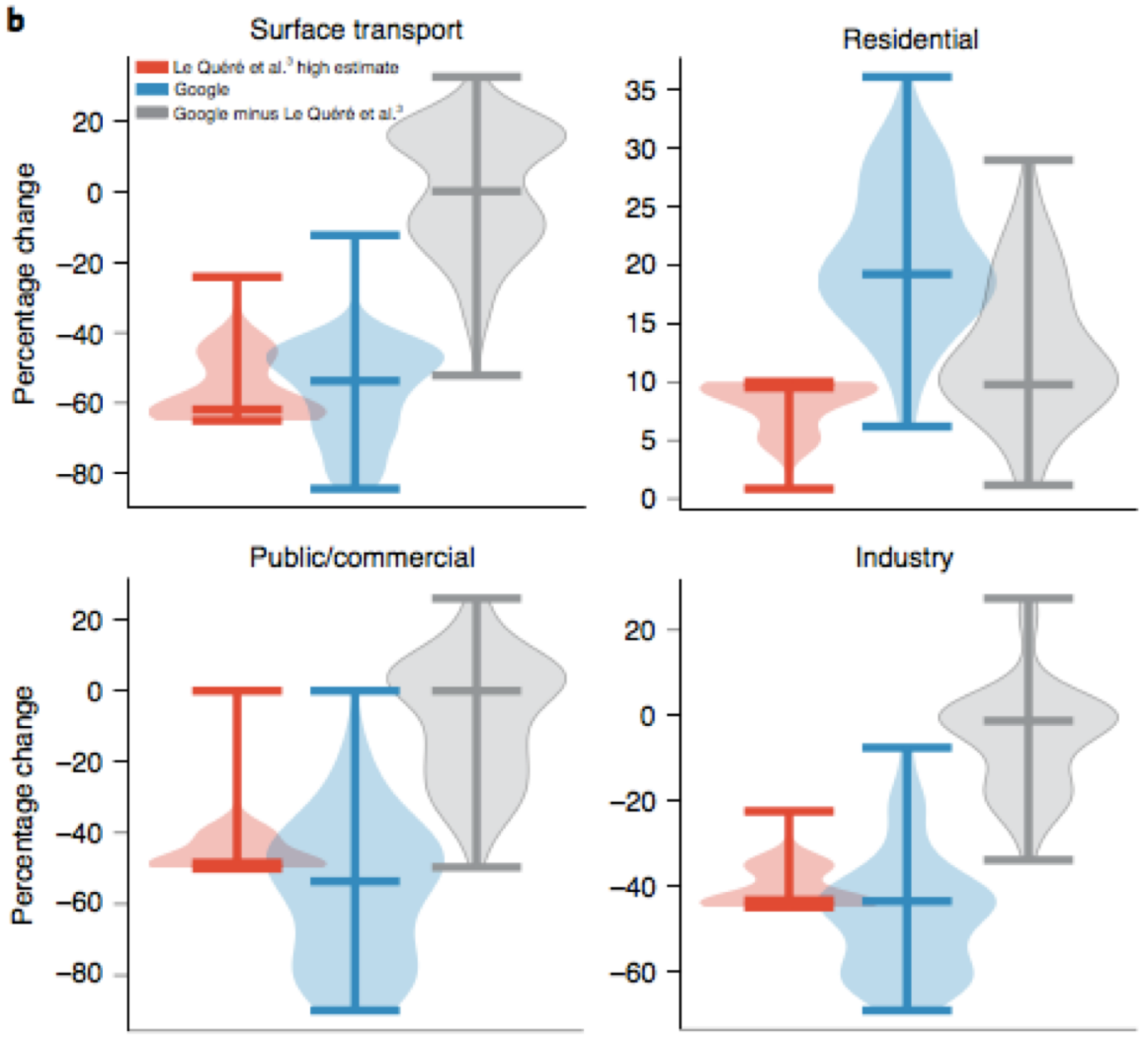
COVID-19 induced lockdown impacts on emissions (Early 2020)

- Emissions varied by sectors
- Leads to specific response for each primary pollutant
- Lockdown and emissions reductions varies by country/states for different seasons
- Observed concentration depends on the environment
  - Chemical regimes
  - Dynamic/physics following weather patterns.



Forster et al., Nature Climate Change 2020

Bottom-up emissions

1. Use (uncertain) proxy of activity to estimate emission reduction or adjustment factor (AF)
2. Apply reduction to an existing inventory.

- Global scale 2020 *bottom-up* emissions exist from 2 studies:
  - ✓ Forster et al. 2020
  - ✓ Doumbia et al. 2021 (ESSD discussion)

CONFORM

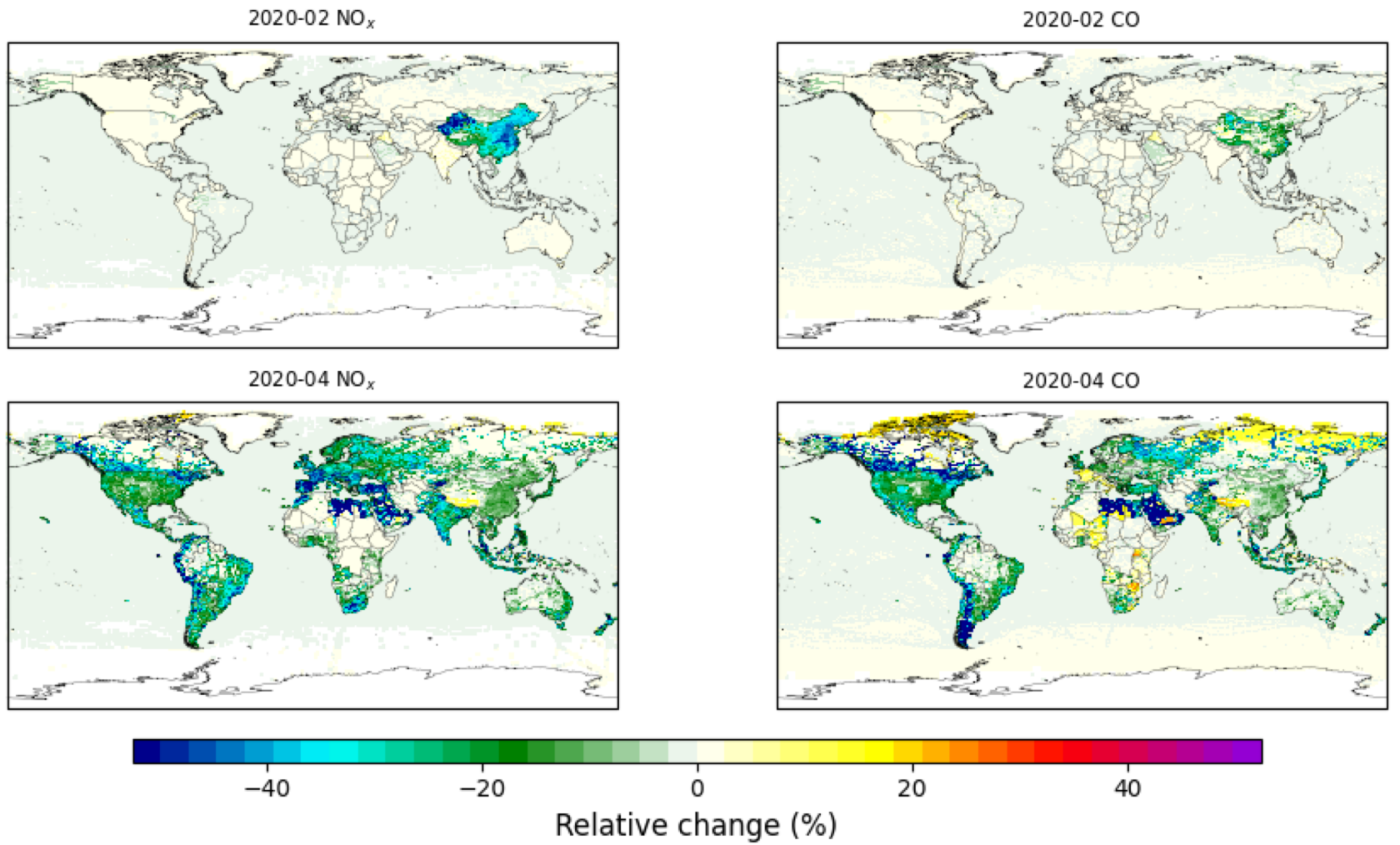
(COvid adjustmeNt Factors fOR eMissions)

- Gridded AFs from January to August 2020 as NetCDF files
- Global, daily and gridded 0.1°x0.1°
- Sectors:
  - ✓ road transport
  - ✓ Industry
  - ✓ Power
  - ✓ Residential
  - ✓ Shipping
  - ✓ aviation

Bottom-up anthropogenic emission reduction

3. CAMS-GLOB-ANT-v4.2-R1.1 interpolated to daily emissions.
4. Apply CONFORM AFs

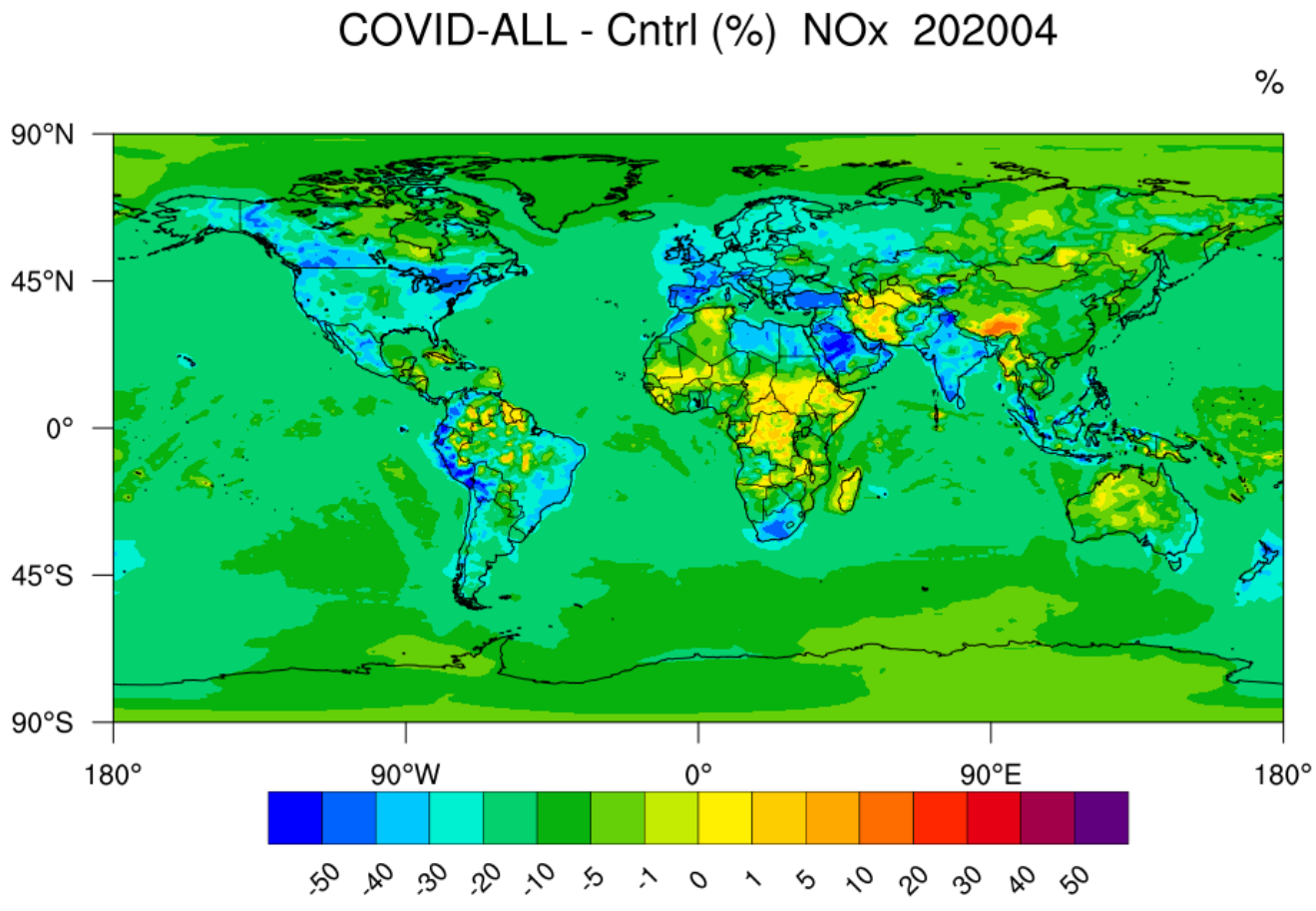
- **China: Reduction starts in February 2020 (40% for NOx, 25% for VOCs)**
- **Rest of the world: Reduction is highest on March-April 2020.**



Global CAM-chem simulations

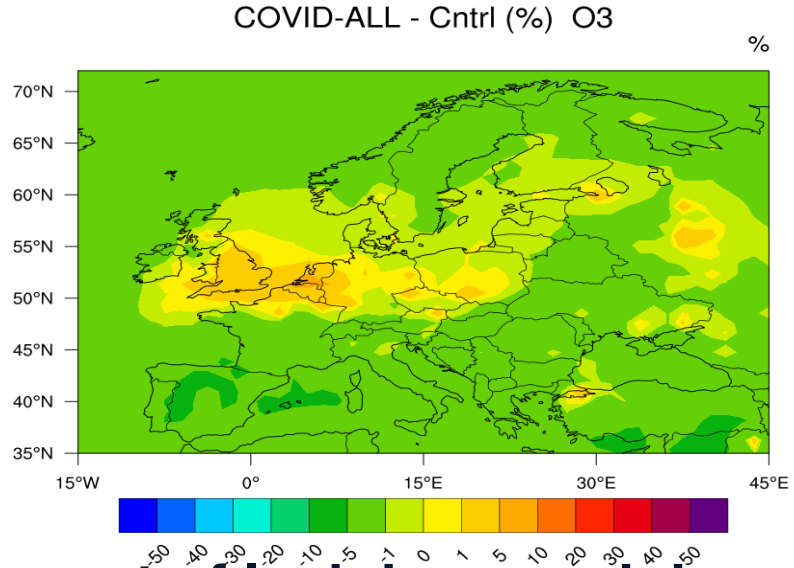
- Daily 2020 fire emissions (QFED 2.5)
- Daily CAMS-CONFORM
- MOZART-TS1 chemistry
- MAM4 VBS aerosols
- Climatological SSTs
- Strong nudging of winds and temperature to 3 hourly MERRA-2 outputs (Modern-Era Retrospective analysis for Research and Applications, Version 2)

- Climatological SSTs
- Specified dynamics
- ✓ 3 hourly MERRA-2 outputs
- ✓ U,V,T (Coef. of 0.5 or 6 hours relaxation time)

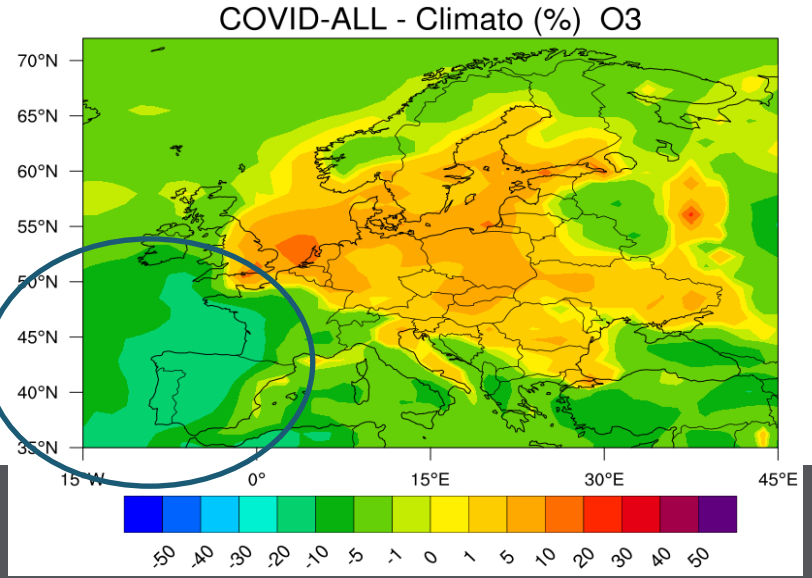


Example for Europe

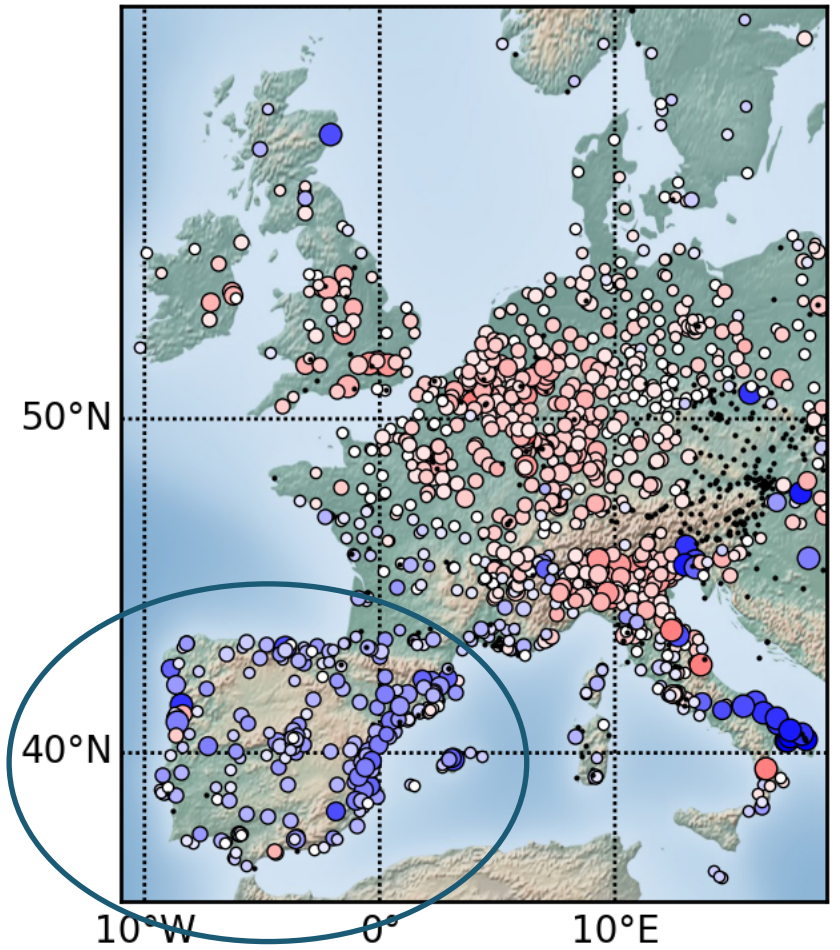
Impact of lockdown



Impact of lockdown and dynamic



Observations
Change in ozone mean concentration



Relative change
- 0% to 10%
- 10% to 20%
- 20% to 30%
- > 30%

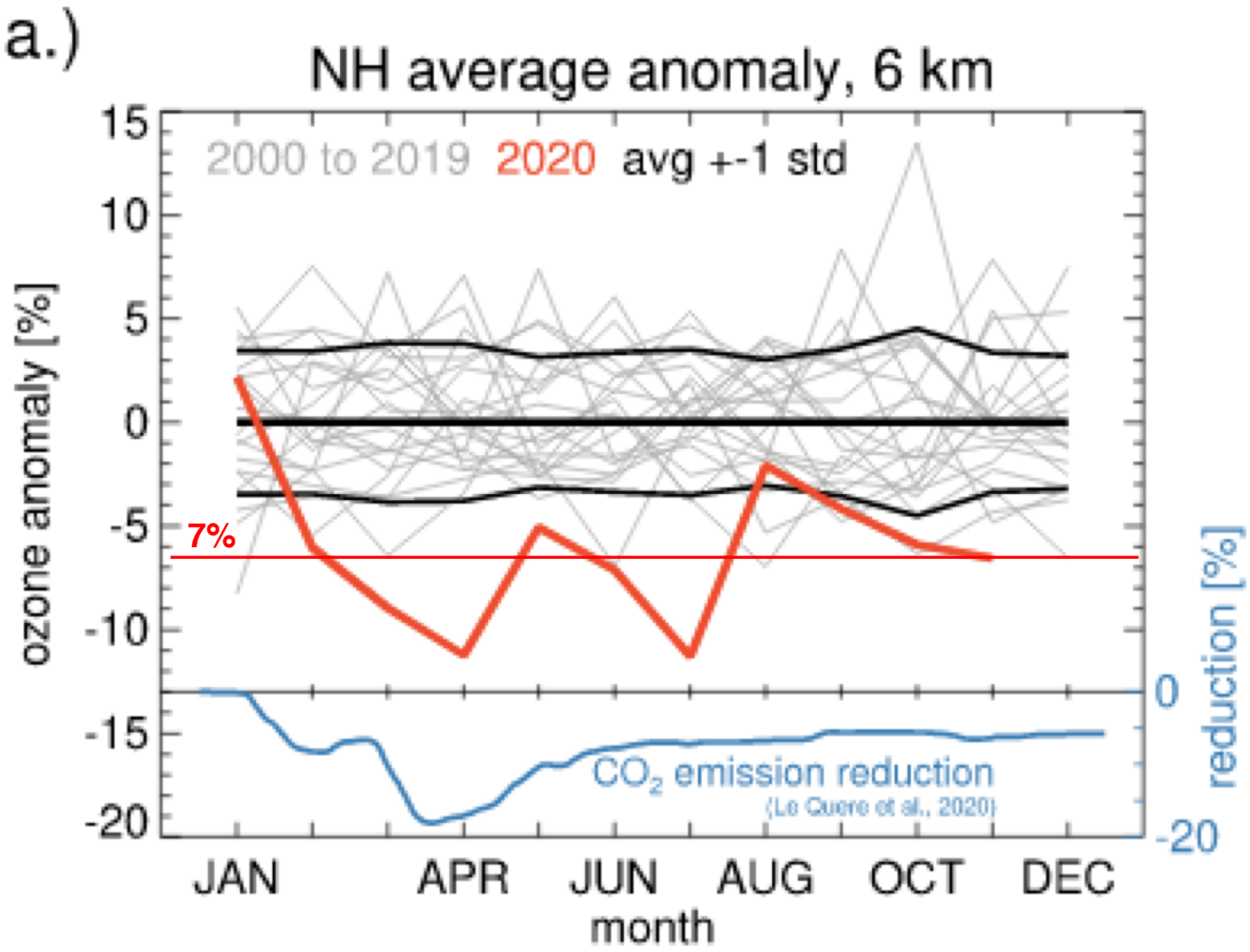
$NaN <$ 30%

O_3 mean concentration at in 2020 compared to the previous seven years (2013-2019) for the period 18 March to 18 May.

Deroubaix et al., in review

Free tropospheric ozone

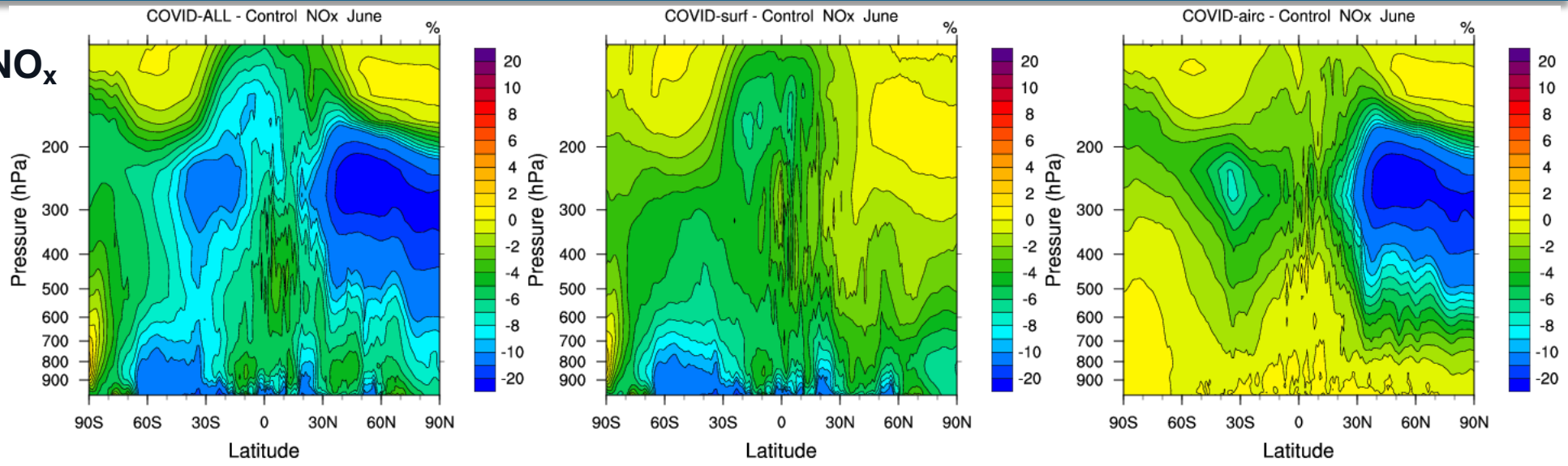
- Steinbrecht et al. (2021, GRL): observations (sondes, NDACC) indicates ozone was on average **7% below 2000 to 2020**
  - ✓ April to August
  - ✓ 1 to 8 kilometers altitude



Relative impact of aircraft and surface emission reduction

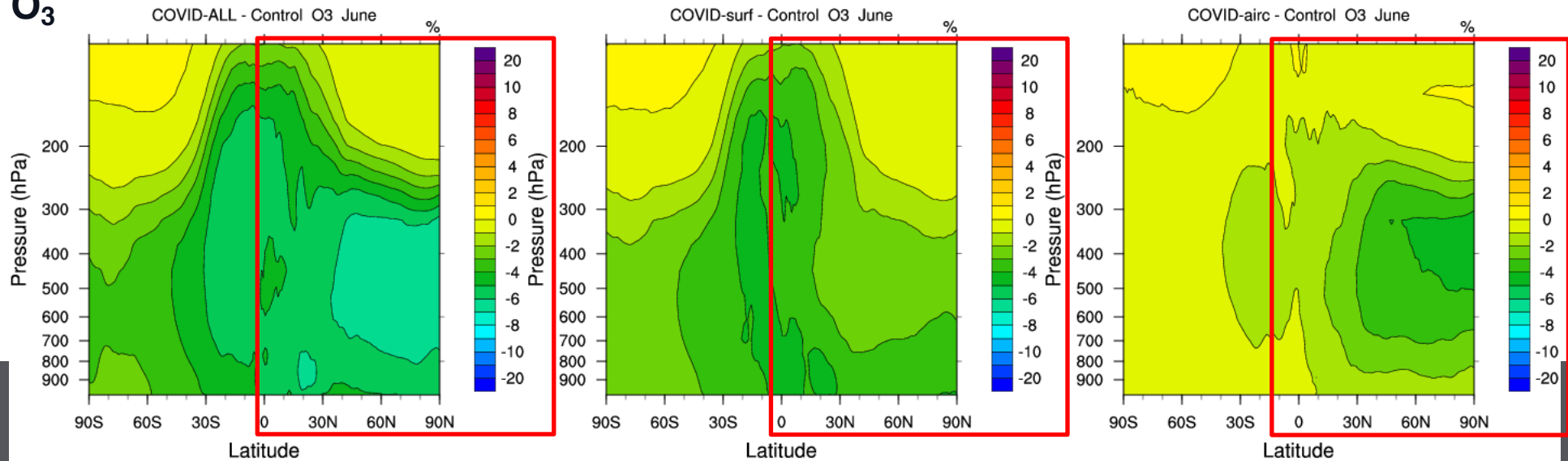
Emissions lowered ozone by 6-7% in the NH / free trop.

NO_x



Total lockdown effect | **Surface only** | **Aircraft only**

O_3



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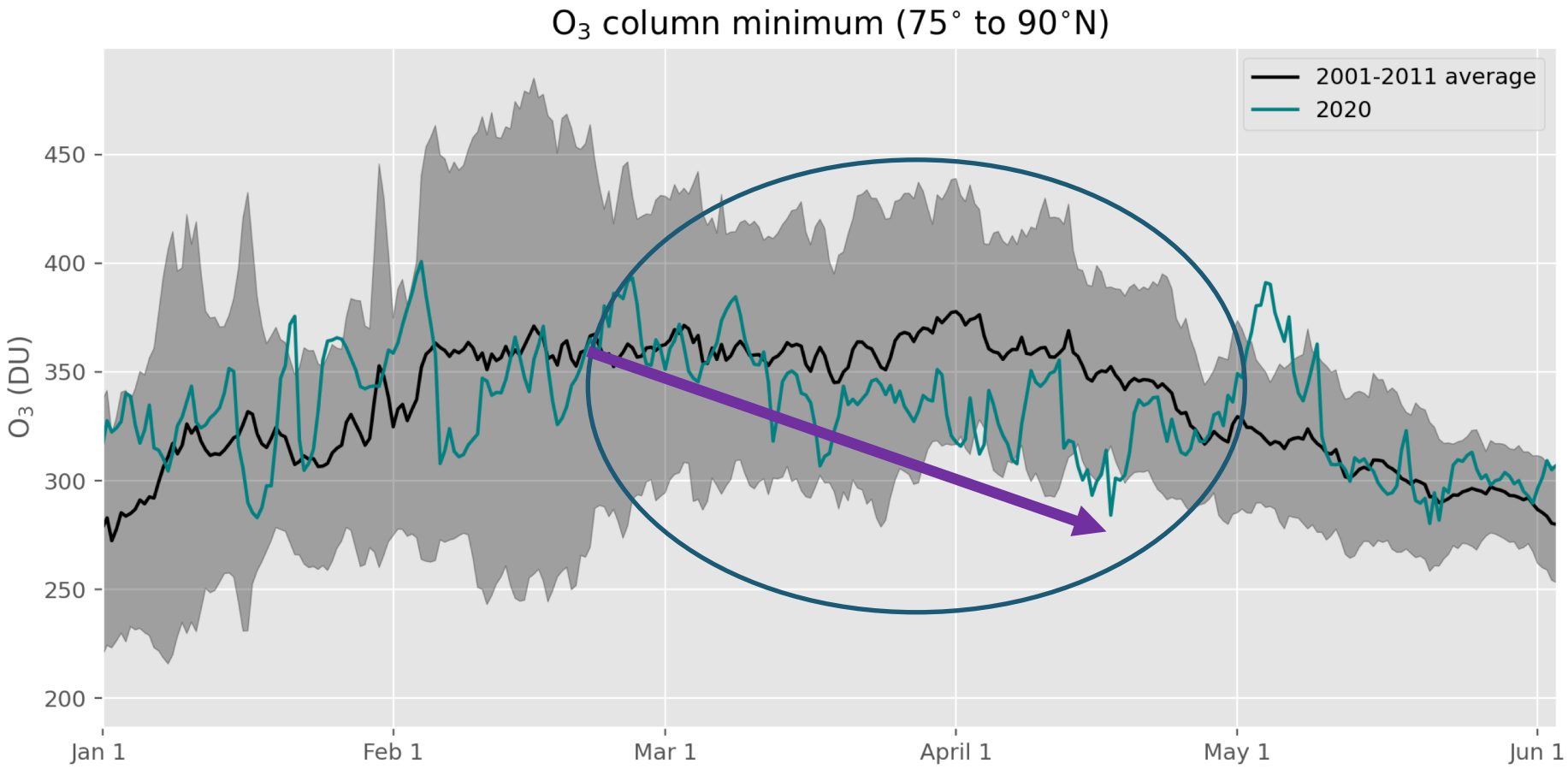
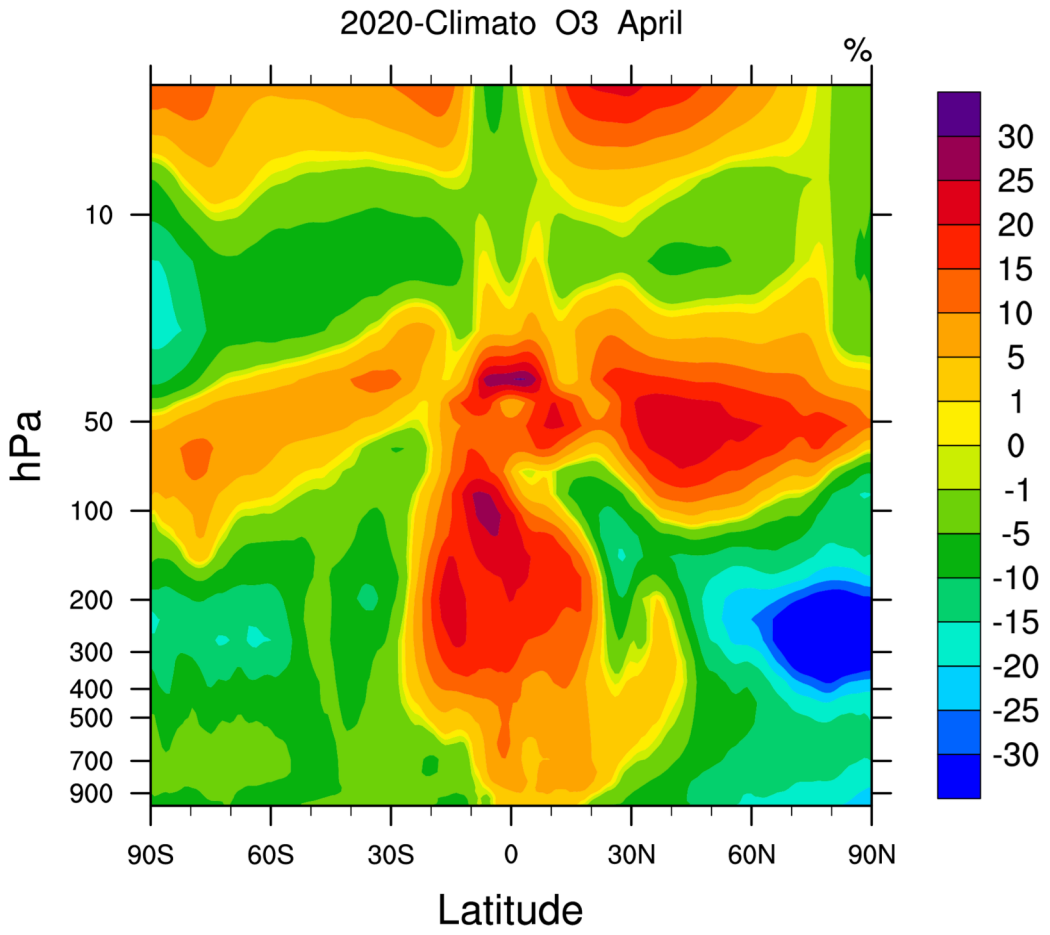
Stratospheric ozone: exceptionally low arctic ozone in Spring 2020

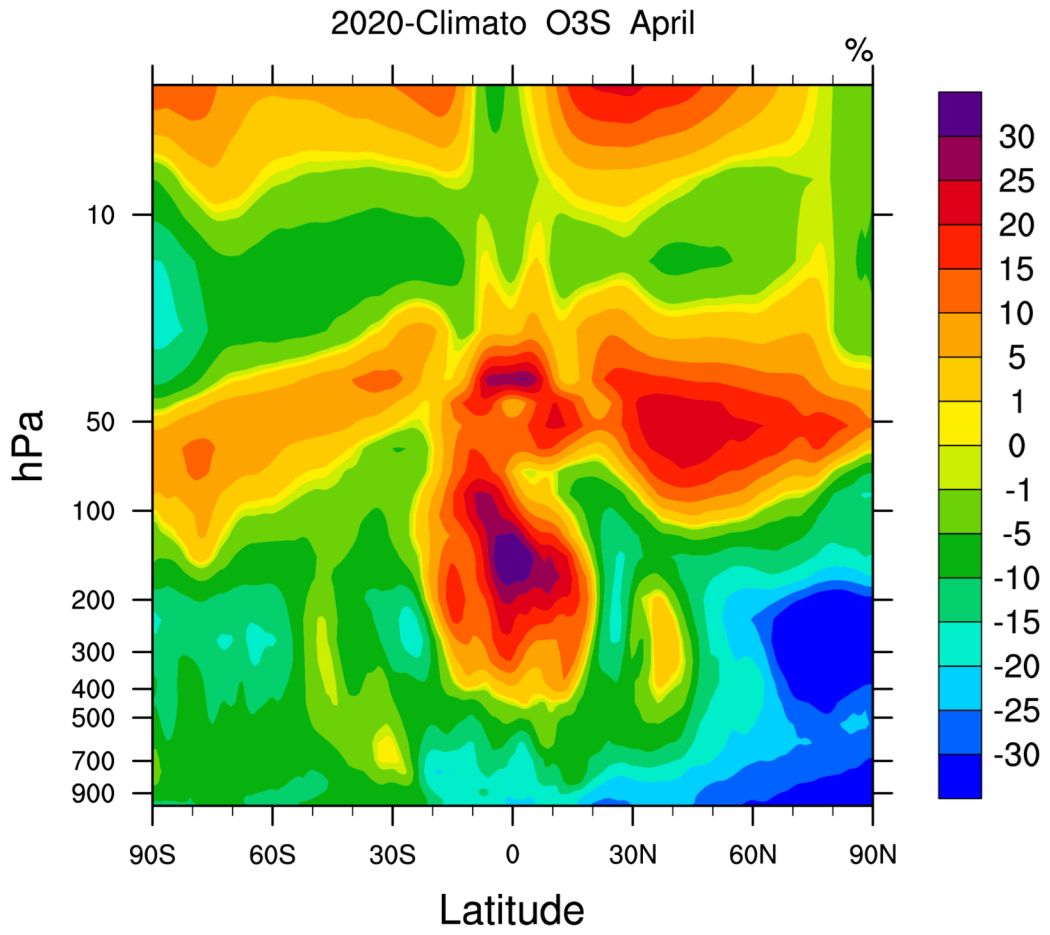
- Arctic ozone columns in spring 2020 were the lowest since 1979 (Inness et al. 2020, GRL)
- Minimum is found in March and April (Wilka et al., 2021, ACPD)
  - ✓ WACCM/CAM-chem is *denitrifying too little*



Impact of stratospheric ozone intrusion during spring 2020

- How much stratospheric ozone got into troposphere compare to usual ?



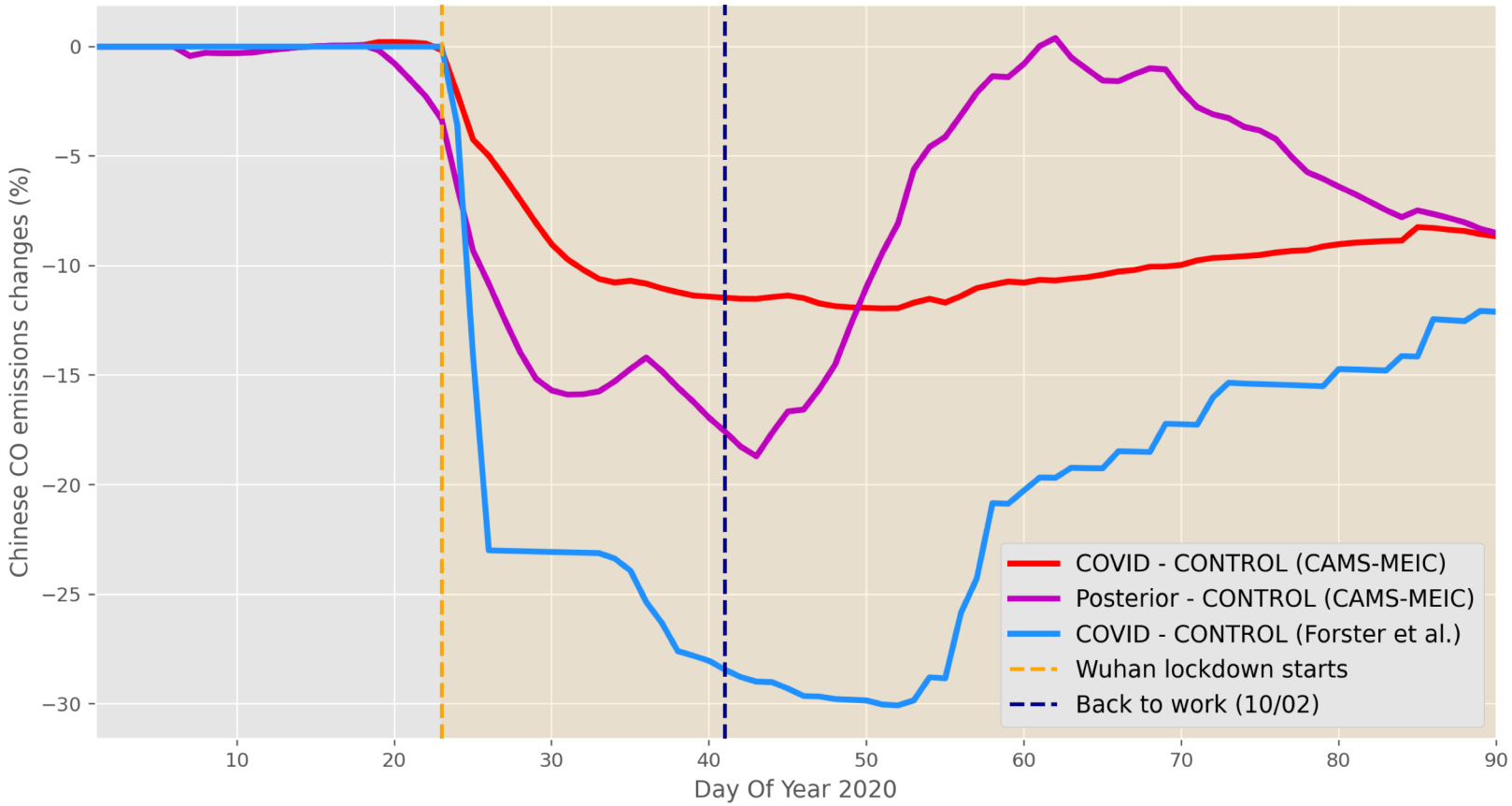


Uncertainties: Emission verification using MOPITT CO

CAM-chem/DART assimilation of MOPITT CO observations

- Forster et al. daily reduction
- CAMS-CONFORM reduction
  Our prior: COVID lockdown estimate (CAMS)
- MOPITT inversion (using CAMS-CONFORM as prior)

Reduction in emissions during the Chinese lockdown



Average increments suggests a good agreement between CAMS-CONFORM prior with MOPITT inversion

Conclusions

- CAM-chem reproduces observed ozone features with great accuracy.
- Free tropospheric ozone reduction of 6-7% (observations are 7%).
- Emission test alone suggest aircraft contributes to more than half of the free tropospheric ozone reduction.
- Investigation and quantification of the role of stratospheric ozone change is on-going.
- Uncertainties in emission reduction can be large, but not larger than error in emissions.

Perspectives:

- MUSICA simulations will allow to take full advantage of the spatial resolution of the anthropogenic emissions (~0.1 degree), including for biomass burning.
- Assimilation of CO and AOD to improve combustion emissions (CO, VOCs, black carbon and organic aerosols).