

# Peculiar COVID-19 effects in the Greater Tokyo Area revealed by the variability in tropospheric gases and light-absorbing aerosols

<sup>1</sup>Alessandro Damiani, <sup>1</sup>Hitoshi Irie, <sup>1</sup>Dmitry Belikov, <sup>1</sup>Tamio Takamura,  
<sup>2</sup>Syedul H. M. Hoque, and <sup>3</sup>Raul R. Cordero

<sup>1</sup>Center for Environmental Remote Sensing, Chiba University, Chiba, Japan

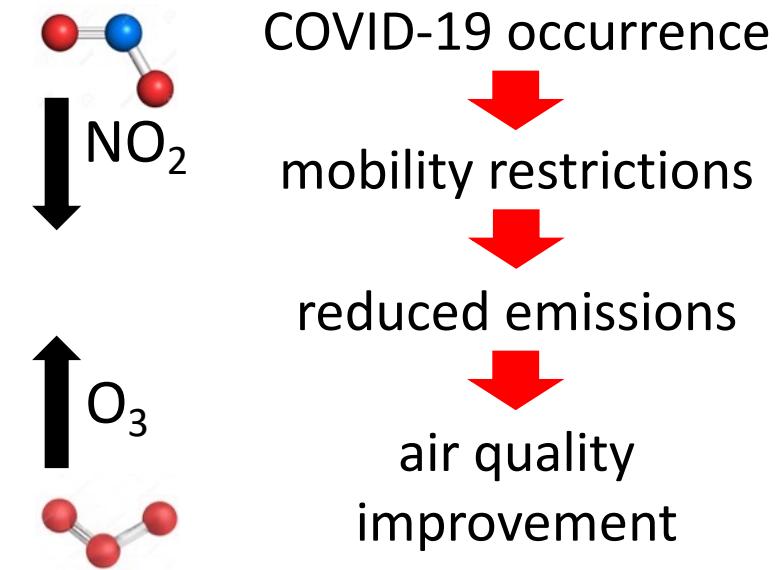
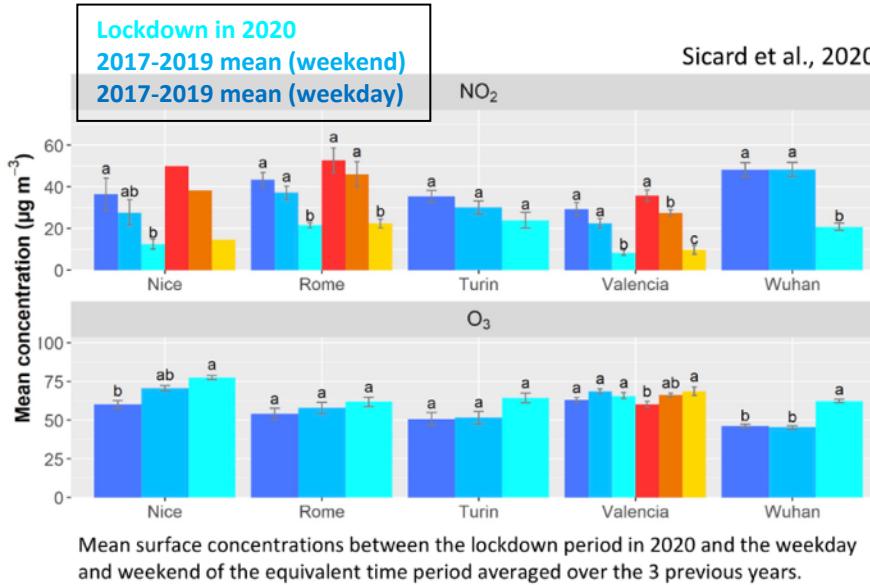
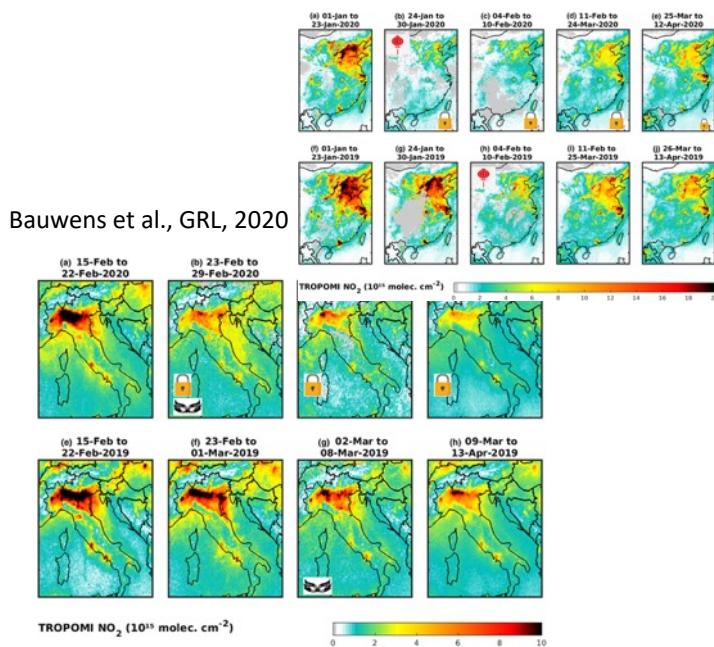
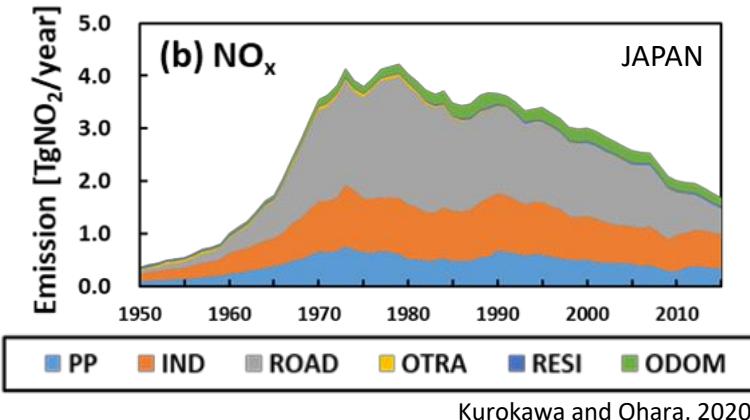
<sup>2</sup>Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan

<sup>3</sup>Department of Physics, Santiago University, Santiago, Chile

damiani@chiba-u.jp

# Introduction

- Overview on the variability (i.e., trends & weekly cycles) in tropospheric gases and light-absorbing aerosols in the Greater Tokyo Area in recent years. Focus on NO<sub>2</sub> (mainly) as well as HCHO, O<sub>3</sub>, and light-absorbing aerosols from multiple platforms.
- Nitrogen oxides (NO<sub>x</sub>) are among the main drivers of air quality degradation in urban areas. Fossil fuel combustion is the dominant source. NO<sub>x</sub> are precursors of secondary aerosols and catalyze tropospheric O<sub>3</sub> formation with consequences for climate and health.
- Formaldehyde is released by both anthropogenic and natural sources. Here, it is used as a VOC proxy.
- Light-absorbing aerosols in the BL estimated by combining SKYNET and MAX-DOAS obs.
- The COVID-19 pandemic gives an opportunity to assess human activity's impact on the environment -> focus on 2020



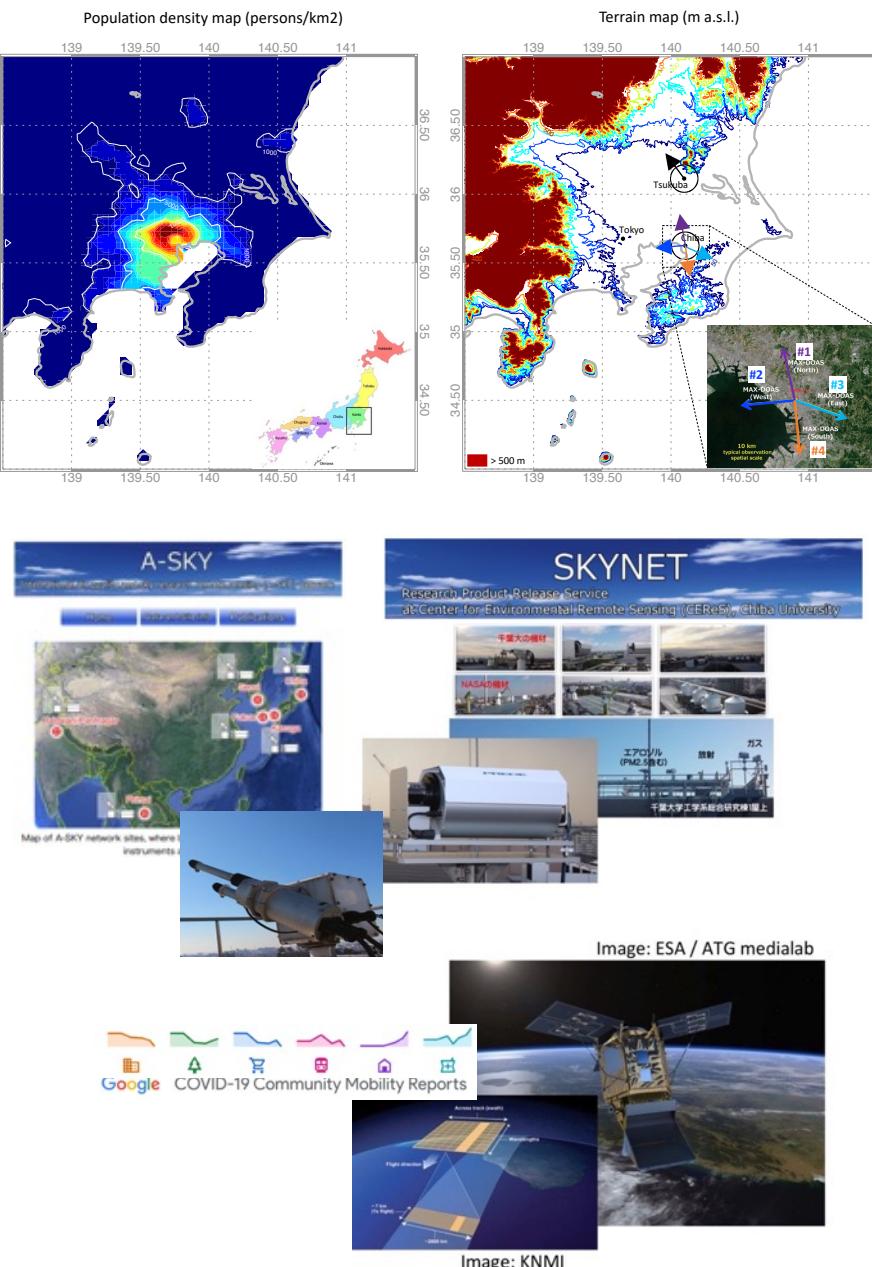
# Datasets and methods

## Main datasets used

- The **MAX-DOAS** utilizes the differential absorption structures of the oxygen collision complex ( $O_4$ ) in UV-VIS to derive information on aerosol and tropospheric gases. Scattered sunlight is measured at various elevation angles to below  $10^\circ$  and spectra were recorded in the 310–515 nm range. The retrieval is based on DOAS and optimal estimation methods (Irie et al., 2011,2015). Partial column below 1 km of  $O_3$ ,  $NO_2$ , HCHO and AEC recorded at Chiba U. and Tsukuba were used.
- TROPOMI/S5P** satellite. The L2  $NO_2$  and HCHO offline (OFFL) products are used as a proxies of NOx and VOC, respectively. Retrieval algorithms use the DOAS method and are based on the DOMINO retrieval (van Geffen et al., 2019) and previously developed OMI QA4ECV products (De Smedt 2017). It renders a tropospheric column density. The profile shape of the TM5-MP model is used to compute the AMF without accounting for aerosol.
- OMI/Aura** satellite. We used  $NO_2$  tropospheric column in 2005-2020 (from NASA/GES DISC).
- Air quality surface network** (NIES Environmental Numerical Database). Surface punctual obs.
- SKYNET** observations (aerosol optical properties)
- Chemistry Land-surface Atmosphere Soil Slab (**CLASS**) model (van Stratum et al., 2012).

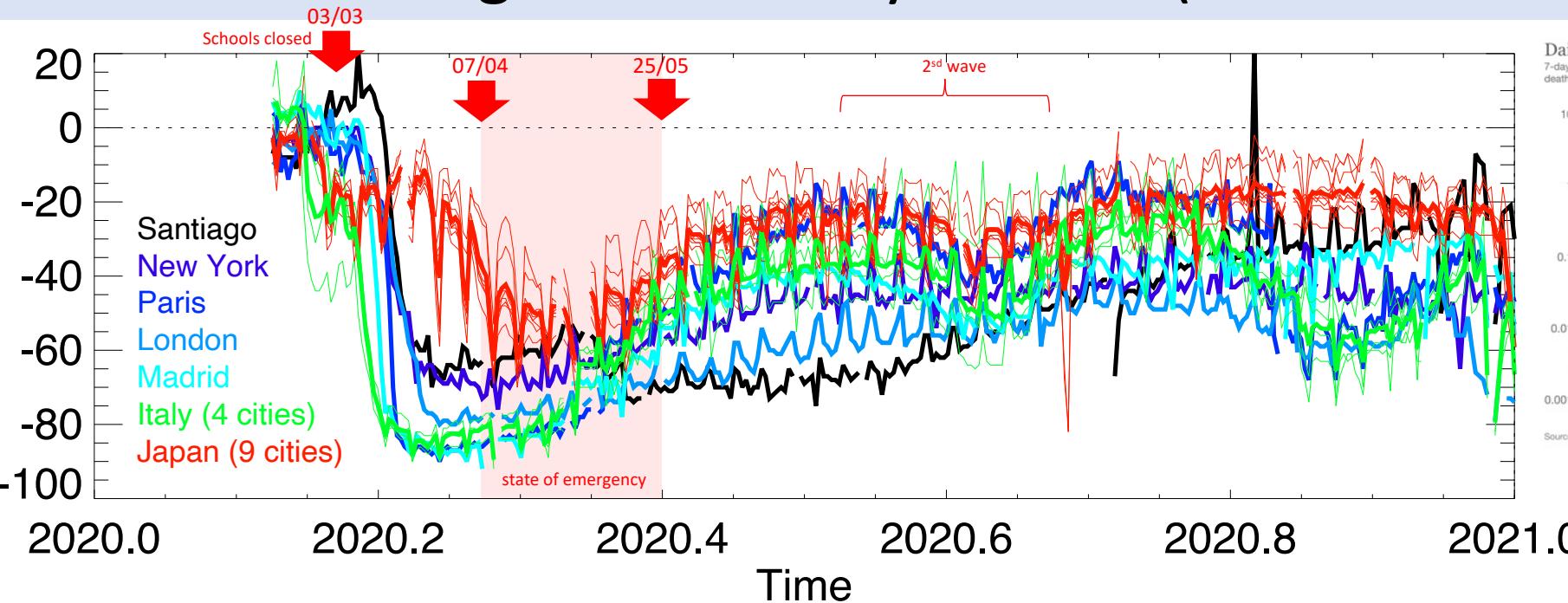
## Additional datasets

- Ozonesonde** observations at Tateno (Tsukuba/Japan) recorded by JMA
- Google Mobility** data. They show how visits to places are changing in each region
- CAMS** global reanalysis (EAC4) of ECMWF and **MERRA-2** NASA's reanalysis

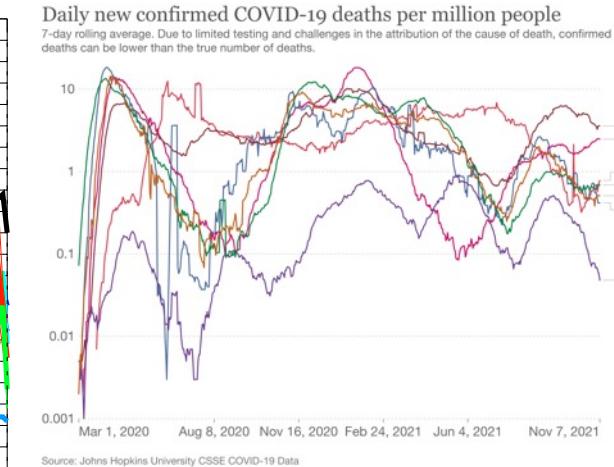
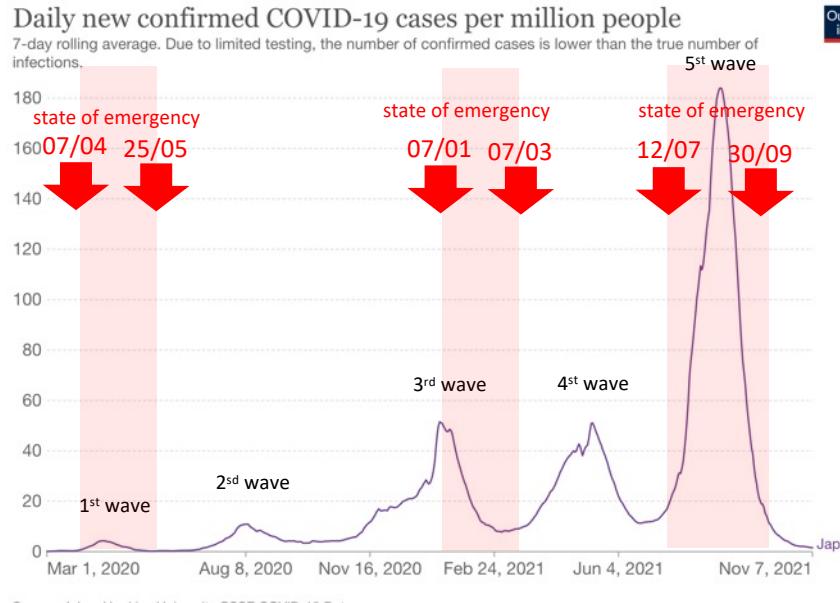


# Changes in mobility in 2020 (due to COVID-19)

Mobility changes (%)



Google Mobility data.  
Changes for each day are compared to a baseline value for that day of the week. The baseline is the median value, for the corresponding day of the week, during the 5-week period Jan 3–Feb 6, 2020.

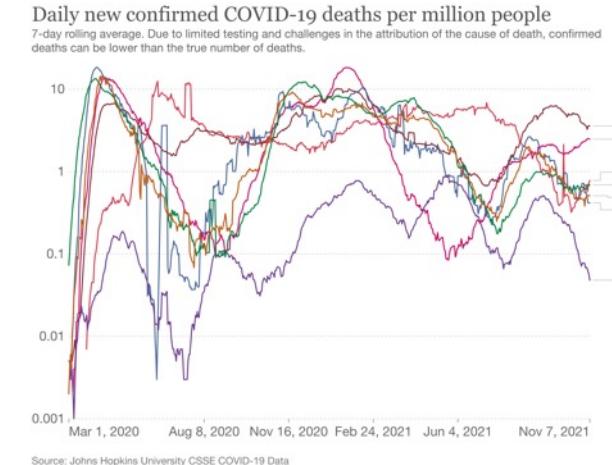
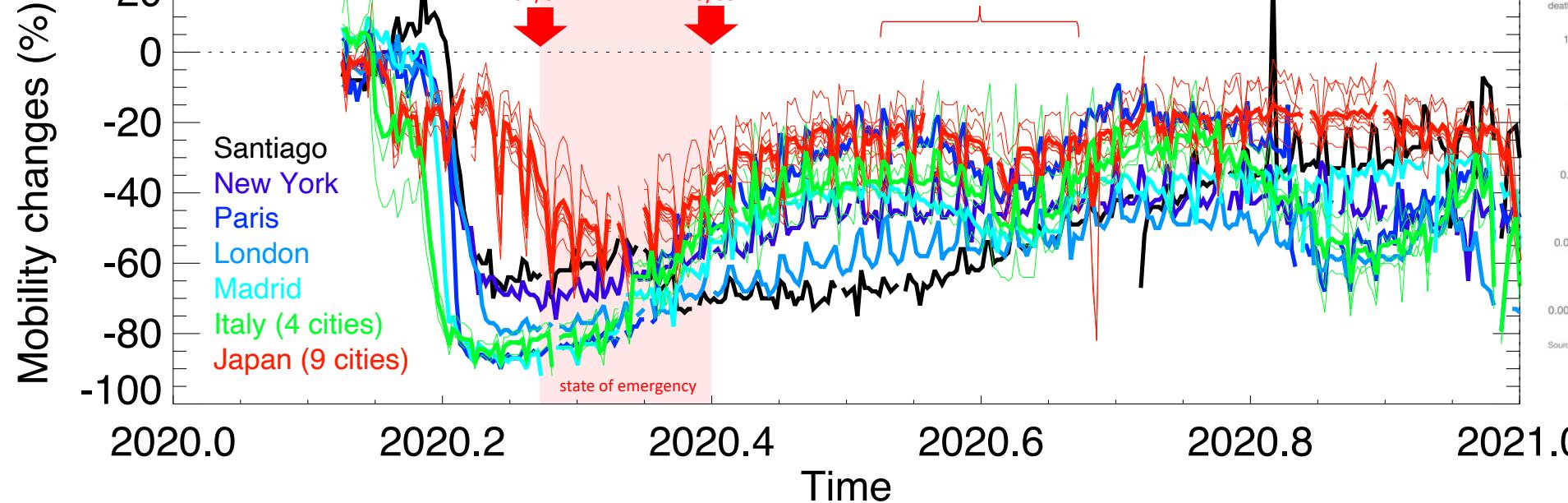


In Japan, there was no lockdown as in Europe, but only the declaration of the state of emergency with a lack of strict legal restrictions.

## COVID-19 in Japan

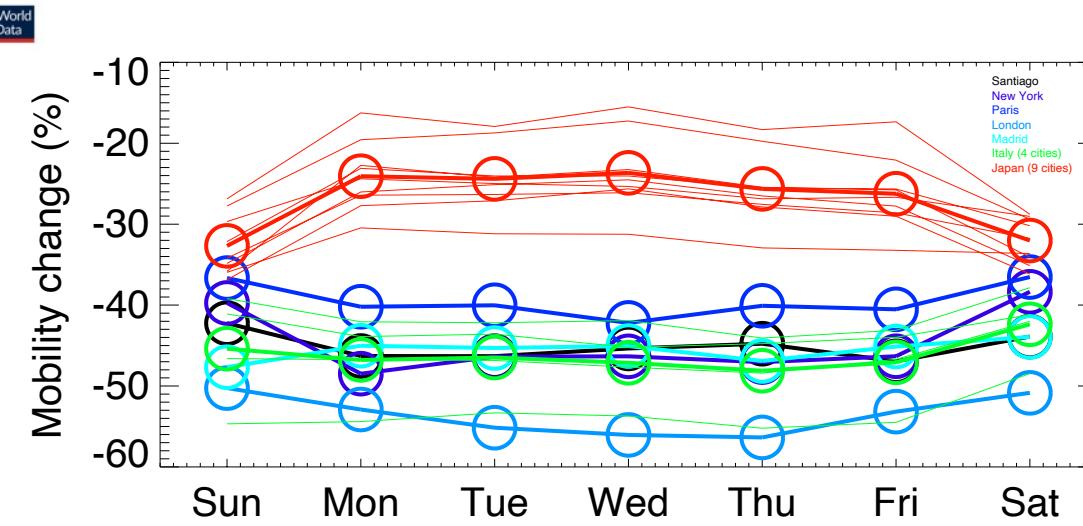
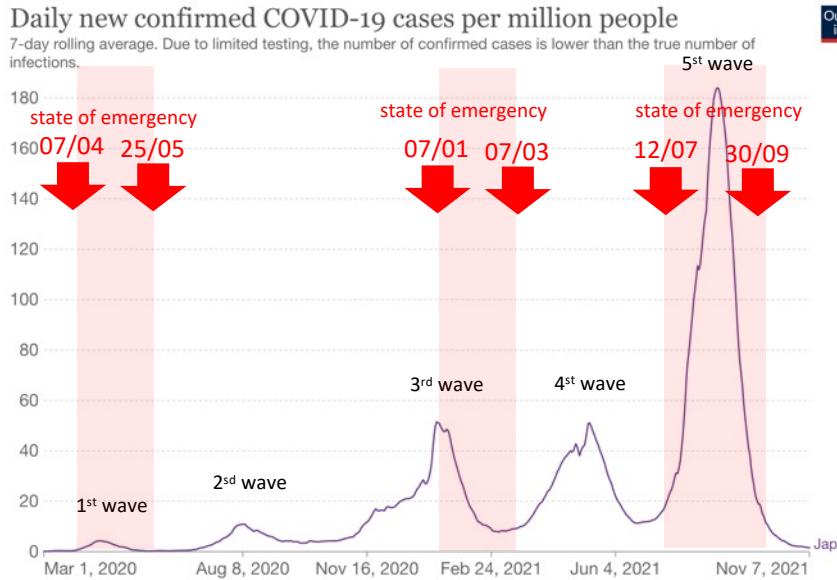
- Jan. 15, 2020 -- 1st COVID-19 infection
- Feb. 3, 2020 -- Diamond Princess cruise ship quarantine
- Feb. 13, 2020 -- Japan confirms 1st COVID-19 death
- Mar. 3, 2020 -- Schools closed
- Mar. 11, 2020 -- WHO declares pandemic
- Mar. 24, 2020 -- Tokyo Olympic Games postponed
- Apr. 7 to May 25, 2020 -- **state of emergency**
- Jul. 22, 2020 -- Government launches "Go To Travel" program
- Jan. 7 to Mar. 7, 2021 -- **state of emergency**
- Feb. 17, 2021 -- Japan begins COVID-19 vaccinations
- Jul. 12 to Sep. 30, 2021 -- **state of emergency**

# Changes in mobility in 2020 (due to COVID-19)

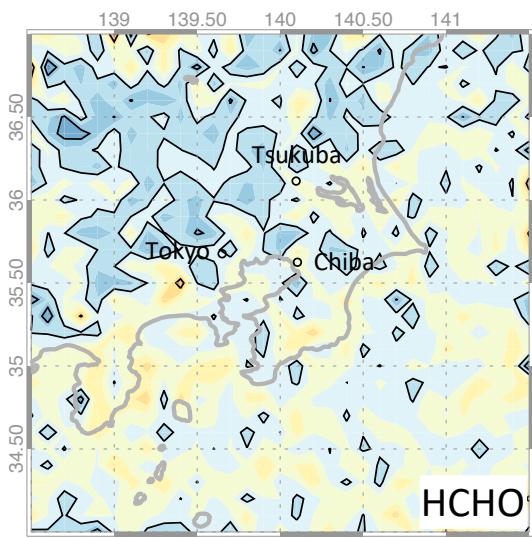
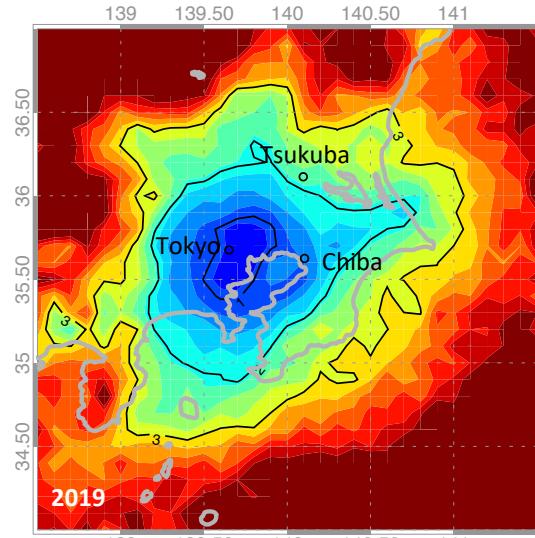
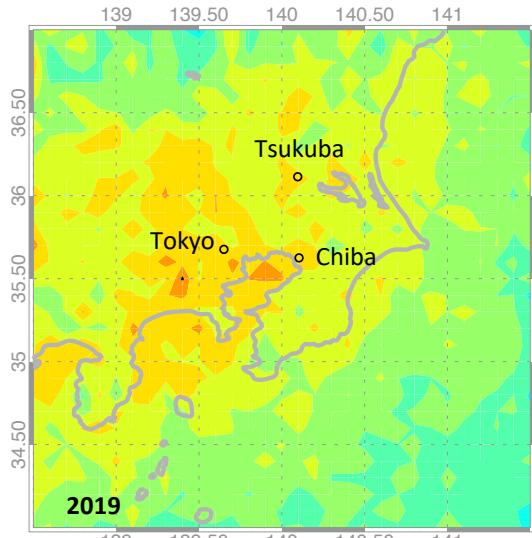
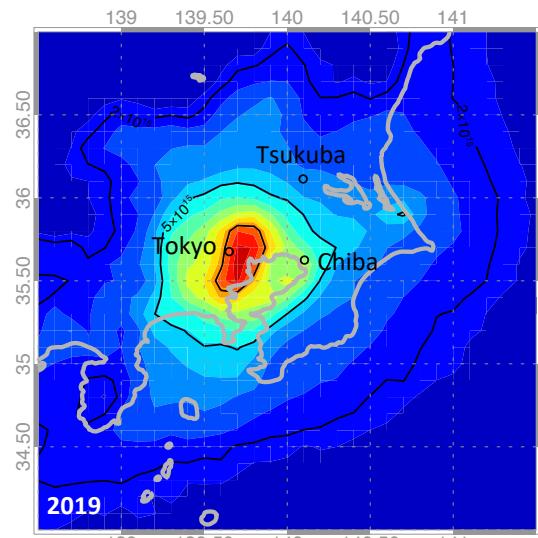
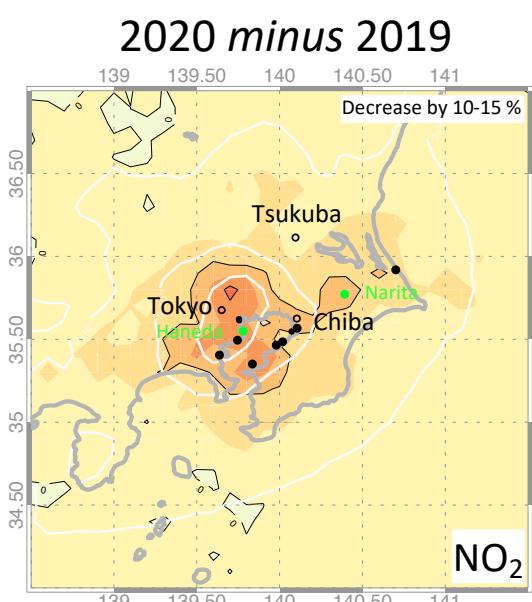
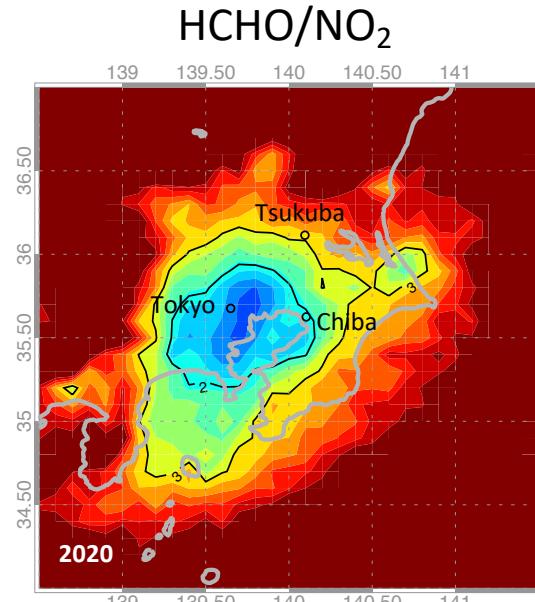
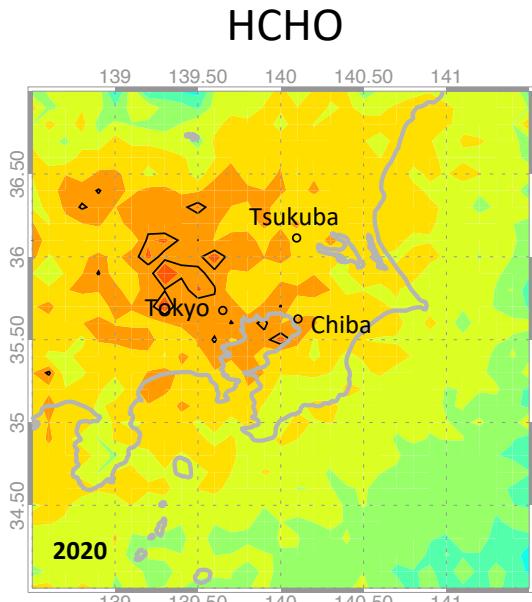
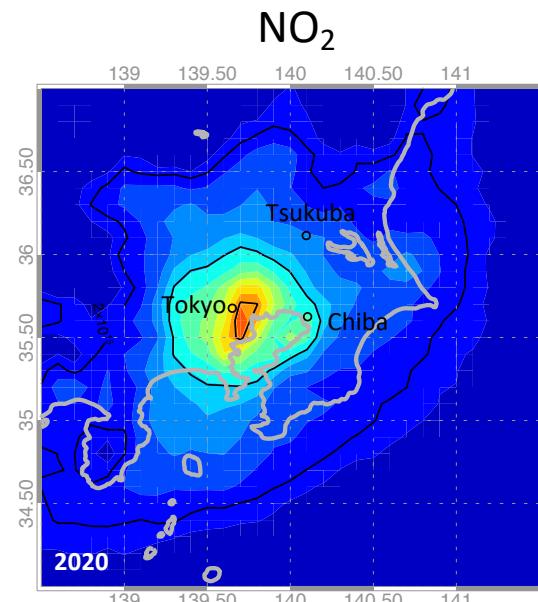


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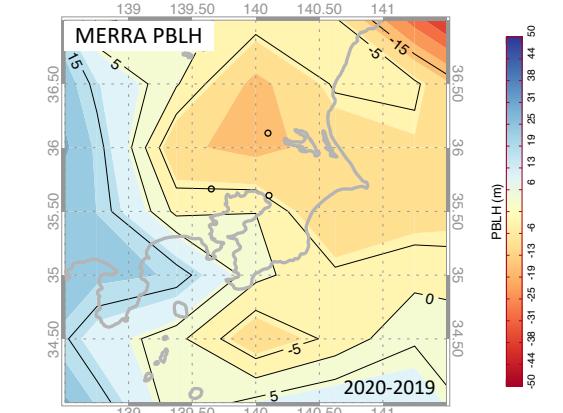
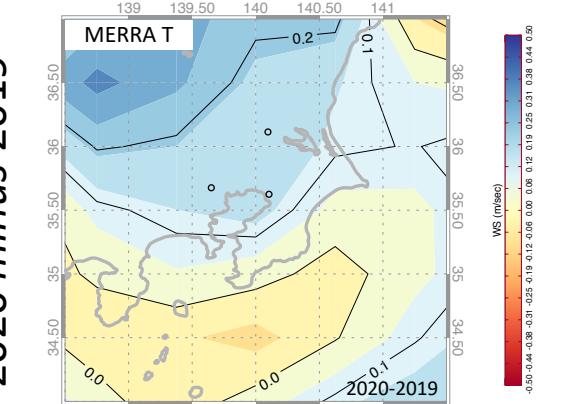
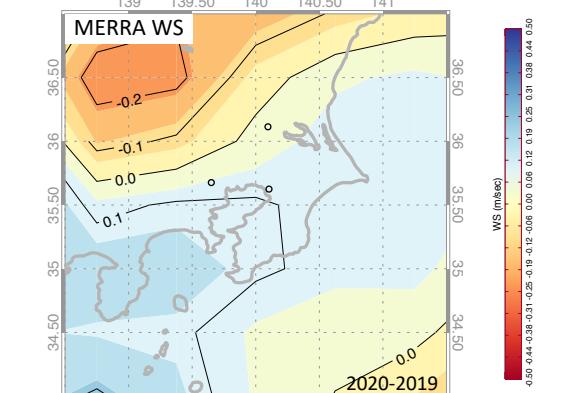
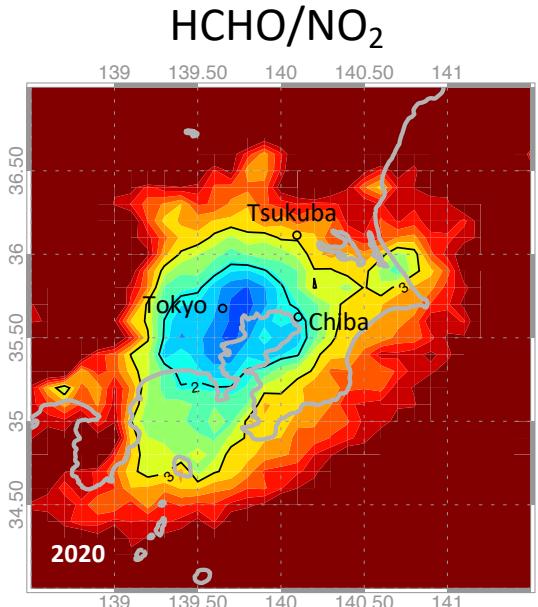
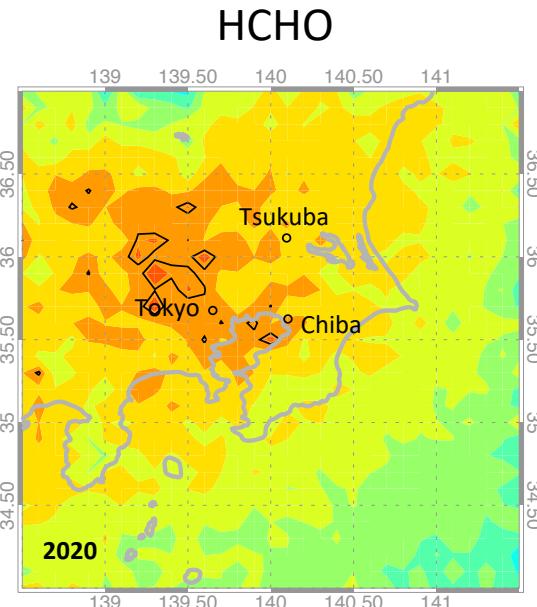
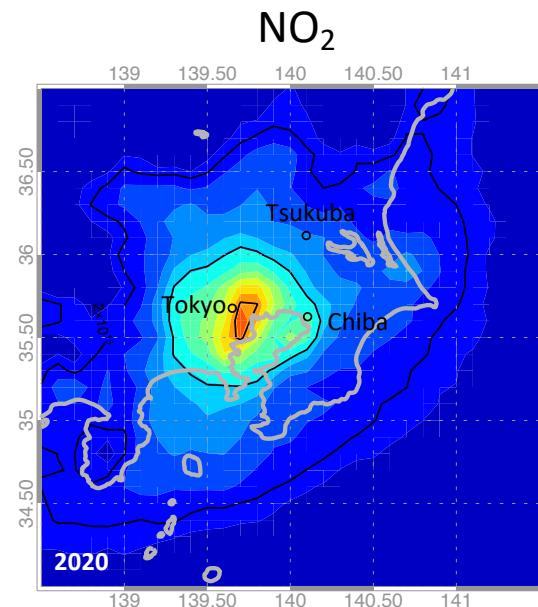
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# TROPOMI $\text{NO}_2$ , $\text{HCHO}$ trop. column and meteorology in 2019 and 2020

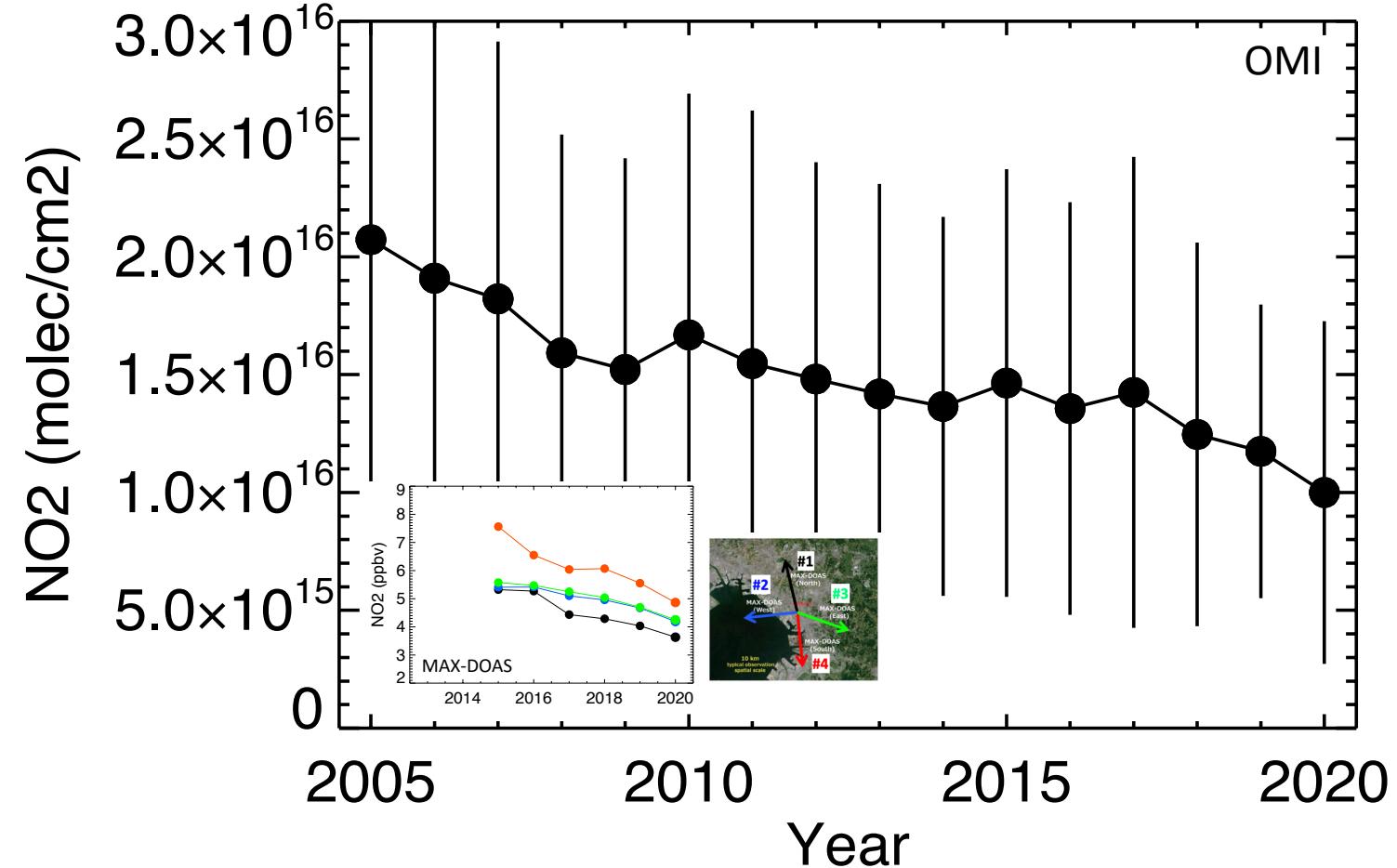
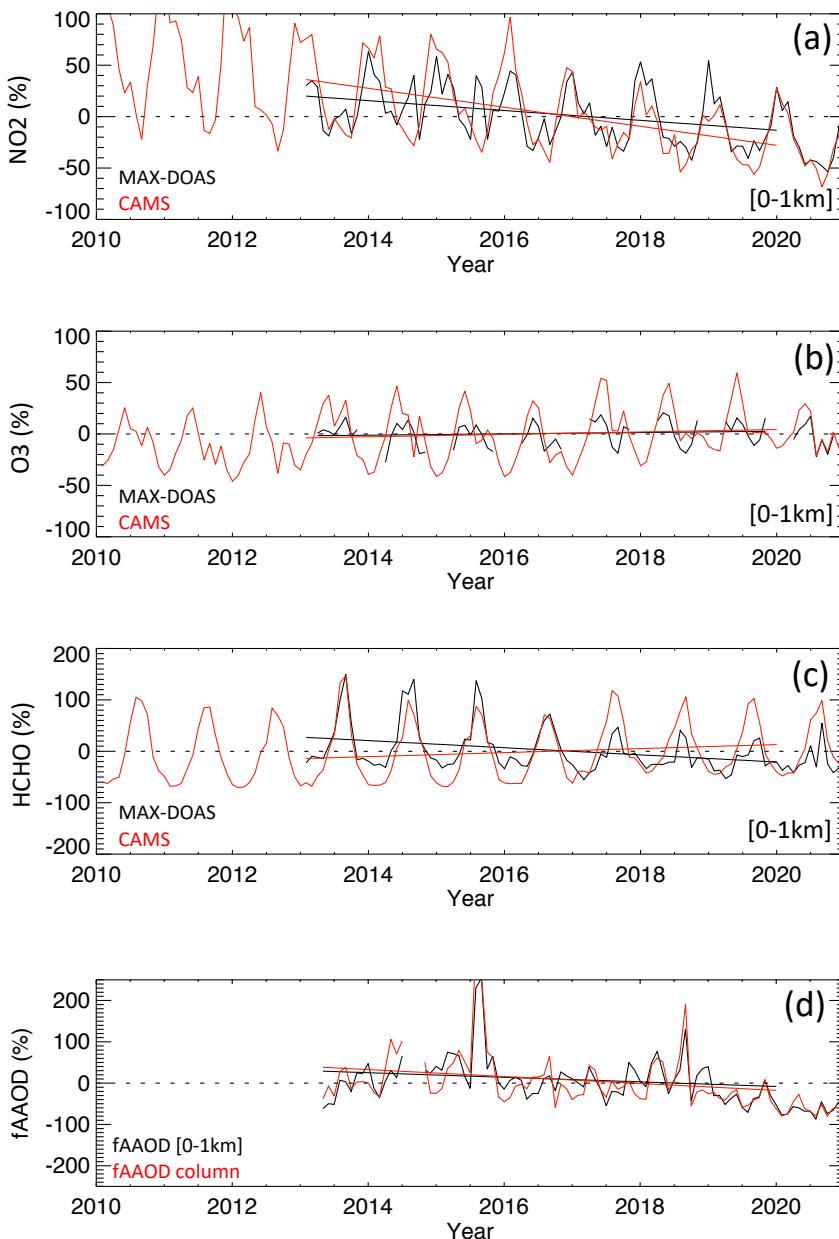


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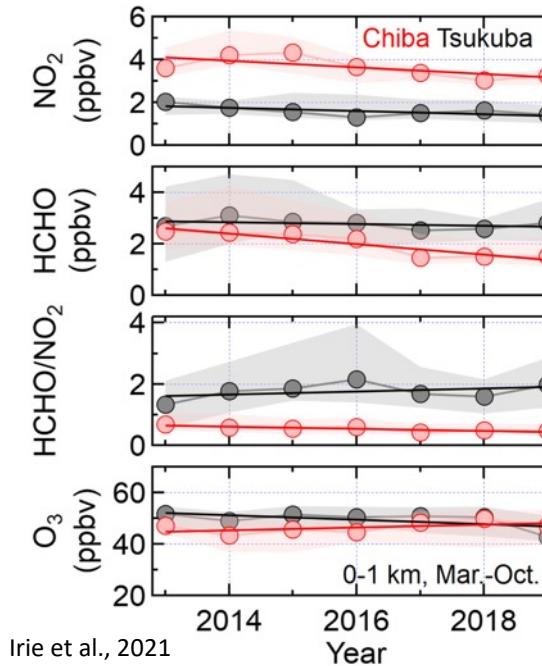
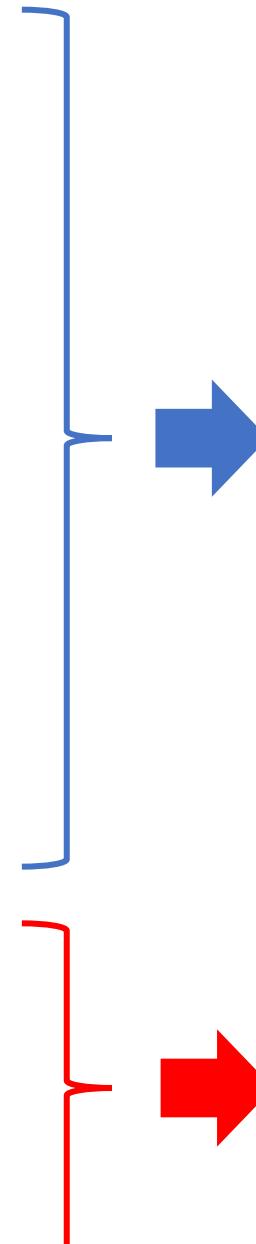
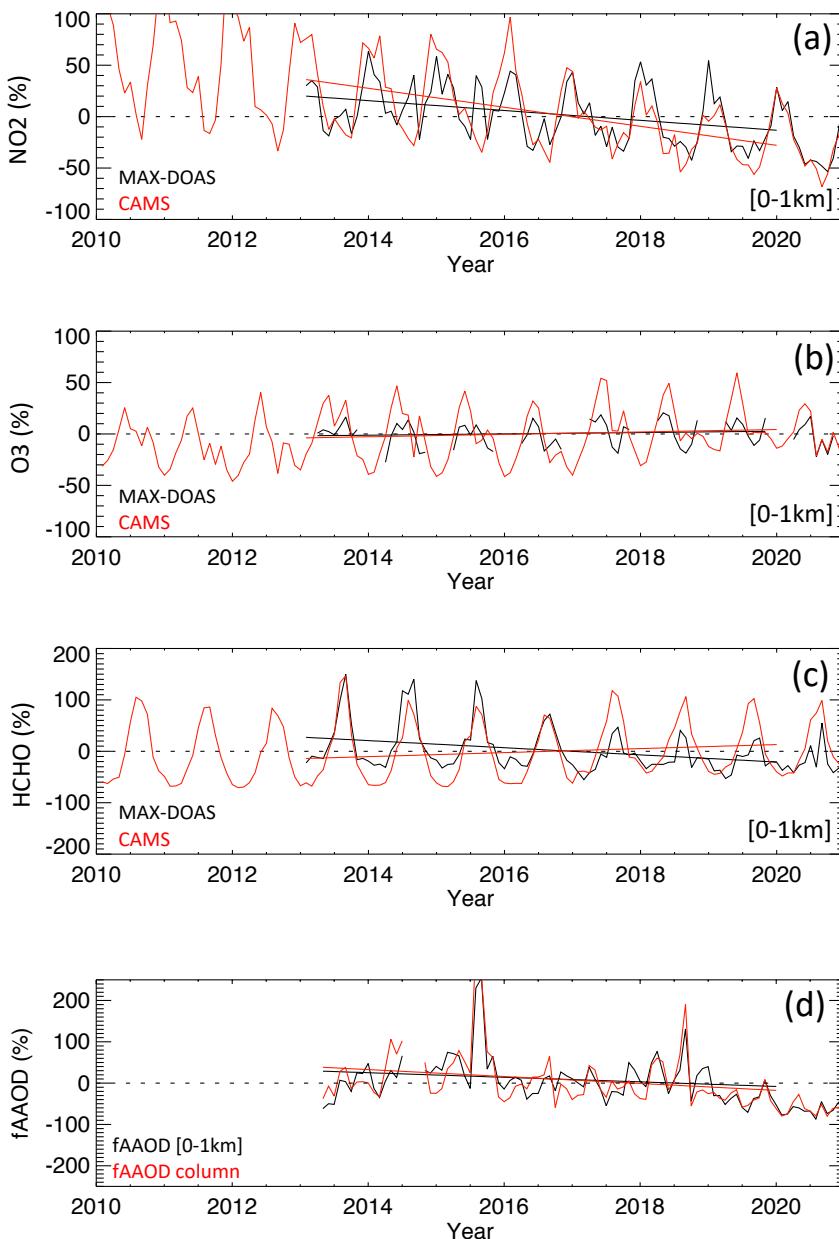


2020 minus 2019

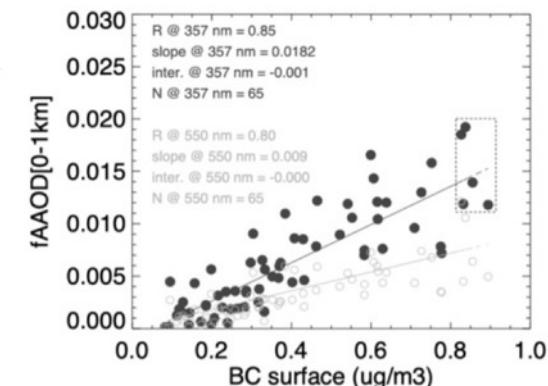
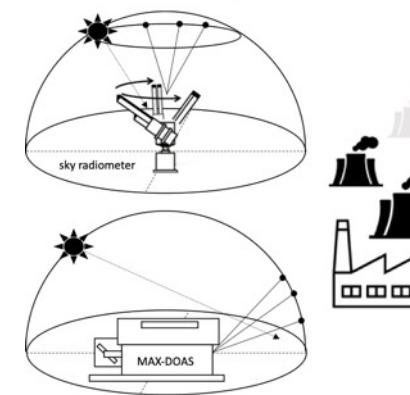
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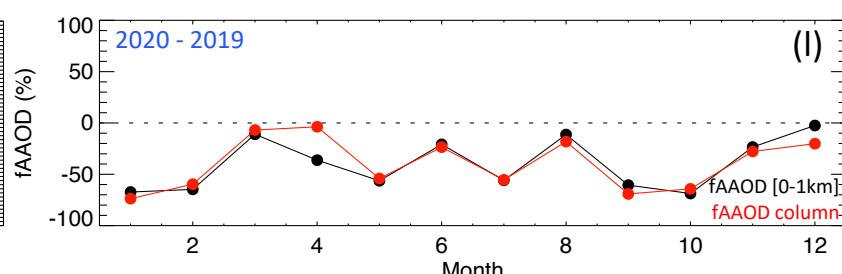
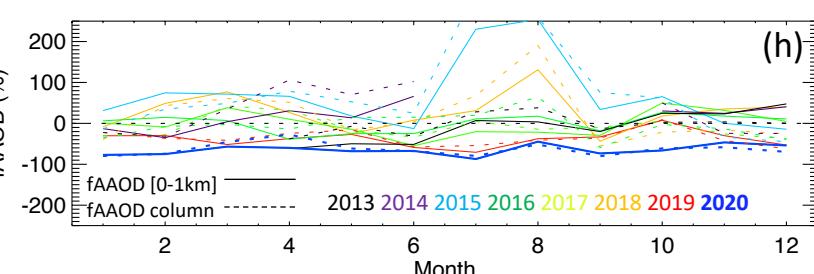
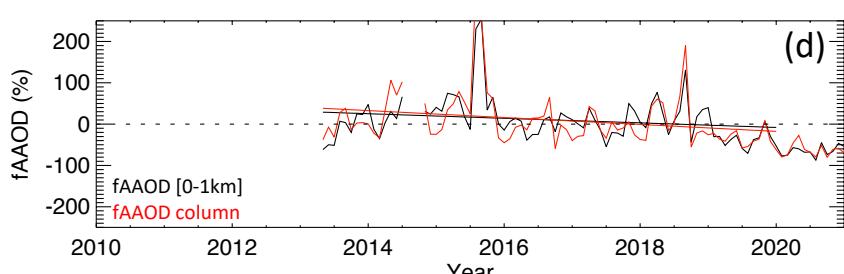
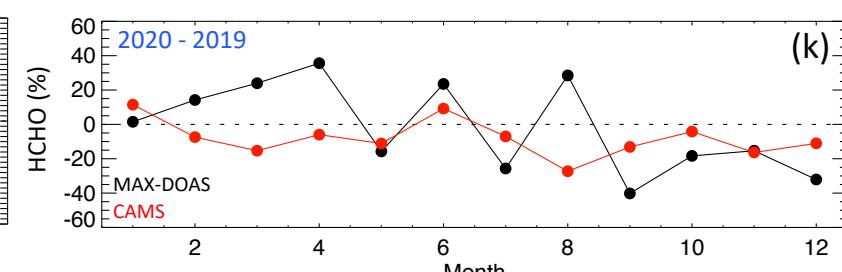
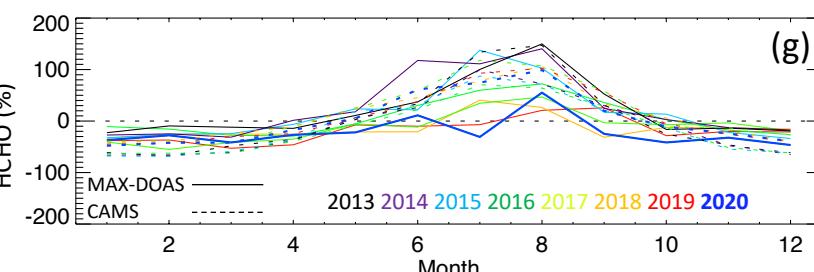
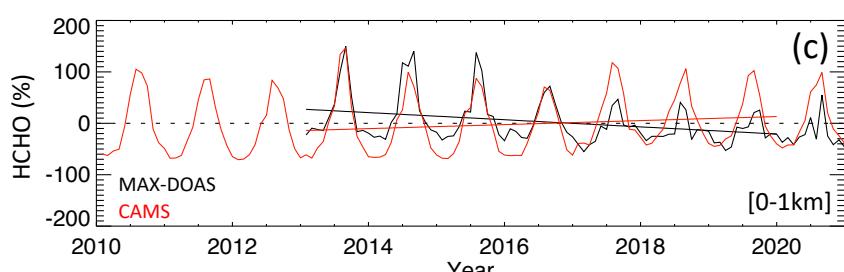
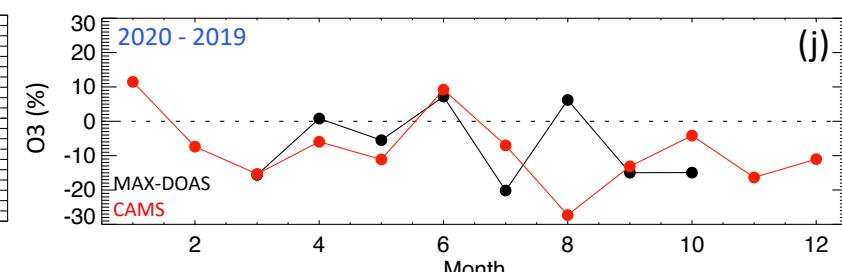
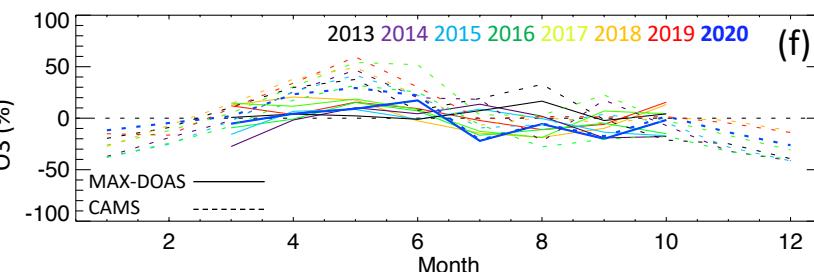
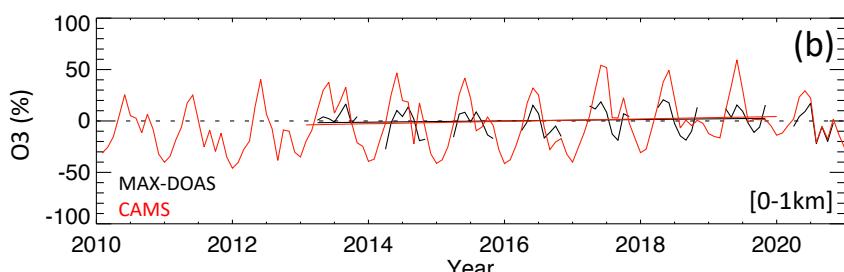
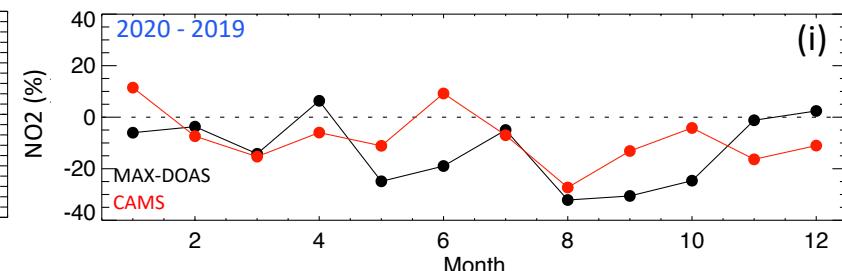
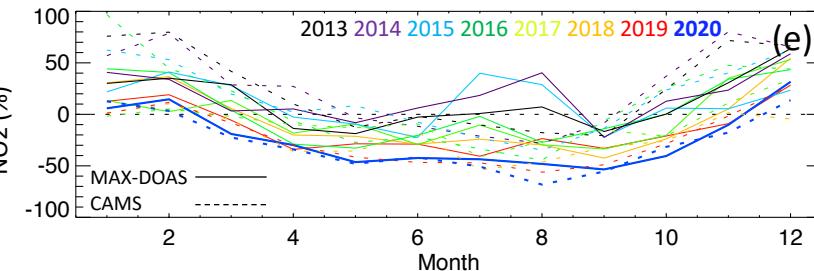
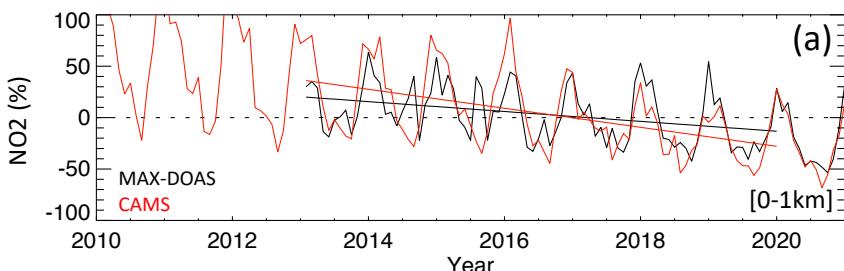
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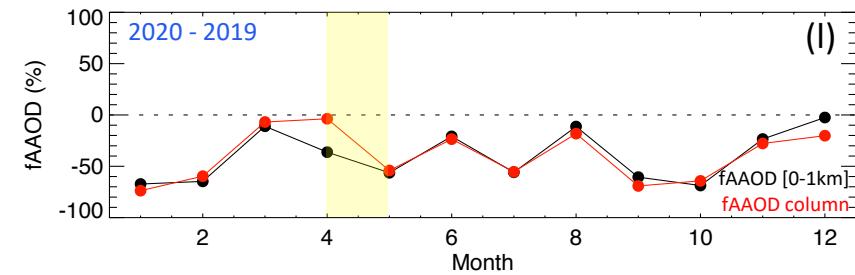
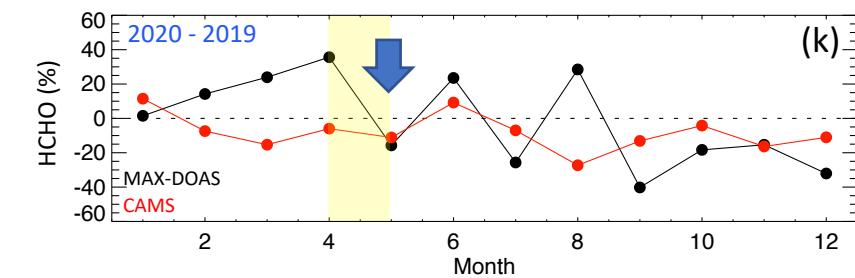
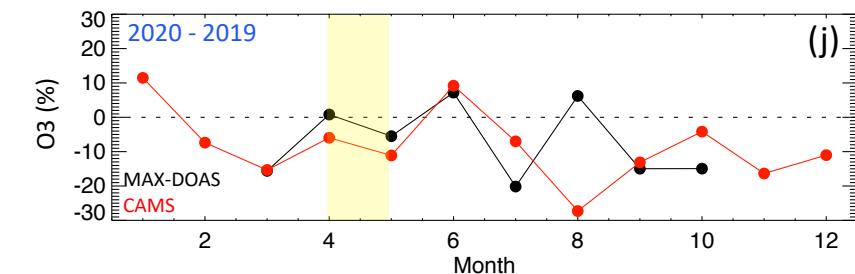
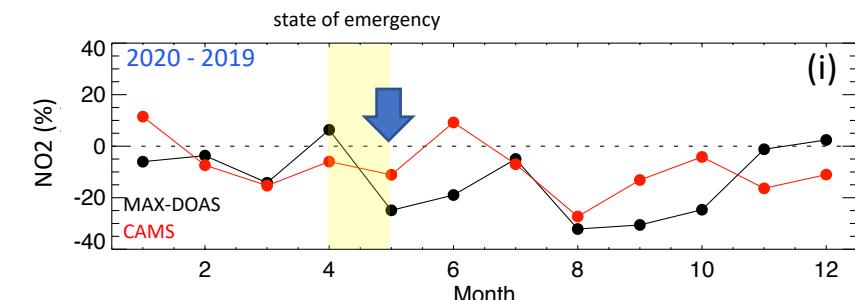
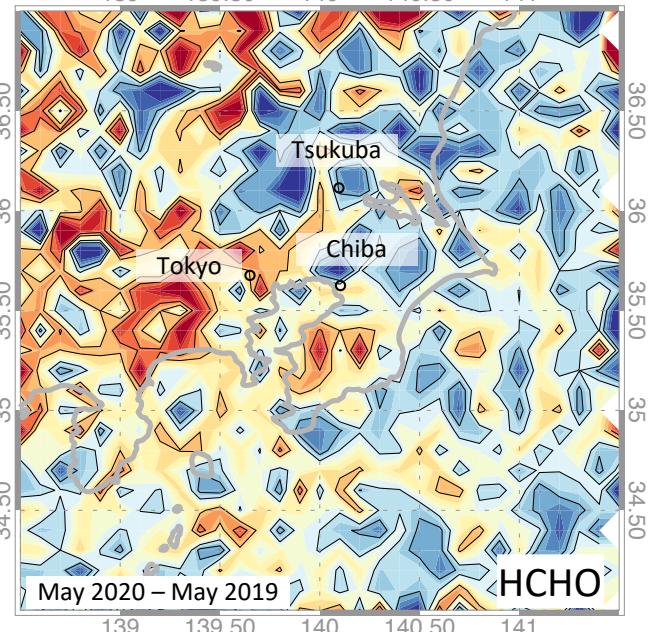
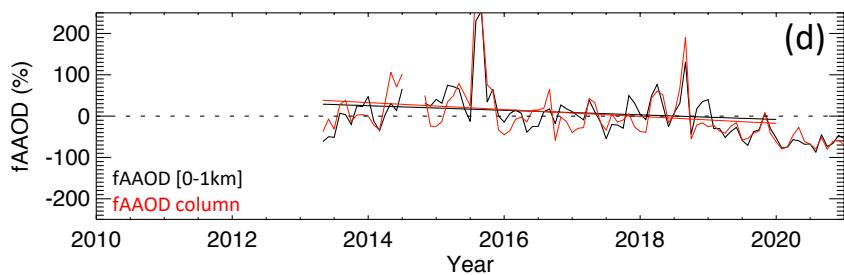
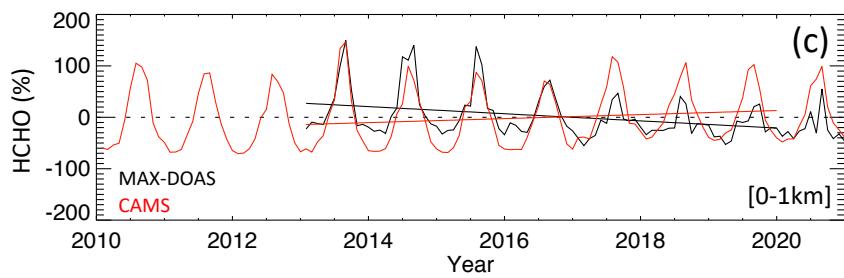
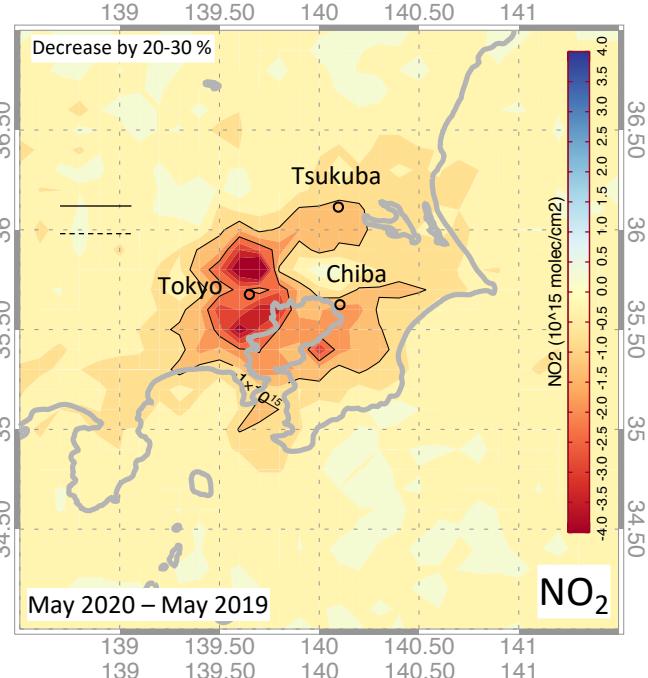
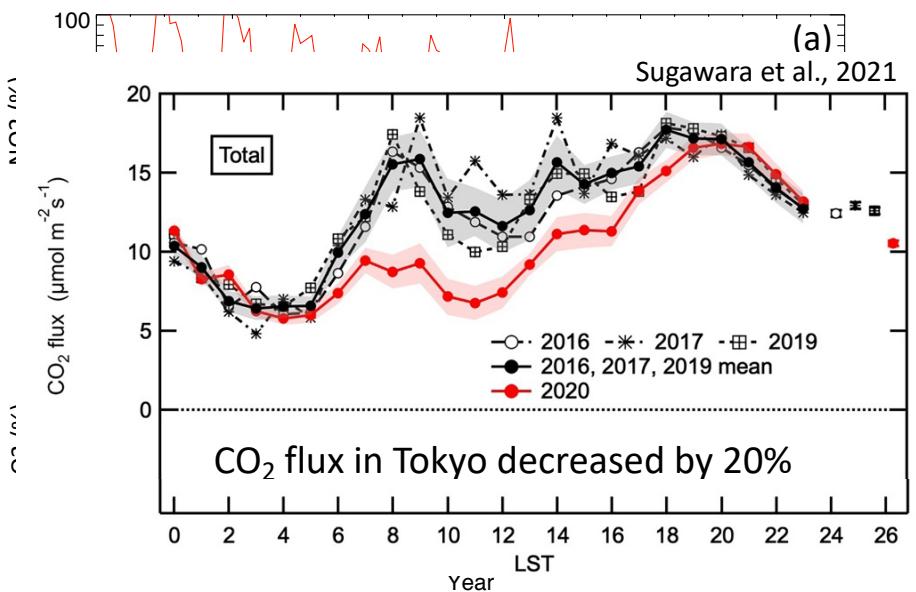
Joining optical properties from the MAX-DOAS and sky radiometer instruments to reproduce the variability of the aerosol concentration



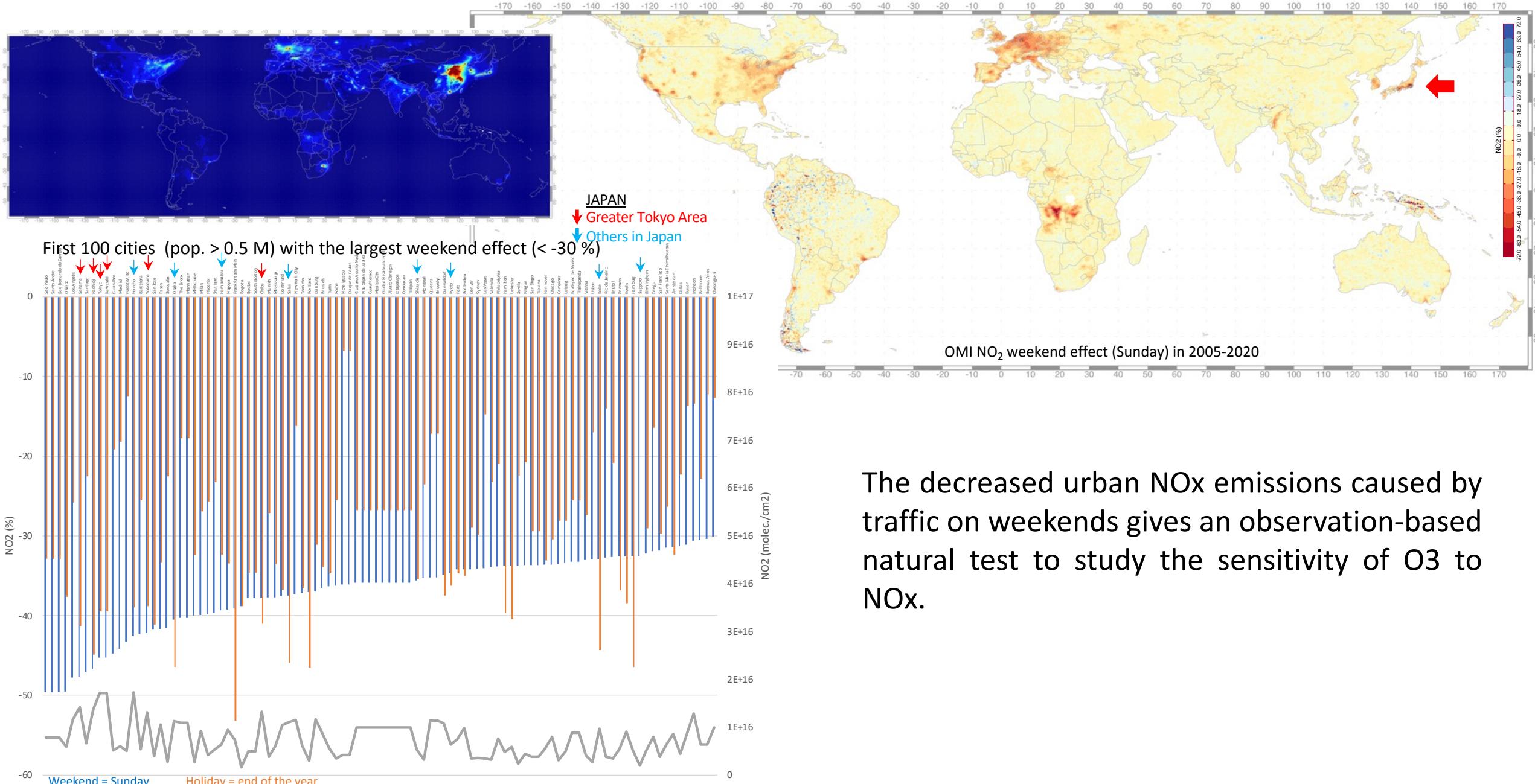
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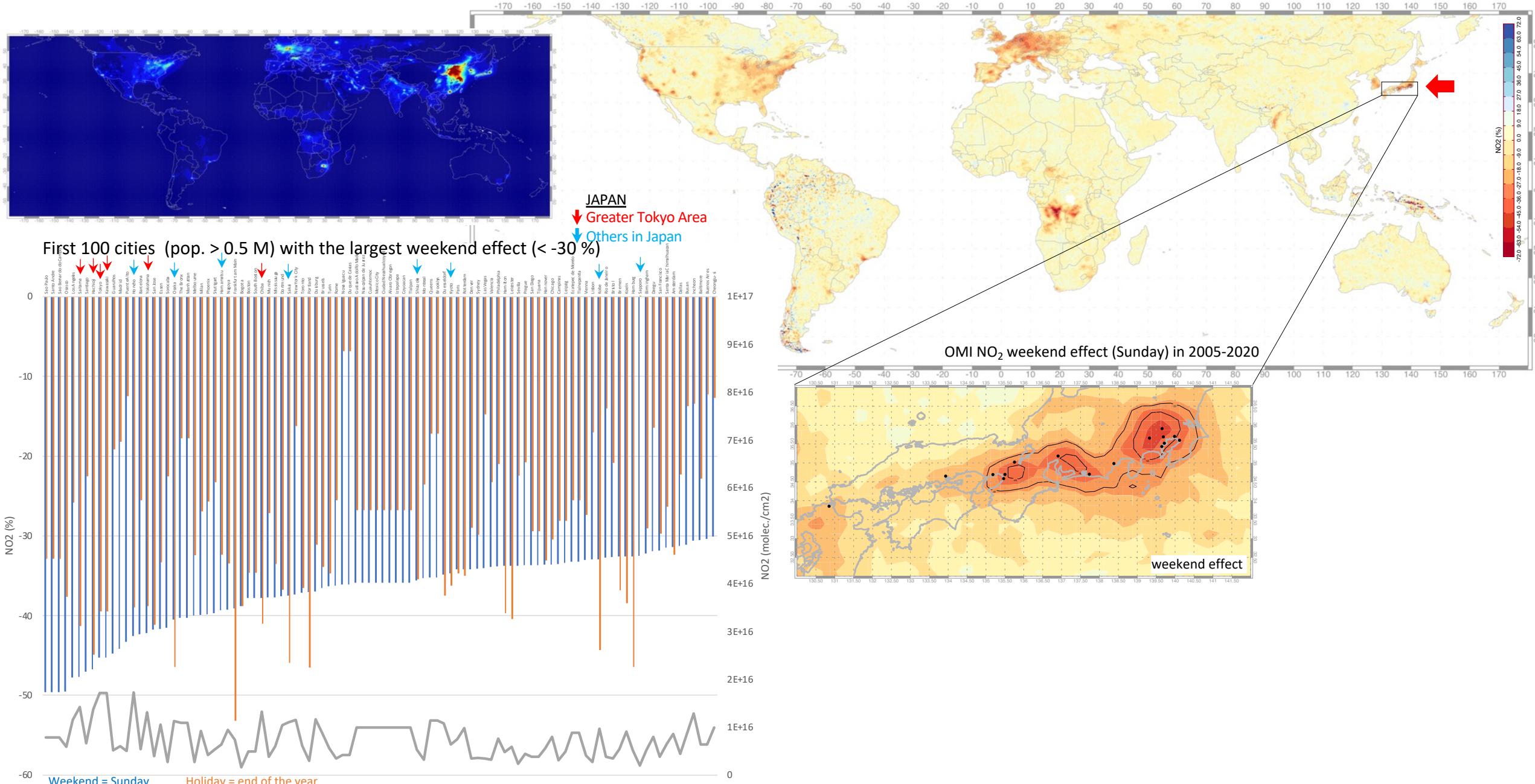
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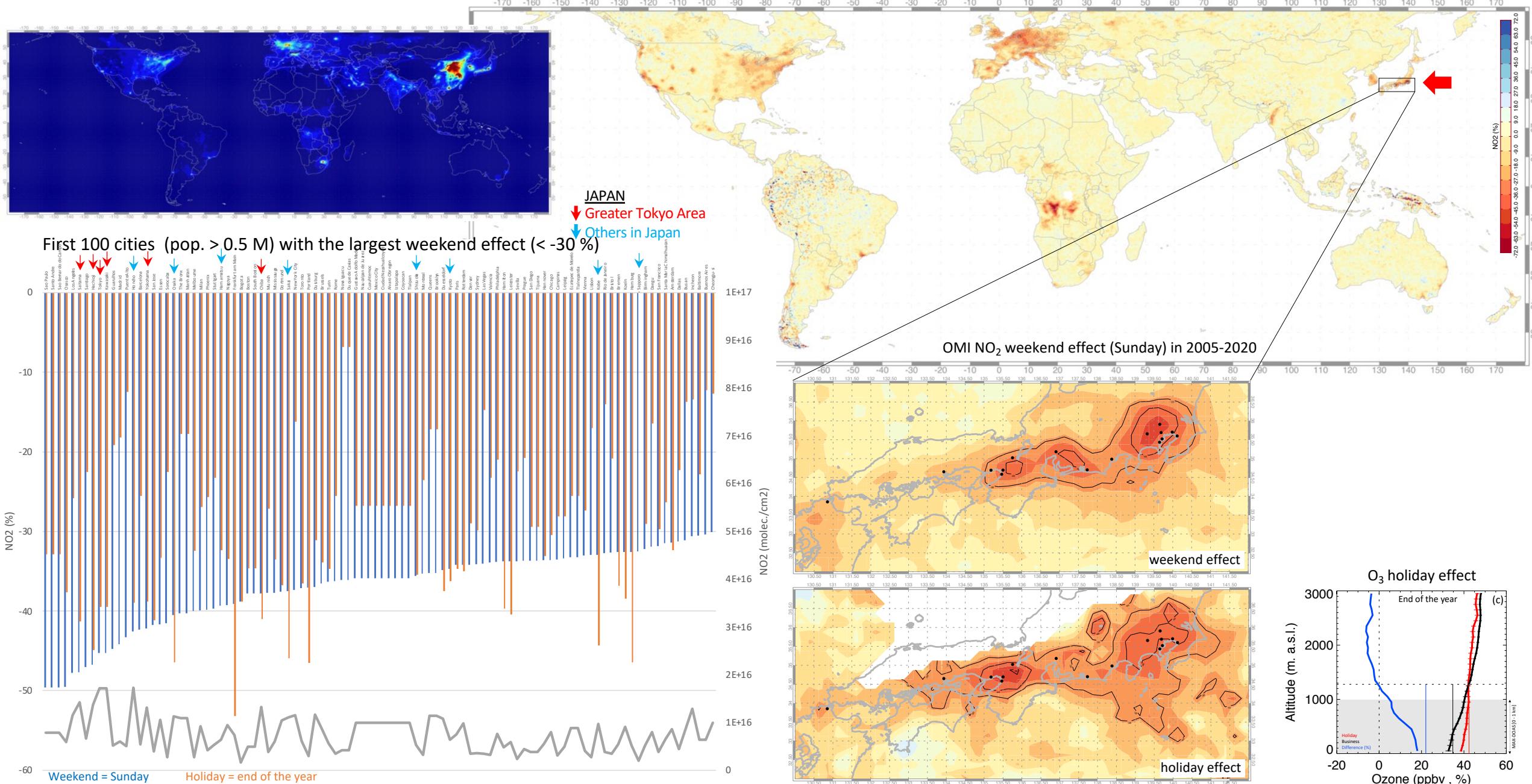
# Why does examining the weekend effect (WE)?



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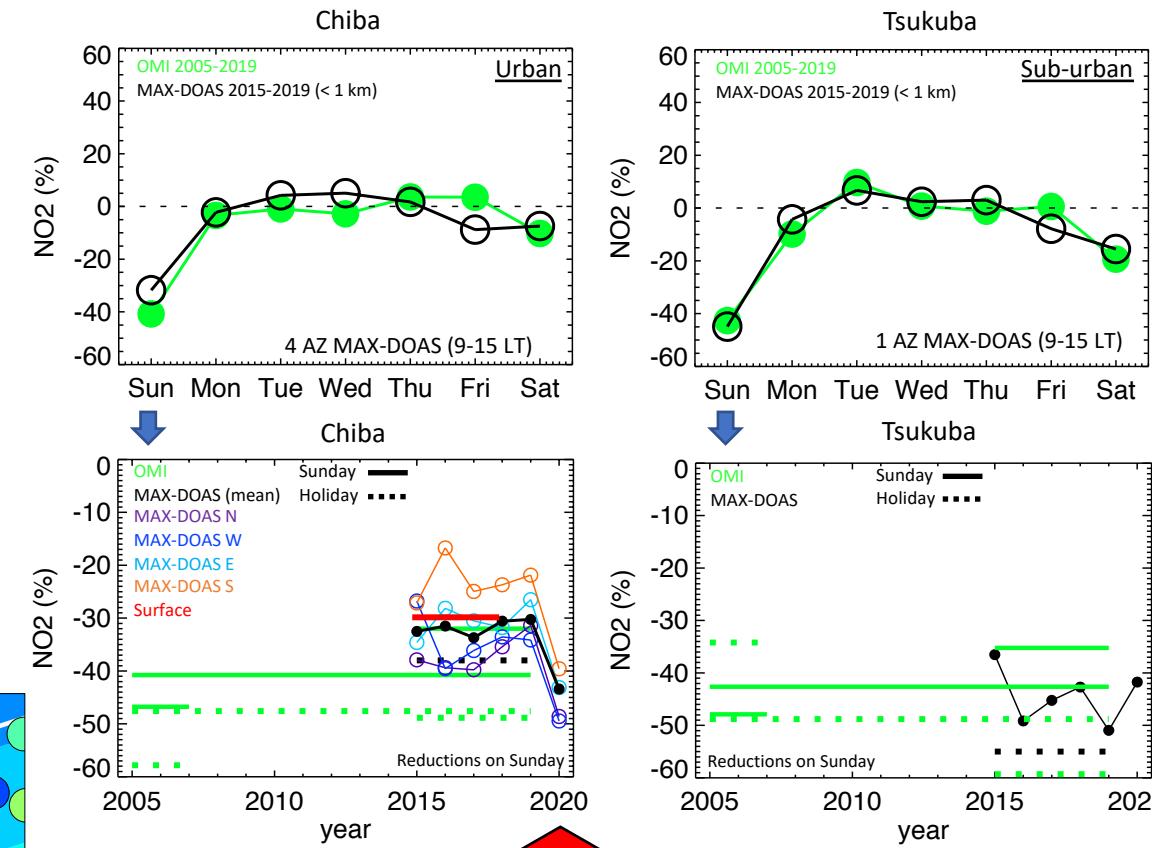
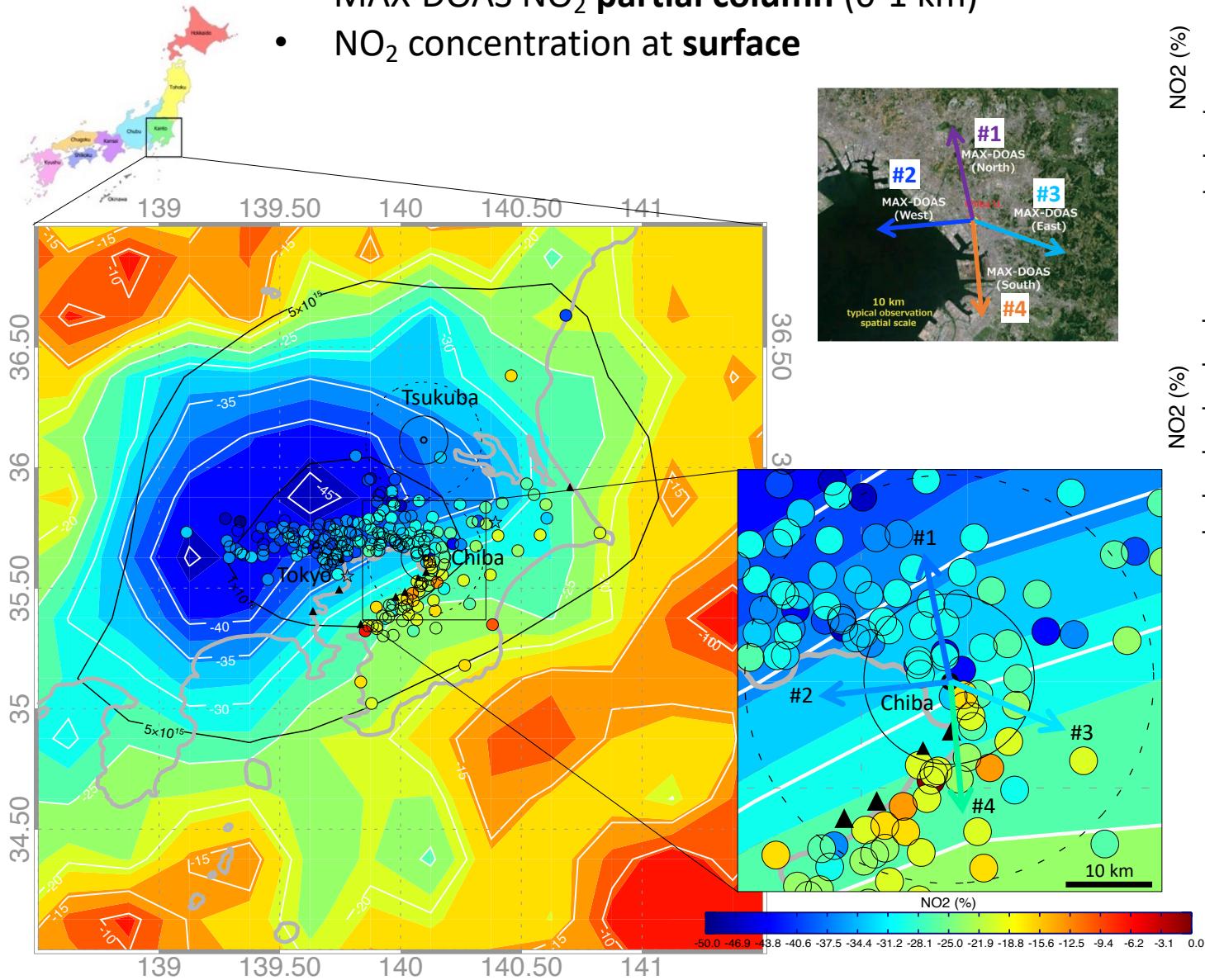


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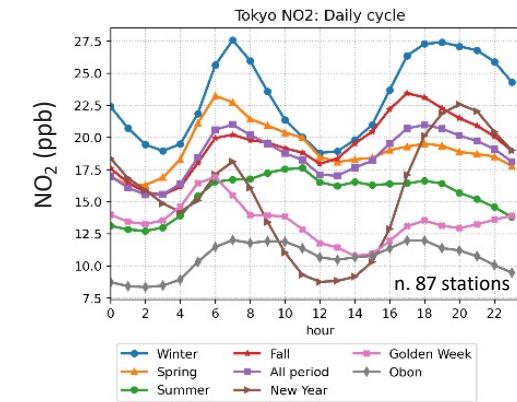


# NO<sub>2</sub> weekend effect (WE) in 2015-2018: surface, partial and trop. column

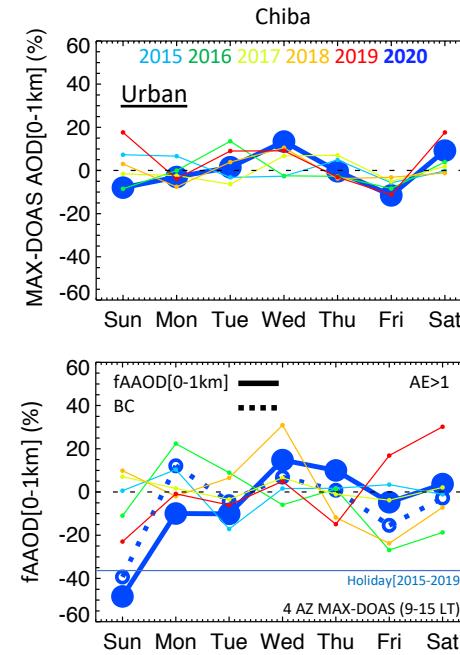
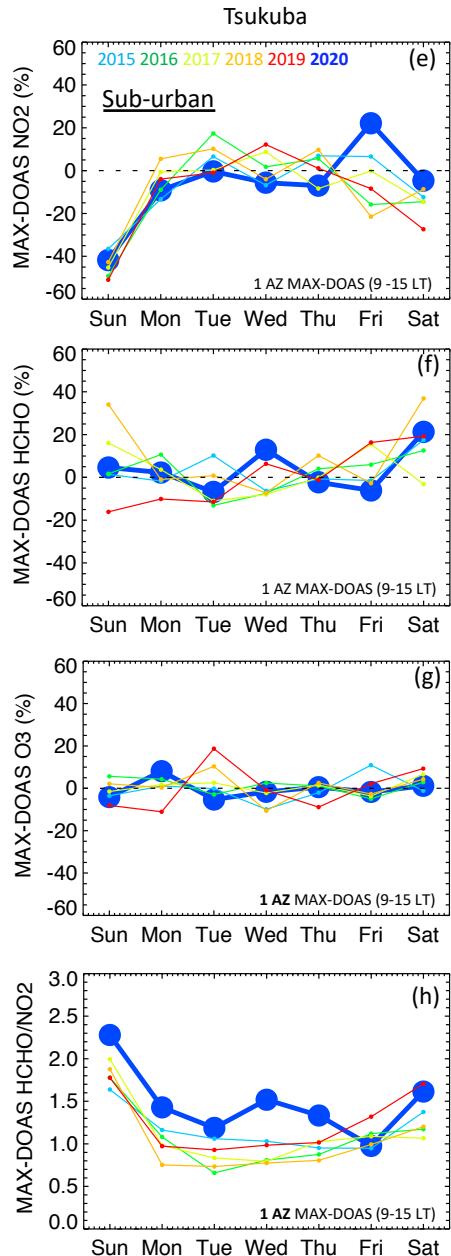
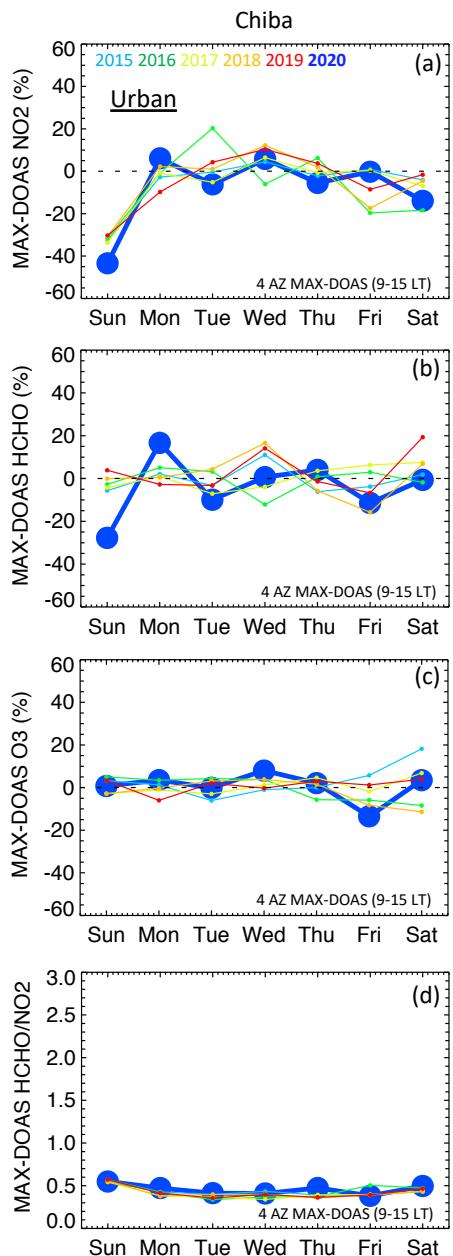
- OMI tropospheric NO<sub>2</sub> **column**
- MAX-DOAS NO<sub>2</sub> **partial column** (0-1 km)
- NO<sub>2</sub> concentration at **surface**



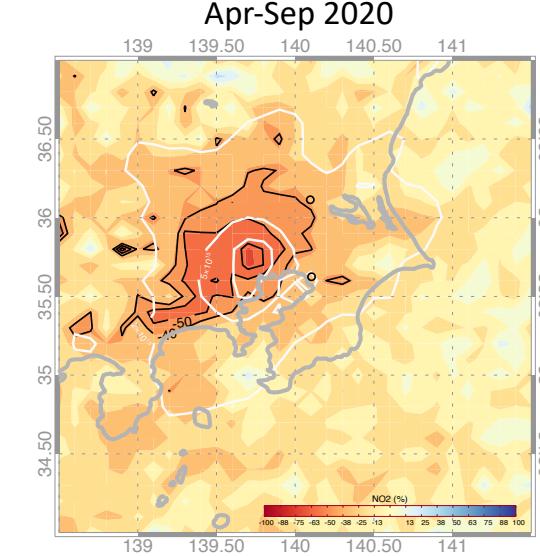
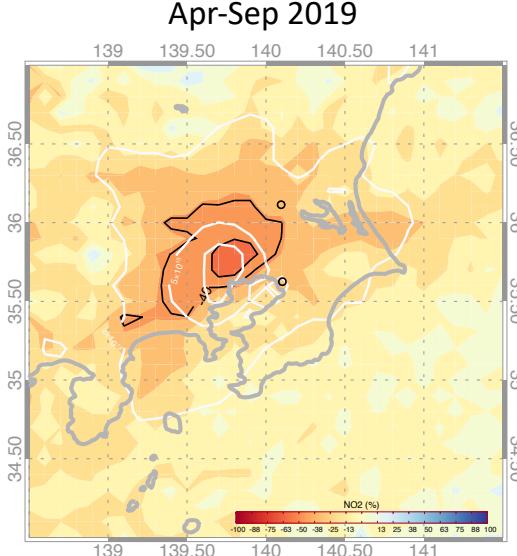
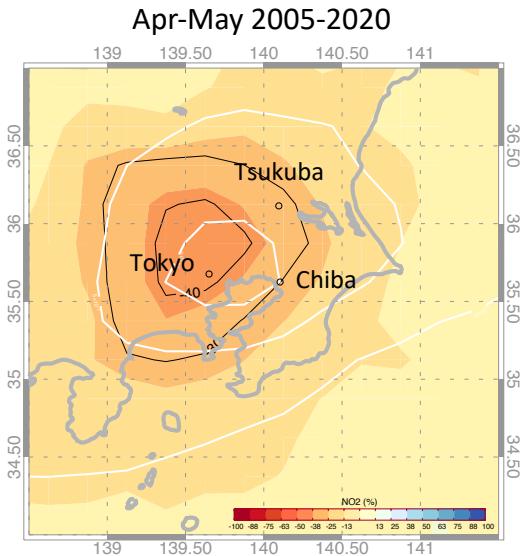
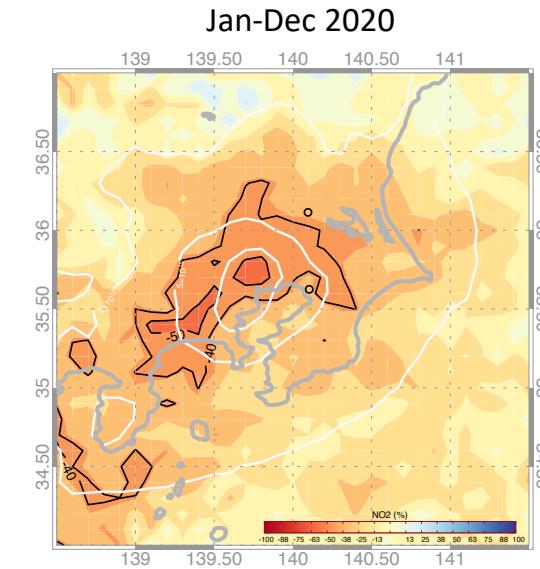
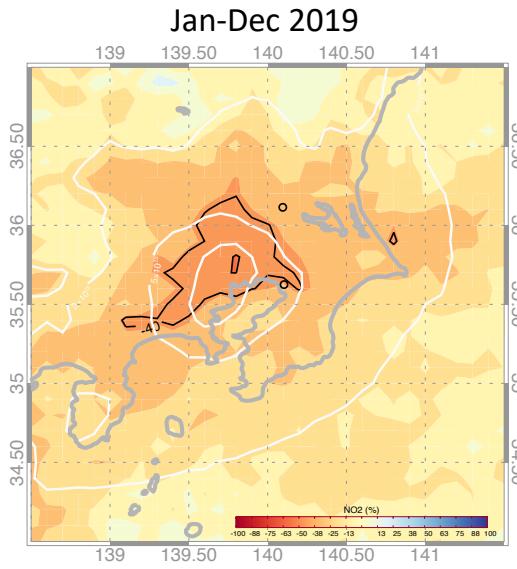
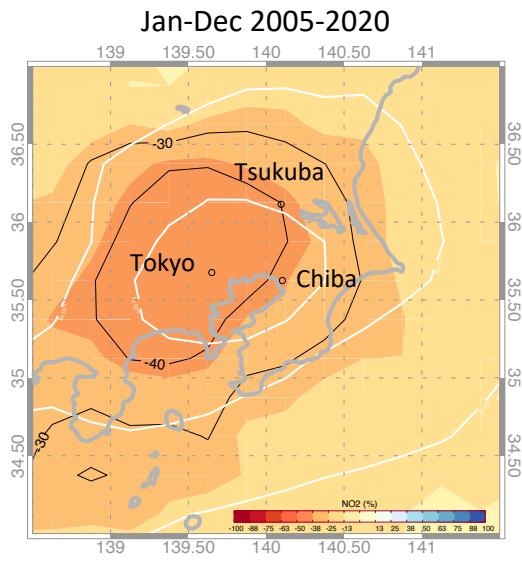
Decreasing trend in OMI NO<sub>2</sub> WE (e.g., Stavrakou et al, 2020). Despite the lowest NO<sub>2</sub> levels in 2020, the WE in 2020 was larger than that of previous years.



# $\text{NO}_2$ , HCHO, O<sub>3</sub> and fAAOD weekend effect (@0-1km)



# OMI and TROPOMI NO<sub>2</sub> weekend effect



# Conclusions

- We analyzed the variability (i.e., trends & weekly cycles) in  $\text{NO}_2$ ,  $\text{O}_3$ , HCHO, and light-absorbing aerosols from multiple platforms in the Tokyo region looking for the impact of COVID-19.
- $\text{NO}_2$  and absorbing aerosols in 2020 were the lowest on records, but the potential COVID-19 impact was superimposed on a decreasing trend. No changes in  $\text{O}_3$  and HCHO partial columns were found.
- During the “lockdown”,  $\text{NO}_2$  decreased by about 25 % compared to the same period of 2019.
- Agreement among the  $\text{NO}_2$  weekend effect (WE) at surface, partial and tropospheric column.
- Despite the lowest  $\text{NO}_2$  levels in 2020, the  $\text{NO}_2$  WE in 2020 was larger than that of previous years.
- WE in HCHO and fAAOD were identified only in 2020 by ground observations. No change in MAX-DOAS  $\text{O}_3$ .
- In Japan, mobility reduction in 2020 was smaller than that of western countries. Nevertheless, the reduction in weekend mobility was even more significant than that of business days. In contrast, western countries mostly showed the opposite behavior. It suggests a larger reception of the recommendations to limit the spread of COVID in Japan despite the lack of legal restrictions.