SCIENCE ADVANCES | RESEARCH ARTICLE

CORONAVIRUS

Global tropospheric ozone responses to reduced NO_x emissions linked to the COVID-19 worldwide lockdowns

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RESEARCH LETTER

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Special Section:
The COVID-19 Pandemic: Linking Health, Society and Environment

Air Quality Response in China Linked to the 2019 Novel Coronavirus (COVID-19) Lockdown

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Societal shifts due to COVID-19 reveal large-scale complexities and feedbacks between atmospheric chemistry and climate change

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Kazuyuki Miyazaki, *Jet Propulsion Laboratory, California Institute of Technology*

Kevin Bowman, Jessica L Neu, Joshua Laughner, and other coauthors

MOMO-Chem (Multi-mOdel Multi-cOnstituent Chemical) Data Assimilation System

MLS

TES

OMI

MOPITT

AIRS

SCIAMACHY

GOME-2

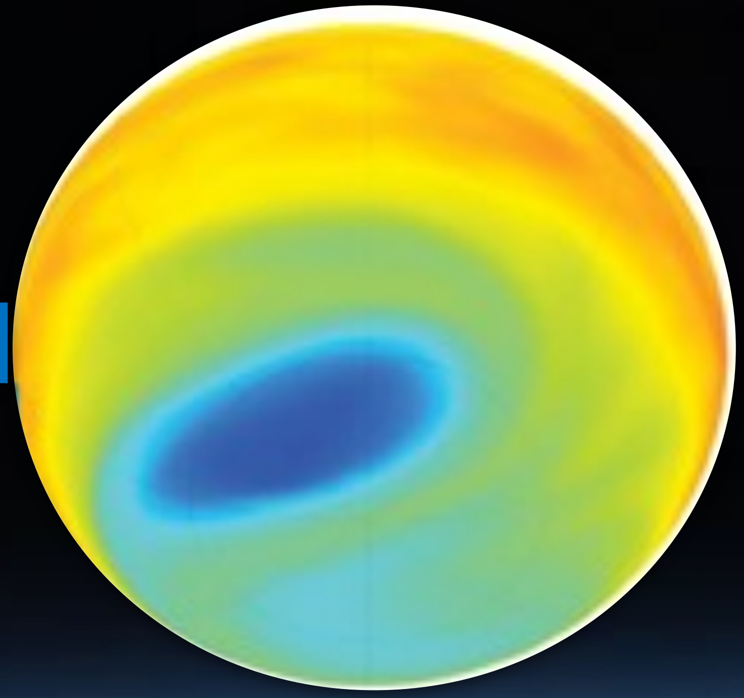
TROPOMI

Satellite Observations Assimilated in MOMO-Chem

Satellite

(O3, CO, NO_2, HNO_3, CO)

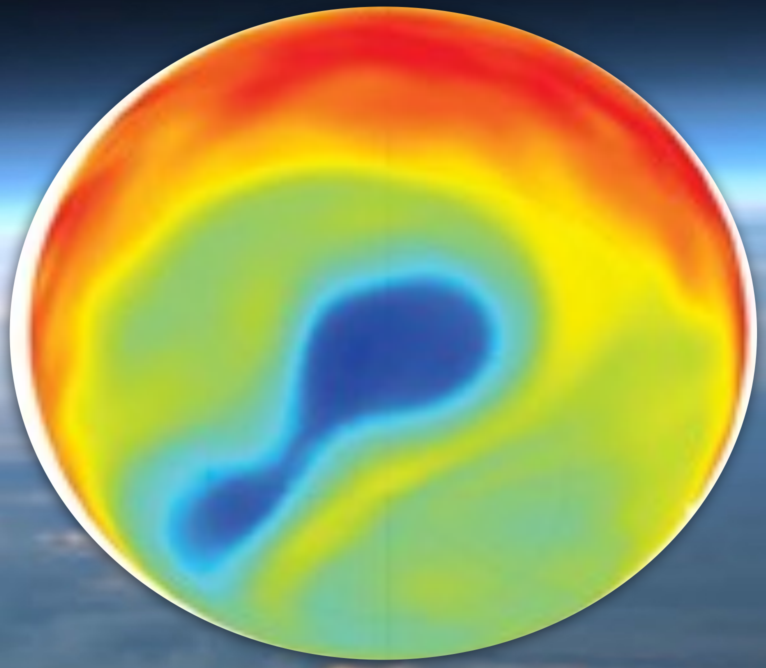
Data Assimilation



Model

(4 models)

Models Used for Assimilation

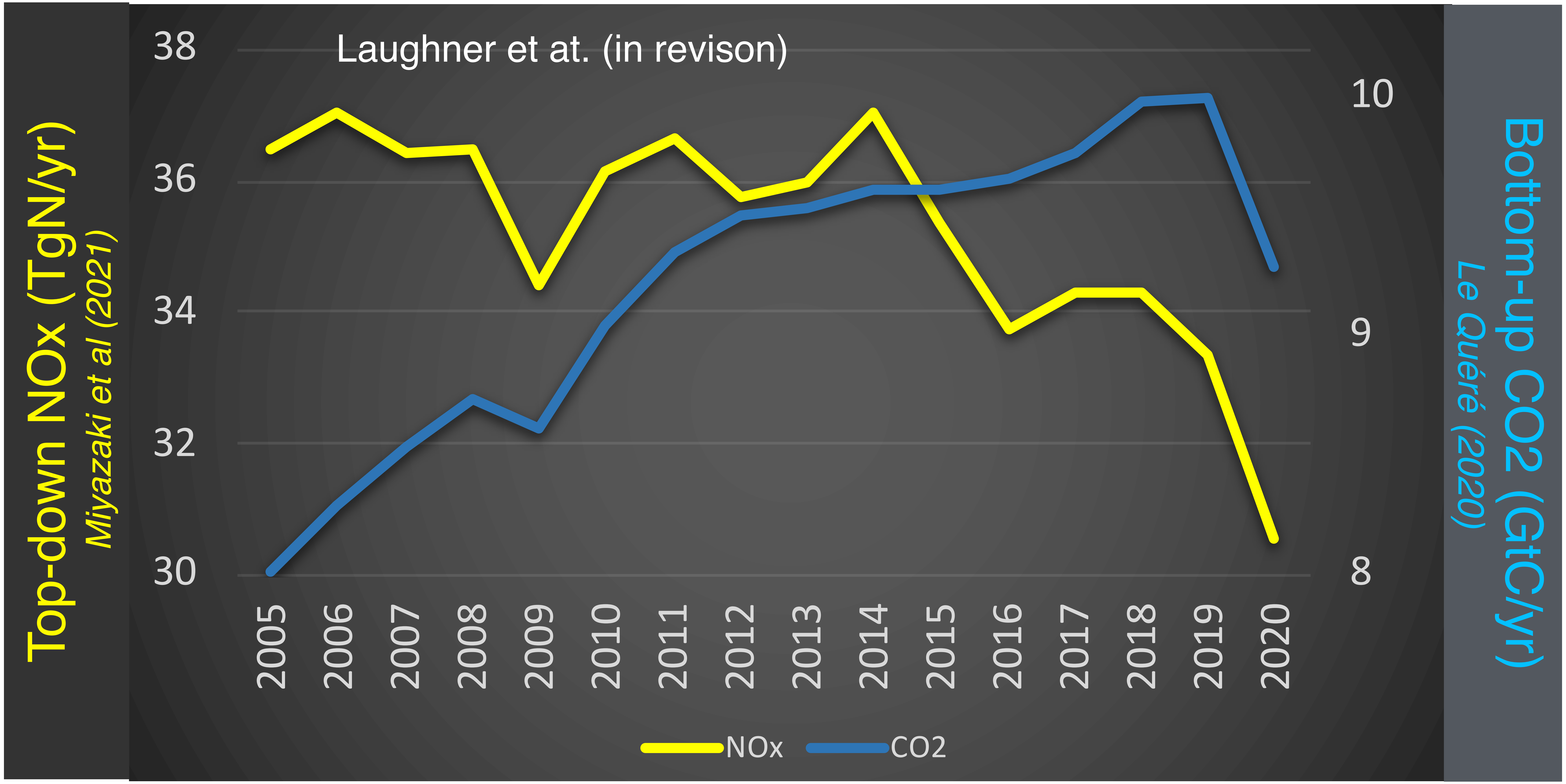


Validation against in-situ & aircraft measurements

Tropospheric Chemical Reanalysis

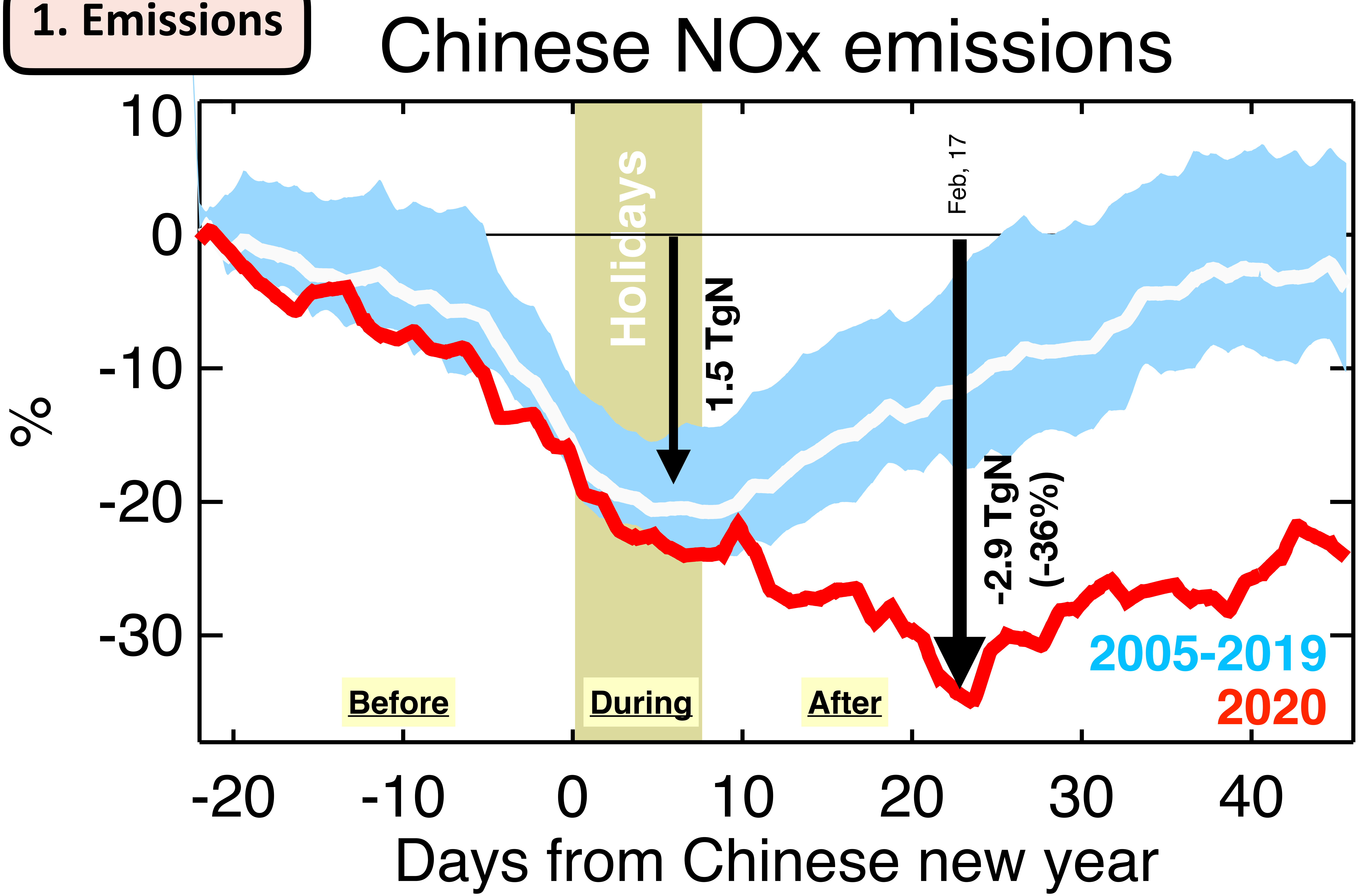
- 16 years (2005-present), two-hourly, global, surface to lower stratosphere chemical concentrations of 35 species, including O_3, NOx, OH, SO_2, VOCs
- Anthropogenic, biogenic, biomass burning, and lightning emissions (NOx, CO, SO_2)
- Used in various science applications, including validation of NASA satellite products
- Able to support OSSE activities in support of mission formulation

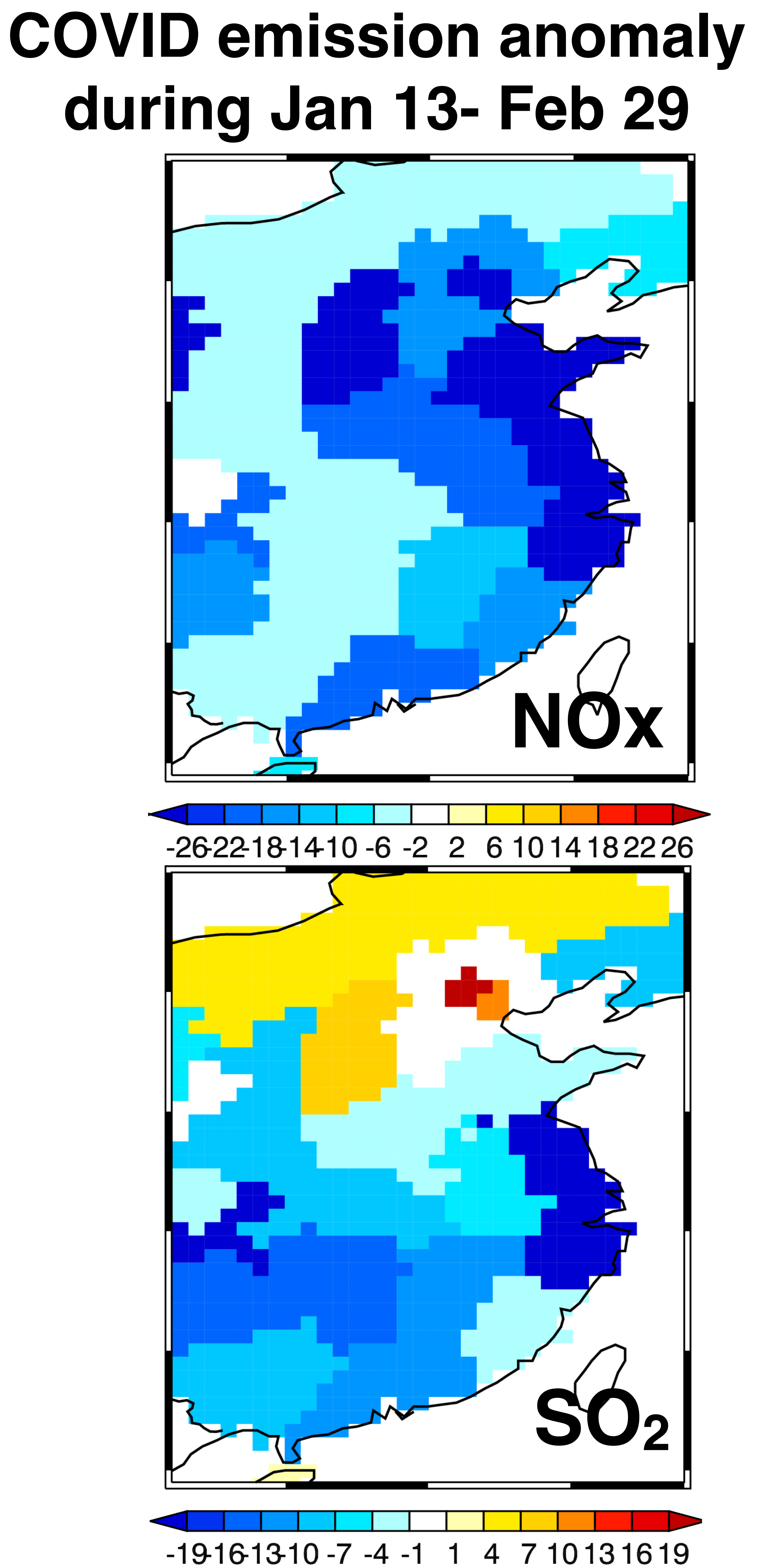
Global anthropogenic emission reductions in 2020: 7% (CO_2) 8% (NOx)



1. Emissions (NOx, SO2, CO) → **2. Concentrations** → **3. Health and climate Impacts**

1. Emissions

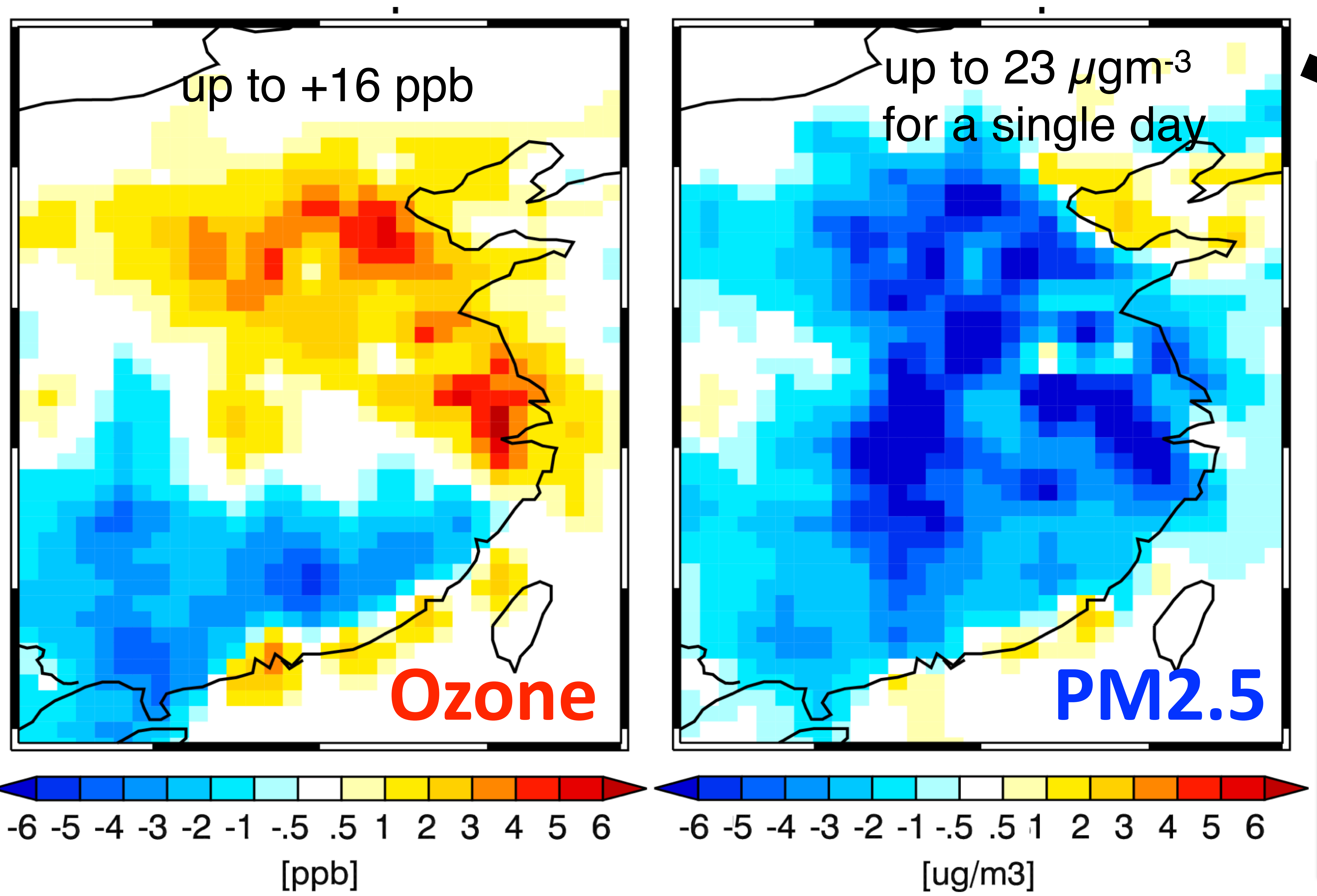




-3 TgN/yr = 10% of global total emissions

~ Europe (4.1 TgN/yr), US (4.2 TgN/yr), India (3.4 TgN/yr)

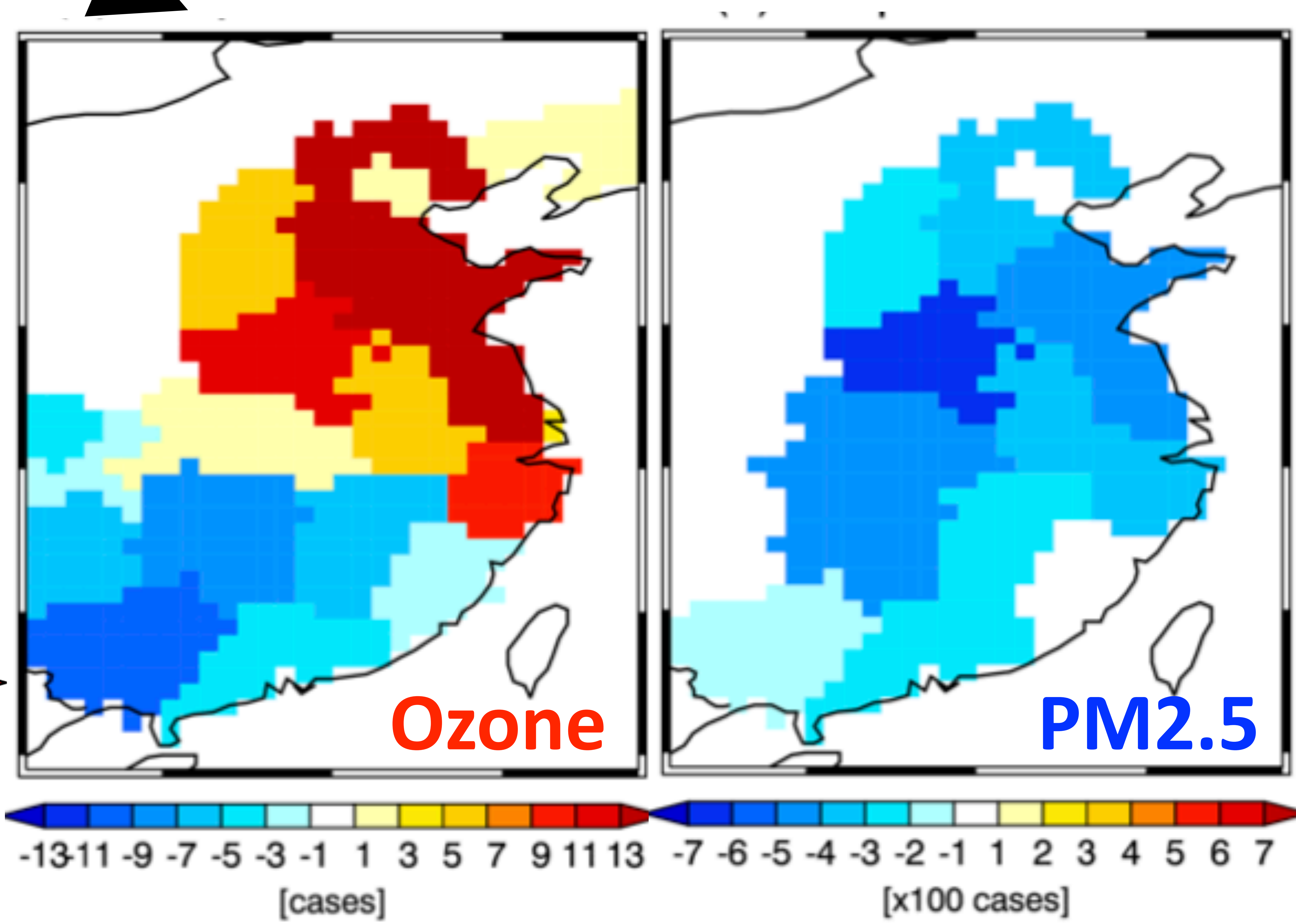
MDA8 ozone and PM2.5 response to the COVID emission anomaly



(Feb 15-25, 2020)

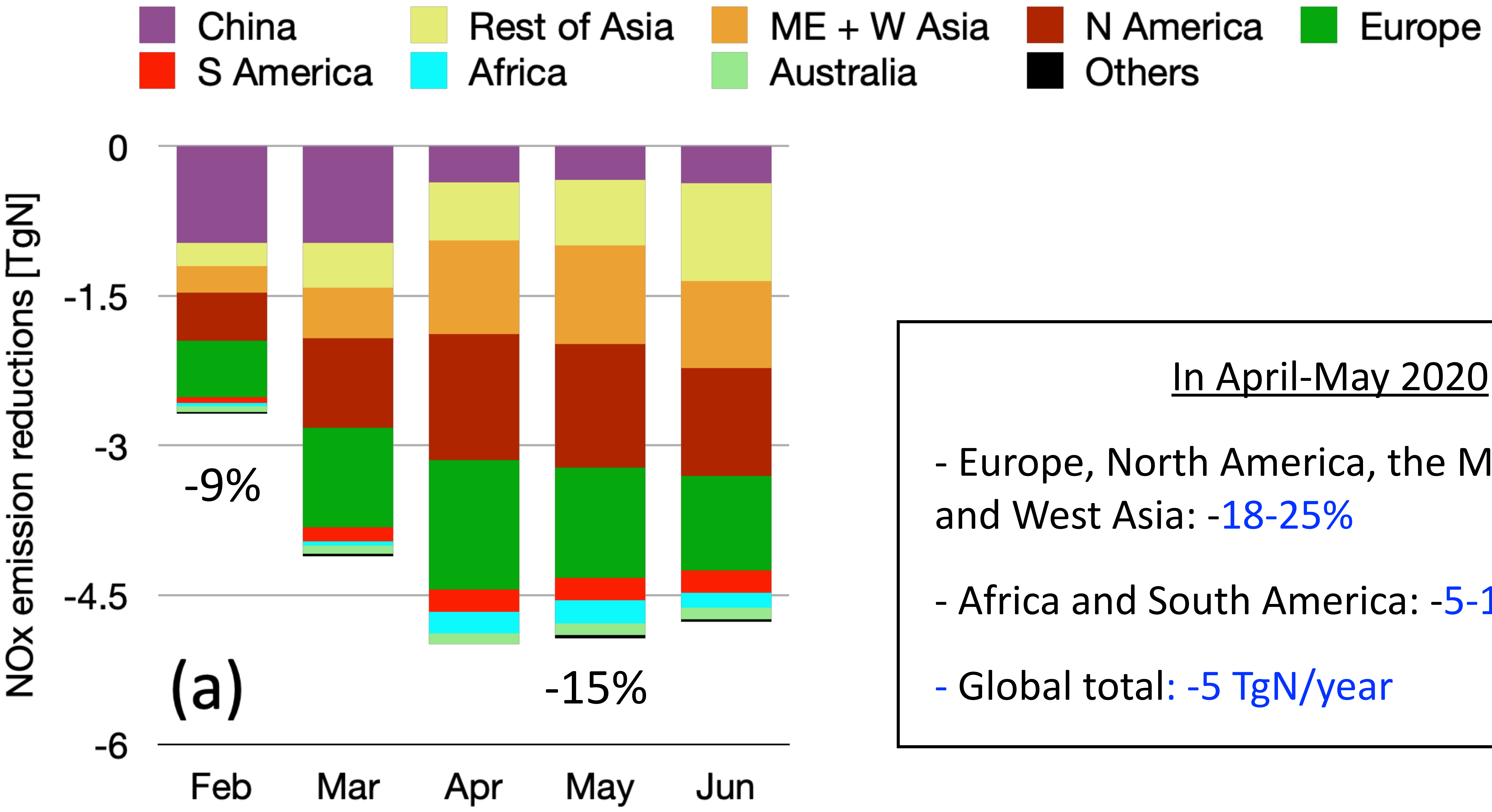
2. Concentrations

3. Health Impacts



- 2,100 more ozone-related and at least 60,000 fewer PM2.5-related morbidity incidences,
- Augmented efforts to reduce hospital admissions and alleviate negative impacts from potential delayed treatments

Estimated NOx emissions



1. Emissions

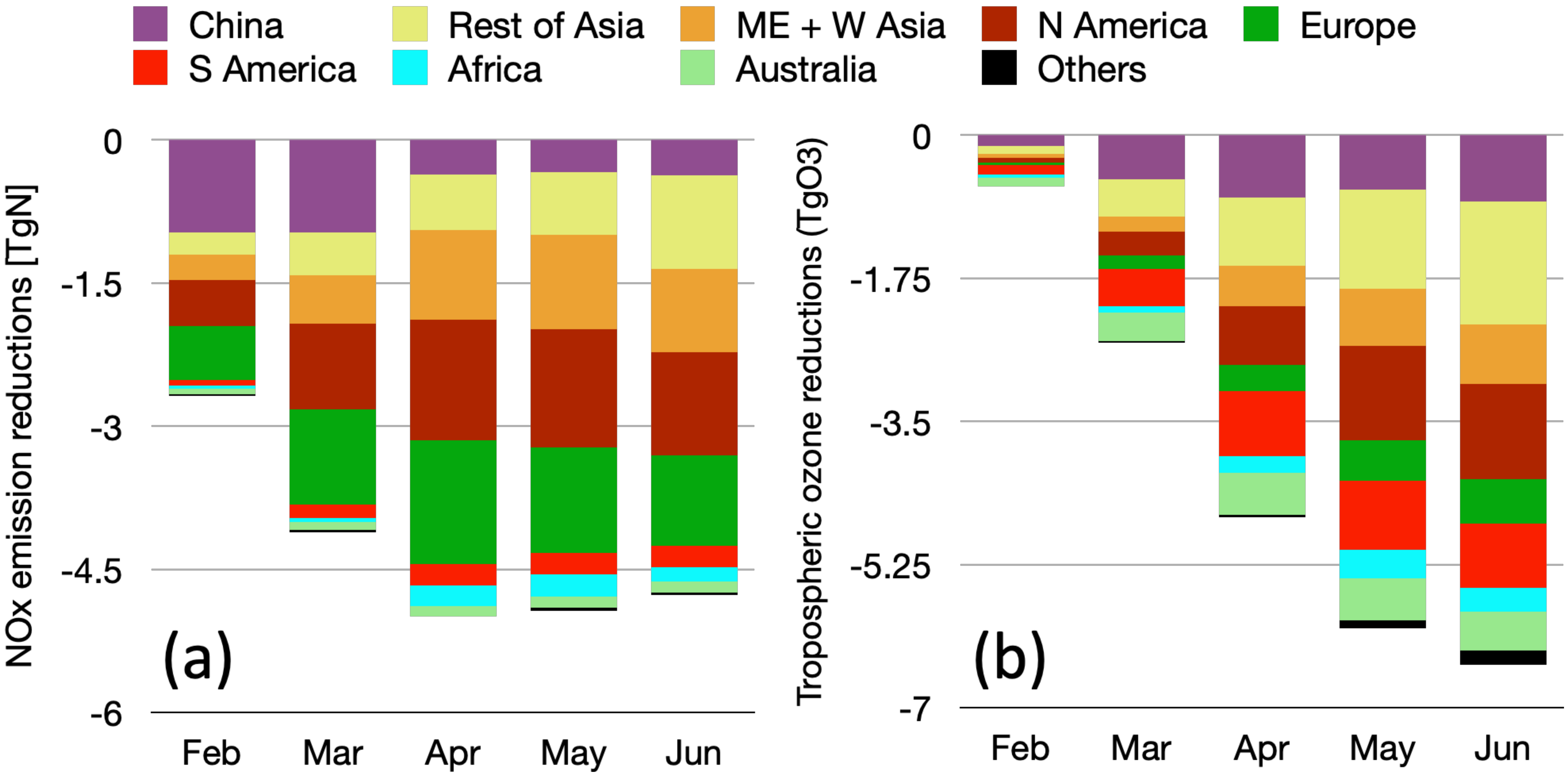
In April-May 2020

- Europe, North America, the Middle East and West Asia: -18-25%

- Africa and South America: -5-10%

- Global total: -5 TgN/year

Global ozone response



1. Emissions

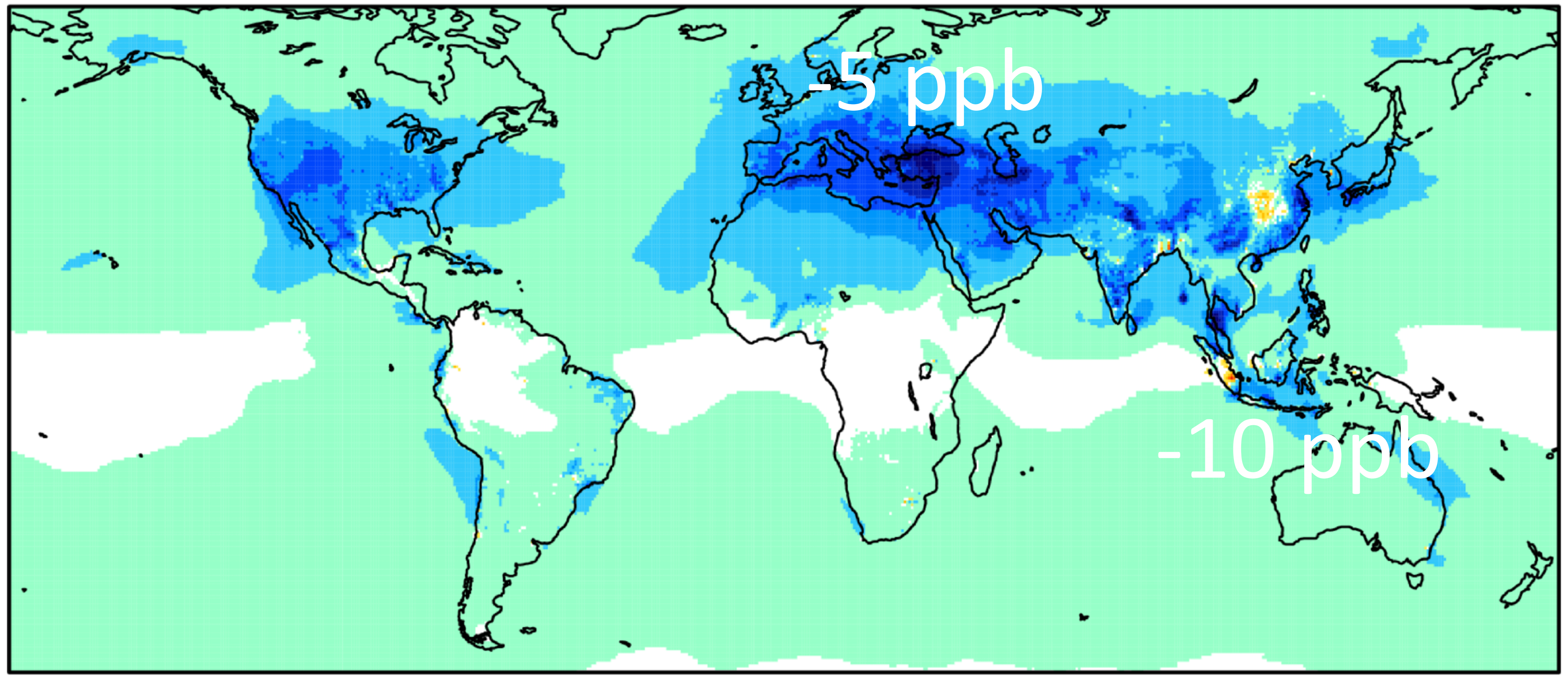
2. Concentrations

Global ozone response: May 2020

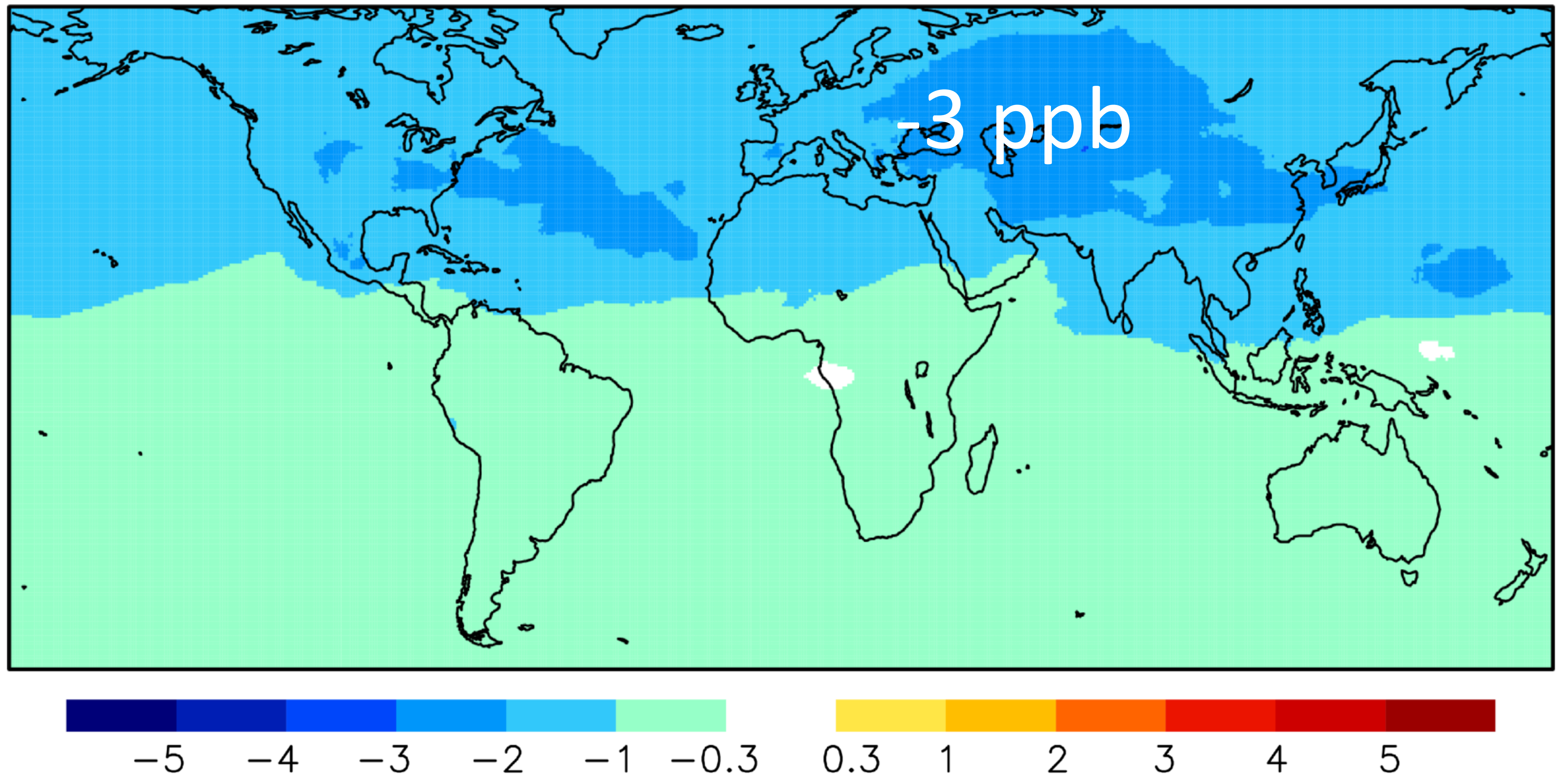
2. Concentrations

3. Climate Impacts

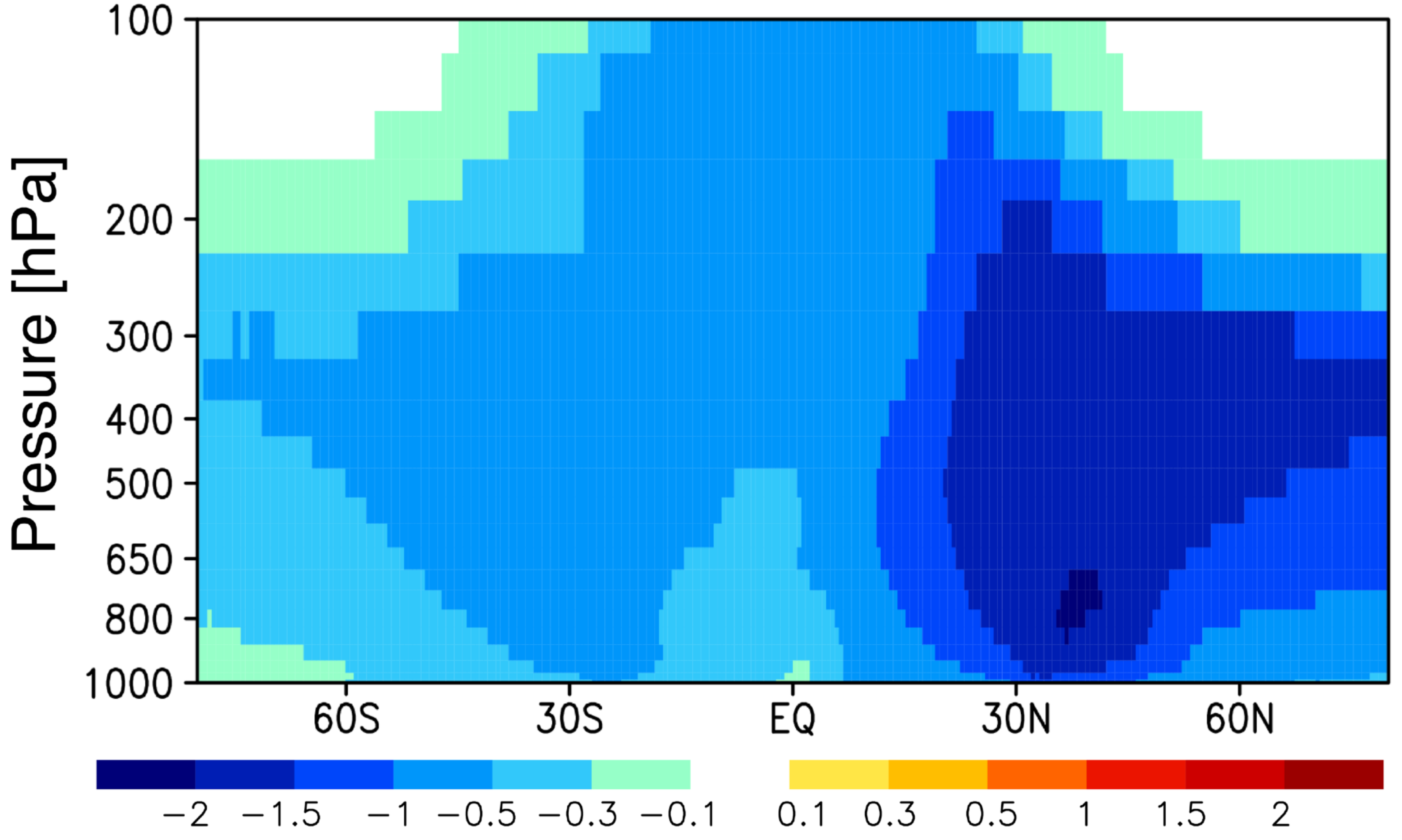
(a) Surface ozone anomaly [ppb]



(b) 500 hPa ozone anomaly [ppb]



(c) Zonal mean ozone anomaly [ppb]



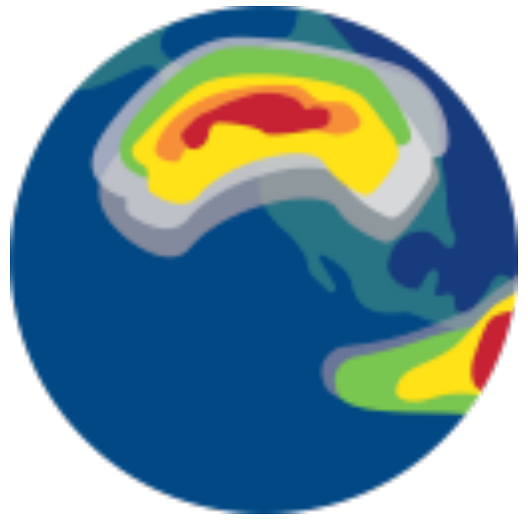
These reductions correspond to a tropospheric ozone radiative forcing of 233-350 mW m^{-2}.

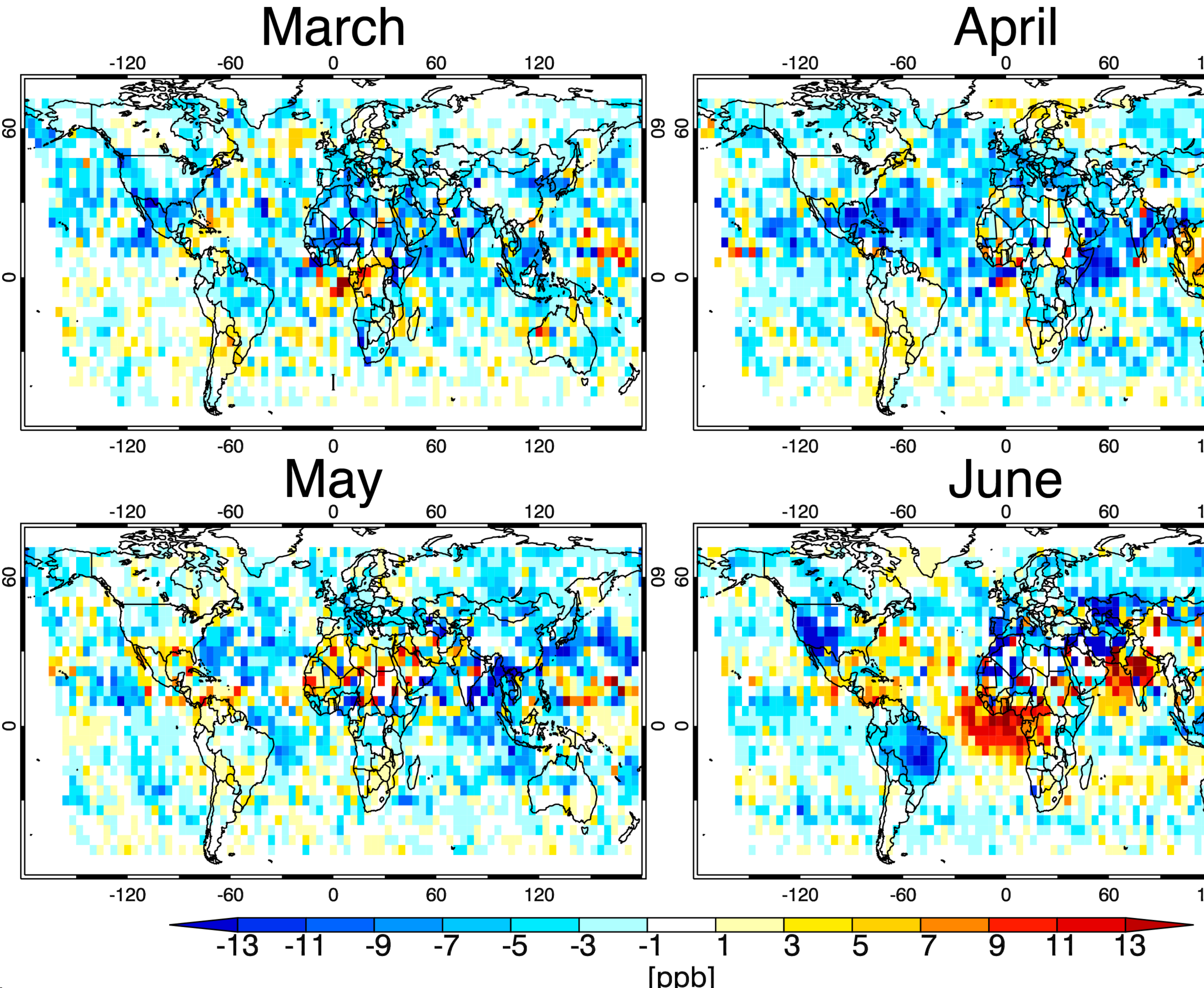
Global ozone response: Comparisons against CrIS satellite

CrIS (JPL TROPESS) ozone 700 hPa: 2020 minus 2019

2. Concentrations

tropess

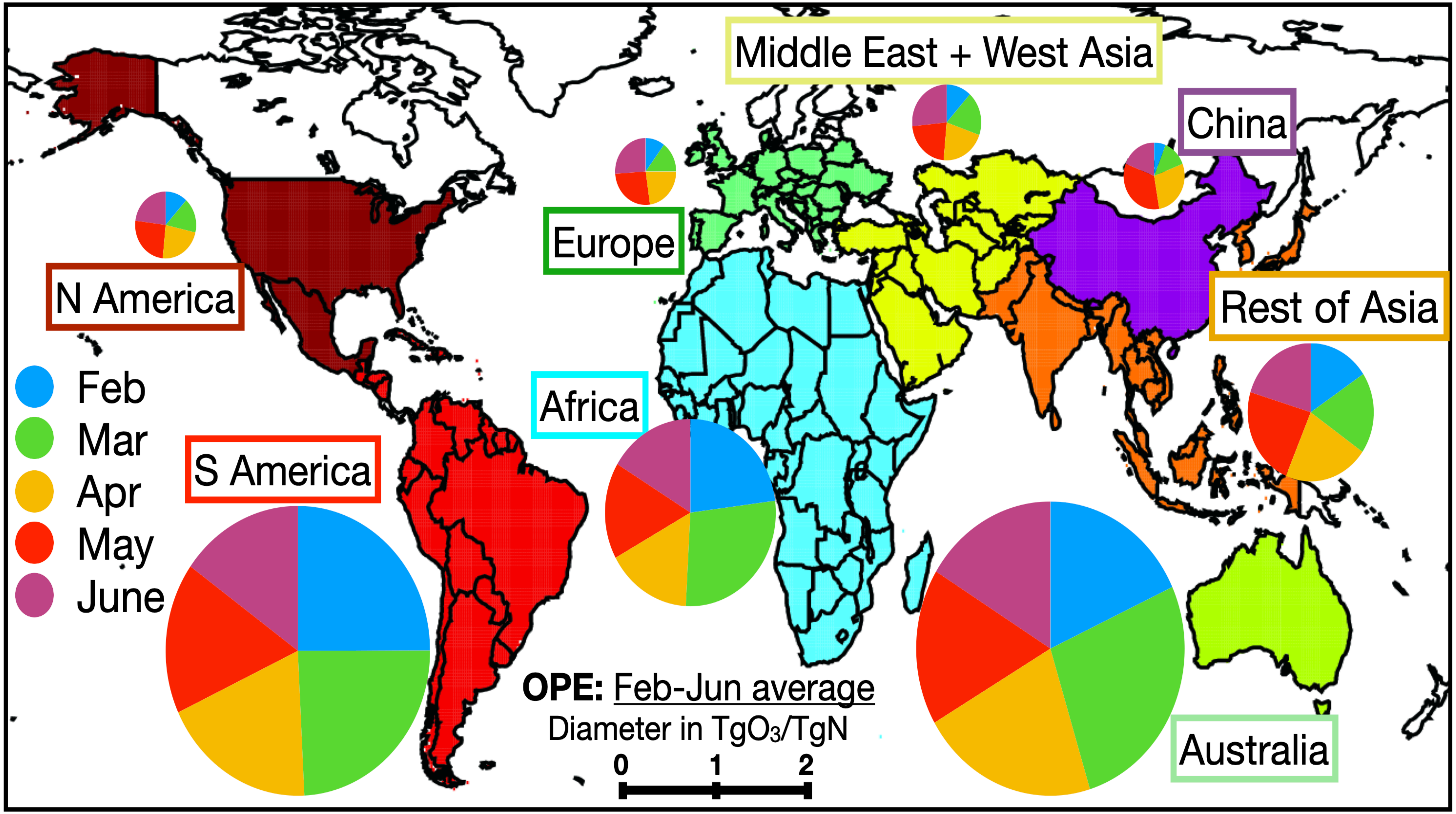




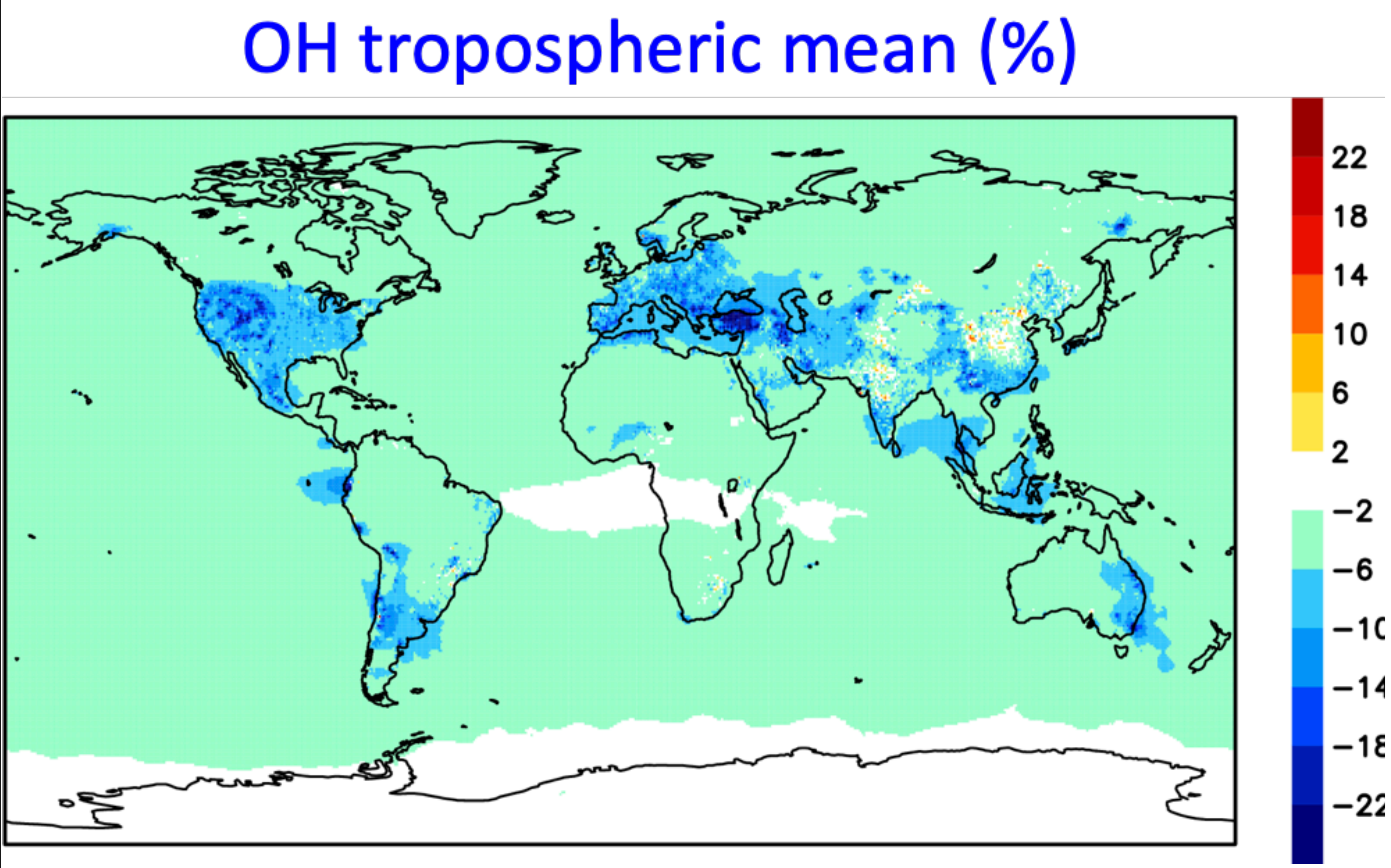
Ozone production efficiency = ΔO3/ΔNOx emissions

1. Emissions

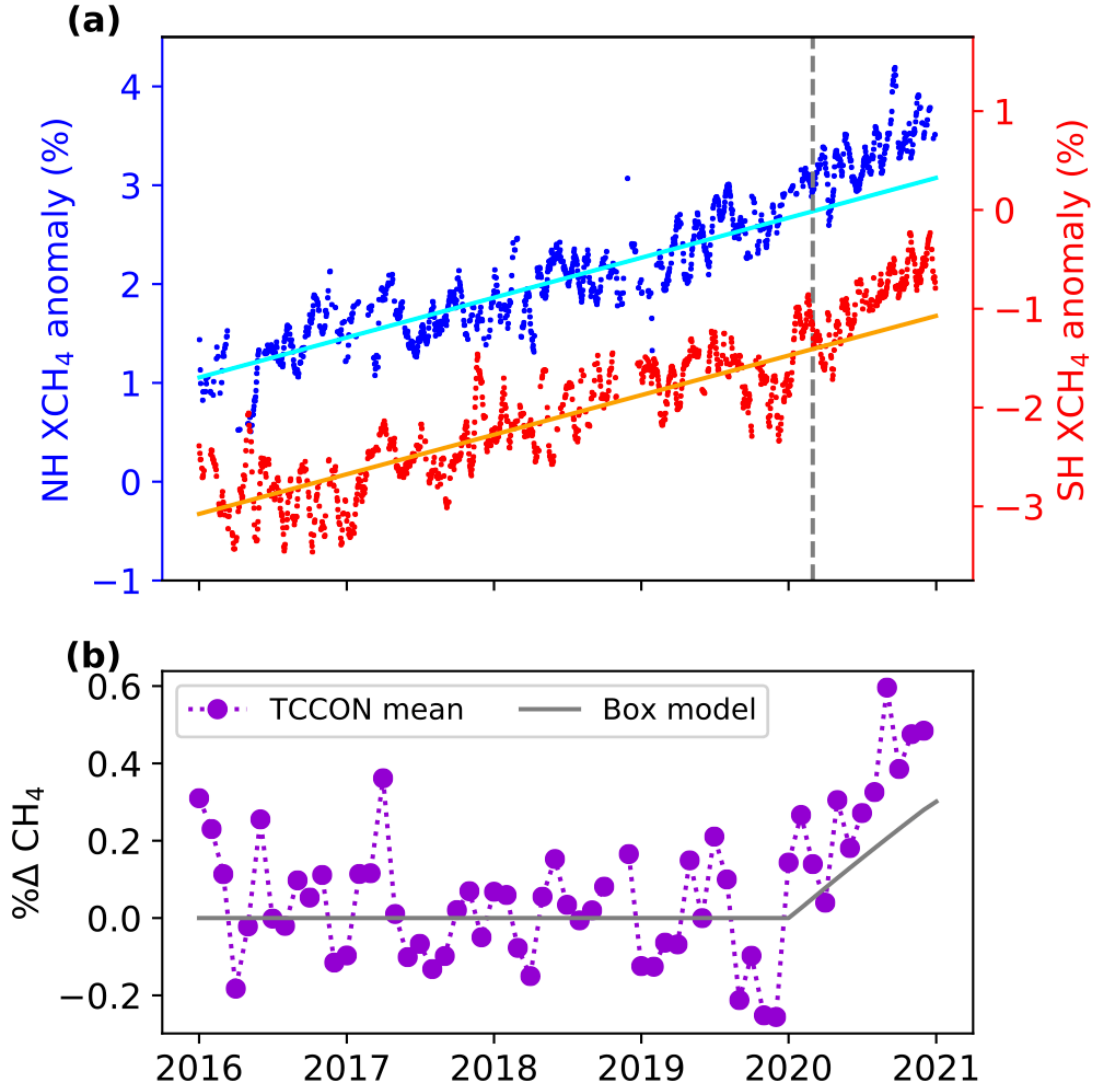
2. Concentrations



Tropospheric OH and CH4 anomaly



The 4% reduction in the tropospheric global mean OH concentration would increase the methane lifetime by about 4 months



2. Concentrations

3. Climate Impacts

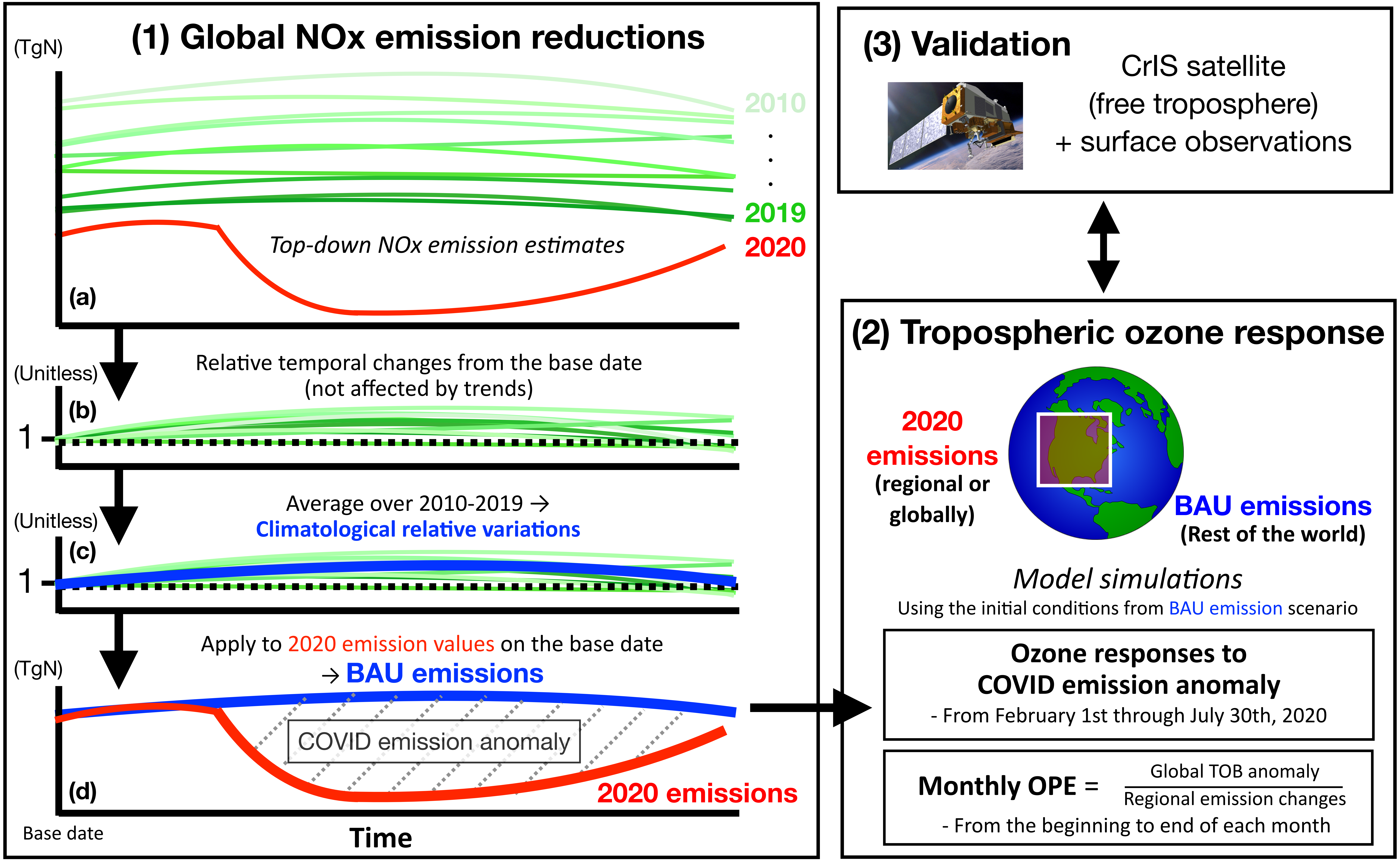
Miyazaki et al., 2021; Laughner et at., in revison.

Summary

- Total anthropogenic NOx emissions dropped by at least 15% globally and 18-25% regionally in April and May 2020, which led to up to a 5 ppb decrease in FT ozone, consistent with independent satellite observations. Similar reductions in VOCs emission would lead to additional 22-26 % reduction in TOB.

- Our results show that COVID-19 mitigation led to a clear and global atmospheric signature that altered atmospheric oxidative capacity and climate radiative forcing and can be used to inform policies that co-benefit air quality and climate.

- New LEO and GEO measurements and multi-spectral retrievals of composition provide much-improved spatial and temporal resolution and coverage in conjunction with the chemical reanalysis. They should lead to greater usefulness of satellite measurements for climate and air quality applications. E.g., GEMS NO_2 with CrIS/TROPOMI O_3 would better isolate sources and attribute sectors and their influences on ozone at daily scales.


(1) Global NOx emission reductions
(TgN)
2010
2019
2020
Top-down NOx emission estimates
(a)
(Unitless)
Relative temporal changes from the base date
(not affected by trends)
(b)
1
(Unitless)
Average over 2010-2019 →
Climatological relative variations
(c)
1
Apply to 2020 emission values on the base date
→ BAU emissions
(TgN)
COVID emission anomaly
2020 emissions
(d)
Base date
Time
(3) Validation
CrIS satellite
(free troposphere)
+ surface observations
(2) Tropospheric ozone response
2020
emissions
(regional or
globally)
BAU emissions
(Rest of the world)
Model simulations
Using the initial conditions from BAU emission scenario
Ozone responses to
COVID emission anomaly
- From February 1st through July 30th, 2020
Monthly OPE = Global TOB anomaly / Regional emission changes
- From the beginning to end of each month