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Supporting Information for

# Assessing the impact of Corona-virus-19 on nitrogen dioxide levels over southern Ontario, Canada

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## Introduction

Supplementary material for "Assessing the impact of Corona-virus-19 on nitrogen dioxide levels over Southern Ontario, Canada" by D. Griffin et al. This document contains further details about the methodology used in this study to determine the alternative air mass factors (AMFs). Figures that help with the interpretation of the results, but could not be included in the main manuscript (due to size limitations) are also included here.

**Text S1.**

**Alternative Air Mass Factors**

The information on the NO2 profile shape is taken from ECCC's operational regional air quality forecast model; the Global Environmental Multiscale - Modelling Air-quality and Chemistry (GEM-MACH). The operational version of the model (Moran et al, 2010; Pavlovic et al., 2016; Pendlebury et al, 2018) has a 10x10km$^2$ grid cell size for a North American domain and considers 41 gas-phase chemical species a 2-size bin particulate matter (PM) size distribution, and 8 PM chemical species (sulphate, nitrate, ammonium, black carbon, primary organic matter, secondary organic matter, sea-salt, and crustal material). The meteorological component of GEM-MACH is within the physics module of the Global Environmental Multiscale (GEM) weather forecast model (Coté et al., 1998; Girard et al., 2014). Further details on GEM-MACH can be found in, e.g., Makar et al. (2015a,b), Gong et al. (2015, 2018), and Akingunola et al. (2018).

The operational forecast makes use of 2013 Canadian and 2017 projected U.S. emissions information (Zhang et al., 2018; Moran and Ménard, 2019). The emissions used in the model are processed using the Sparse Matrix Operator Kernel Emissions (SMOKE; Coats et al., 1996; Houyoux et al., 2000).

Here, we use the hourly model output for the closest hour of the measurements and the closest grid-box of the 10 km resolution version of GEM-MACH. The TM5-MP model used for the standard TROPOMI product has global coverage but with coarser horizontal spatial resolution (1°x1° , or about 111 x 80 km$^2$ at 44°N) and thus will be unable to capture fine-scale spatial gradients in the NO2 profile distribution, due to very localized enhancements. This performance can be improved by using input from regional models. To generate an improved a priori NO2 profiles, we use the NO2 concentrations from 0-1.5 km from the GEM-MACH model for the closest hour of the TROPOMI overpass. Between 1.5-12 km we use the concentrations from a monthly GEOS-Chem model run at the approximate time of the TROPOMI overpass on a 0.5$^0$x0.67$^0$ resolution version v8-03-01 (http://www.geos-chem.org) (Bey et al., 2001; McLinden et al., 2014), as the GEM-MACH model currently does not include NOx sources in the free troposphere, such as lightning and aircraft emissions at cruising altitude.

MODIS provides white-sky albedo (WSA) and black-sky albedo (BSA), based on 16-day averages available every 8 days, at a resolution of 0.05$^0$x0.05$^0$ (collection 6.1 MCD43C3; Schaaf et al., 2002). From this, a monthly-mean albedo is computed considering only 100 % snow-free pixels. For surfaces with snow-cover, a climatology of the MODIS surface reflectance is used that only includes pixels with full snow-cover. To determine whether the TROPOMI pixel is snow covered, we use the daily IMS snow flag (http://www.natice.noaa.gov/ims/) on a on a 4x4 km$^2$ resolution. It has been shown that the IMS product is better suited than other snow-products in differentiating between snow and snow-free scenes (Cooper et al., 2018), including the NISE snow flag used for the standard TROPOMI product that has a tendency of missing thin snow layers (McLinden et al., 2014). The MODIS snow albedo shows that the value over snow and ice is not necessarily 0.6 as assumed for the original TROPOMI product. For many areas in North America this can be as high as 0.9, however, over the boreal forest the reflectance is relatively low (0.2-0.3) even with snow cover.

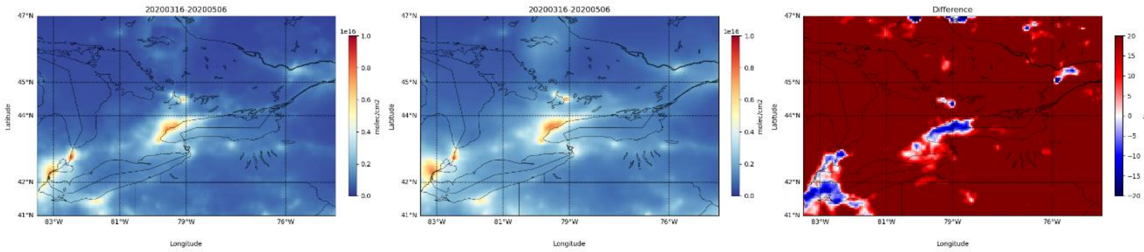


**Figure S1**. Impact of the sampling on the averaged TROPOMI columns. Model VCDs (a) filtered (like TROPOMI with qa>0.75) and (b) unfiltered (still sampled like TROPOMI) NO2 VCDs over southern Ontario averaged over the lockdown time period, 16 March - May 6 for 2020. Panel (c) shows the difference (in %) between panels (a) and (b).

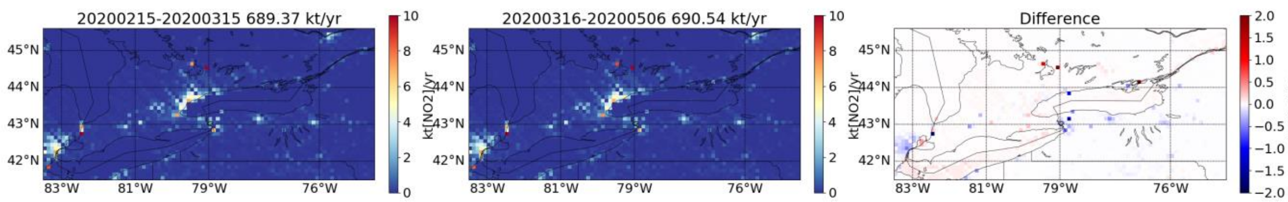


**Figure S2**.Shown are the operational forecast model's seasonal emission changes from the pre-lockdown versus lockdown period. Over the whole domain there is little change, however, in some area emissions decrease and in other increase slightly. The emissions shown here are the averaged emissions between 18-21 UTC.

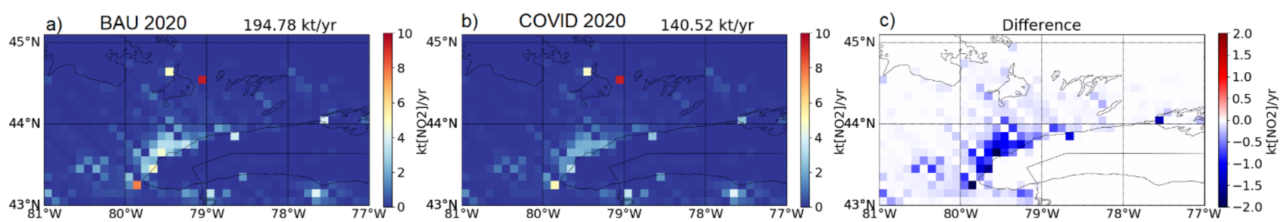


**Figure S3**. The model input $NO_x$ emissions, binned to 0.1⁰x0.1⁰, in the southern Ontario for (a) the 2020 business-as-usual emissions scenario and (b) the 2020 lockdown emissions scenario, assuming: (i) a 30% reduction in industry, (ii) a 60% reduction for traffic, (iii) 80% reduction in aircraft, and (iv) 20% increase of residential fuel combustion. The emissions shown here are the averaged emissions between 18-21 UTC.

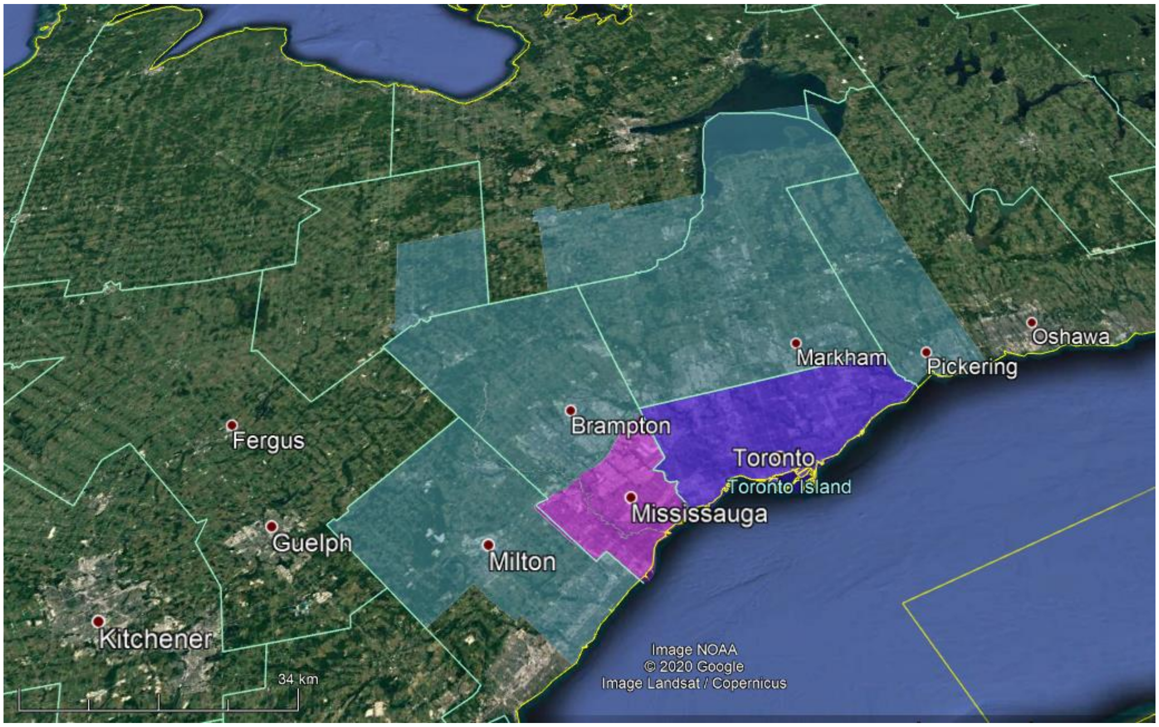


**Figure S4**. Boundaries of the Greater Toronto Area (GTA), shaded in grey. The Toronto and Mississauga city boundaries (used for the time series) are highlighted in violet and magenta, respectively.

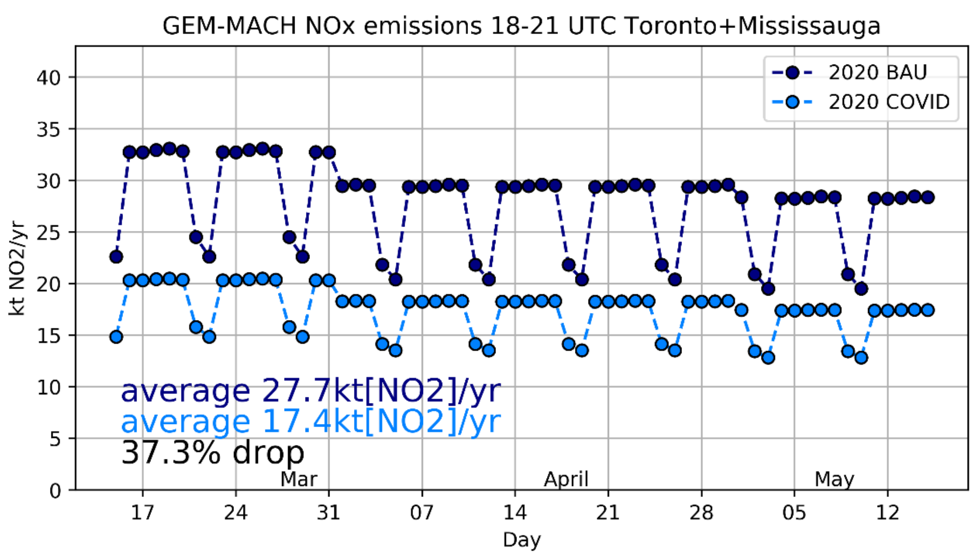


**Figure S5**. The model input $NO_x$ emissions summed over the Toronto and Mississauga city boundaries, for the 2020 business-as-usual emissions scenario (navy) and the 2020 lockdown emissions scenario (blue), assuming: (i) a 30% reduction in industry, (ii) a 60% reduction for traffic, (iii) 80% reduction in aircraft, and (iv) 20% increase of residential fuel combustion. The emissions shown here are the averaged emissions between 18-21 UTC. Input emissions differ by day of week and by month.

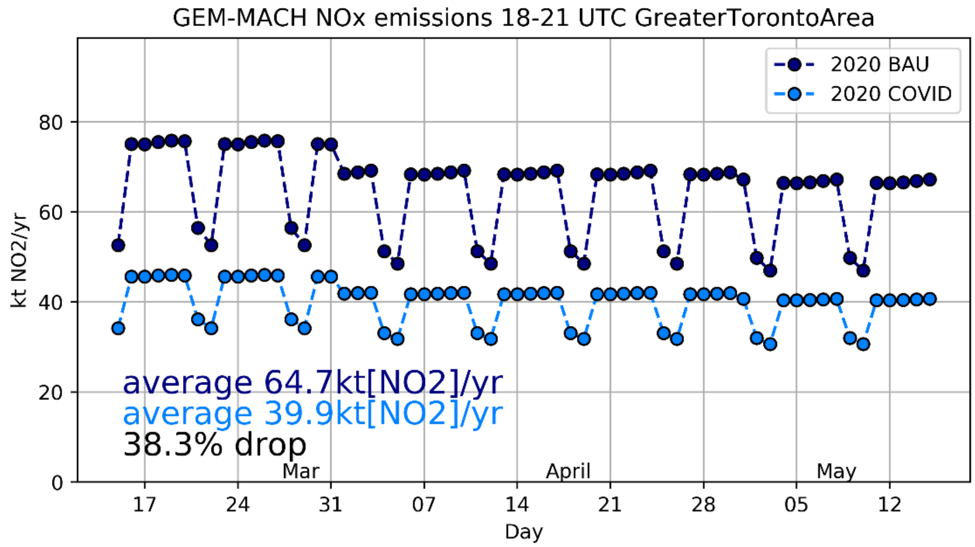


**Figure S6**. The model input $NO_x$ emissions summed over the Greater Toronto Area (GTA, as shown in Figure S4), for the business as usual scenario (navy) and the lockdown scenario (blue), assuming: (i) a 30% reduction in industry, (ii) a 60% reduction for traffic, (iii) 80% reduction in aircraft, and (iv) 20% increase of residential fuel. The emissions shown here are the averaged emissions between 18-21 UTC. Input emissions differ by weekday and month.