Author's response

Dear Editor,
Thank you for reviewing our manuscript number ESS-2021-2018. We have gone through all the referee's commentaries and adjusted the manuscript accordingly. After this paragraph you will find our responses. The style used in the response letter is the following: the original general comments made by the referee are kept in normal text (initiated with R), our responses are *in blue italics initiating with A* (Authors). The corresponding edit in the manuscript will be included in red.

Referee comments 2 (RC2)
Anonymous Referee #2, 13 Sept 2021

R2: This manuscript presents a description of a Chilean high resolution gridded emission inventory of road transport exhaust emissions for the period 1990–2020, as well as a comparison against the emissions reported by the EDGAR inventory. As stated by the authors in the introduction section, the availability of high-resolution emission inventories in Chile that are consistent, updated and cover a long period of time is currently limited. Therefore, the dataset presented in the manuscript if of interest and a good contribution to ESSD. I recommend the manuscript to be published once the following comments have been addressed:

R2: Title of the manuscript: I would suggest to rephrase the title from "High-definition spatial distribution maps of (···)" to "High-resolution spatial distribution of (···)" as it is more frequently used in the scientific literature.

A: The title has been modified according to the suggestion.

R2: Vehicle fleet composition: According to the authors, information on the vehicle fleet composition per political region is obtained from official government data. Is this source of information reporting data on registered vehicles or the actual "in-use fleet" (i.e., on-the-road or circulating fleet)? Several studies have highlighted strong discrepancies between registered and in-use vehicle fleet compositions. Official vehicle registries can suffer from certain limitations, including: i) they may include vehicles that have been scrapped (or that are registered but hardly being used) and ii) they include information regarding where the vehicles are registered but not where are actually driven. How did the authors overcome these limitations? Please provide an explanation.

A: Data provided by INE corresponds to annual registration of vehicles, i.e., the vehicles that each year pay their circulation permit after having approved the annual technical revision. We added this explanation to the methodological section, in sub-section 2.1.

Using annual registration of in-use vehicles partially solves the problem of deregistration and scrapped rate for each vehicle cohort. However, some of the vehicles with annual circulation permit may be not used, may have very low circulation rates or may be used in a different region of that of their register. To consider these issues, we contrasted calculated fuel consumption (TFC) with real fuel sales by region (line 155), and used a correction factor to adjust the number of registered vehicles in each region, as explained in sub-section 2.2 of the methodology.

R2: Total Fuel Consumption (TFC): Could you provide a figure (or summary table) that shows the results of the comparison between calculated TFC and reported fuel sales for each region? This would allow understanding better the discrepancies between the two datasets.

A: Figure 2 has been added to the main text, showing the difference between official fuel sales and estimated total fuel consumption, for gasoline and diesel.

R2: Spatial distribution: Could you provide a reference for the toll barrier vehicle counts used for computing the average road weight factors? Could you provide a summary table with the shares regarding the distribution of vehicles into urban and interurban activity per region? Perhaps this information could be included as part of Table 3 (Annual activity level not only per region and vehicle type but also discriminated between urban and interurban).

A: The reference (MOP, 2020) was added (line 212, page 10) and the official link has been included at the References section.

R2: Emission factors: Authors use the emission factors reported by COPERT 5, which is a vehicle emission calculator originally developed for Europe. Can the authors say something on how precise is COPERT in reflecting the Chilean fleet and driving conditions? Is there any database of measured local emission factors that could be used for comparison purposes?

A: Unfortunately, Chile does not have a robust database of local emission factors covering all existing vehicle technologies and driving conditions. There are some local measurements using dynamometer facilities as well as portable emission measurement systems, but not enough for supporting a national emission model, particularly for newer technologies such as EURO 5/6. The Chilean homologation process allows both US and Europe-based emission standards, but most of the vehicles are certified with EURO standards. For this reason, COPERT has been accepted as an appropriate international model by Chilean researchers and authorities (Osses, 2010; MMA, 2014; Osses, 2014; Tolvett, 2016; Gallardo, 2018; Mazzeo, 2018; Huneeus, 2020).

R2: Cold-start emissions: Are cold-start emissions included in the inventory? These type of exhaust emissions could be significant in certain regions of the country during winter time. Please specify.

A: Cold-start emissions effect was not considered and this was added to the conclusions regarding limitations of the dataset, as proposed by the Reviewer.

R2: Comparisons with EDGAR (1): At the beginning of section 3.2.4, authors mention that they performed a comparison between INEMA and EDGARv4.3.2. However, it looks to me that the comparison is done against EDGARv5.0, as v4.3.2 reports emissions only until 2012, and v5.0 up to 2015. Please specify and correct if needed.

A: The observation is correct; the dataset corresponds to EDGARv5.0 and it has been corrected through the text and references. The following references where updated:

Crippa, M., Guizzardi, D., Schaaf, E., Solazzo, E., Muntean, M., Monforti-Ferrario, F., Olivier, J.G.J., Vignati, E.: Fossil CO2 and GHG emissions of all world countries - 2021 Report, in prep.

Crippa, M., Solazzo, E., Huang, G., Guizzardi, D., Koffi, E., Muntean, M., Schieberle, C., Friedrich, R. and Janssens-Maenhout, G.: High resolution temporal profiles in the Emissions Database for Global Atmospheric Research. Sci Data 7, 121 (2020). doi:10.1038/s41597-020-0462-2.

R2: Comparisons with EDGAR (2): The discrepancies between the emission trends reported by INEMA and EDGAR are quite significant, especially for NOx. In my opinion, it would be good to include in the comparison other state-of-the-art global emission inventories such as CEDS (http://www.globalchange.umd.edu/ceds/) or ECLIPSEv6b (https://iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv6b.html), in order to see if their trends match better with the one reported by INEMA. Moreover, both CEDS and ECLIPSE report emissions up to more recent years (e.g., 2019).

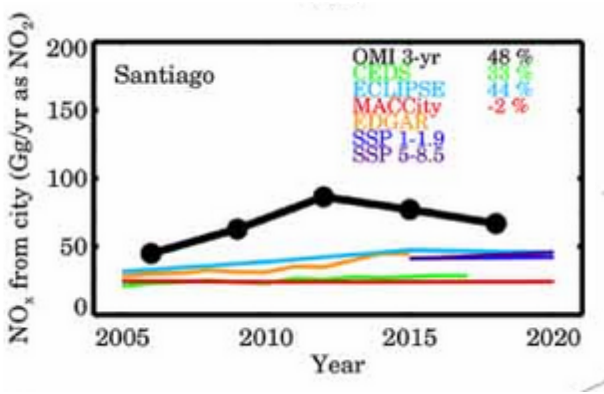
A: We appreciate the comment since we fully agree it is important to reinforce the comparison analysis. Thus, in addition to EDGAR, CEDS and CAMS datasets for Chile have been included in section 3.2.4, with extended comments explaining similarities and differences. Additionally, the official inventory reported by the Chilean government for GHG (INGEI) and a national estimate of transport emissions using LEAP model have been added to the comparison analysis. In summary, our emission inventory for exhaust on-road transportation emissions (INEMA) is compared with two local national inventories (INGEI, LEAP) and three global models (EDGAR, CAMS, CEDS).

R2: Comparisons with EDGAR (3): Regarding the discrepancy between the NOx emission trends reported by INEMA and EDGAR, and considering that road transport is the main contributor to total NOx emissions, perhaps it would be interesting to contrast these results against the evolution of NO2 concentrations in traffic stations for the same period of time (i.e., 1990 to 2015). These would allow seeing if NO2 concentrations show a positive or negative trend (or if concentrations remain unchanged) and subsequently if they correlate better with the trend reported by INEMA or EDGAR.

A: Thank you for the suggestion. Unfortunately, the air quality monitoring network along continental Chile (https://sinca.mma.gob.cl/) does not provide a national coverage of nitrogen dioxide data. Stations outside Santiago do not provide NO2 except for a few sites, and the period covered in those sites is too short to establish long-term trends. Except for mass concentrations of particles, and to some extent sulfur dioxide, the coverage is poor for other pollutants. Another issue is identifying traffic dominated stations. Stations are placed to monitor the compliance of air quality standards set for protecting human health, and not for process understanding. One could try to minimize the effect of residential sources by considering summer values, and rush hours to capture traffic emissions (See Gallardo et al, 2012). This would be feasible but for a few places, and that would not be particularly helpful identifying national emission trends. In previous work, Menares et al (2020) analyzed NO2 trends from in situ data in Santiago and found increasing trends for the period 2001-2018 over Eastern Santiago, which the authors attribute to changing photochemical regimes.

In a recent work, Goldberg et al (2021) estimated urban NOx emissions trends for the period 2005-2019 using satellite borne measurements of the NO2 column. Over Santiago they infer increasing emission trends between 2005 and ca. 2012 and declining trends thereafter (See image extracted from the paper). Previously, Duncan et al (2016) estimated a very high trend (30±17%) in the NO2 column as observed from the Ozone Monitoring Instrument (OMI), in some agreement with in-situ data (Menares et al, 2020). The same data but considering the period between 2005 and 2020 results in a small and insignificant trend (-3.13±12.4%), possibly due to considering the pandemic and the political unrest after October 2019.*

Thus, all in all, at this point it appears difficult to resolve the inconsistencies in trends inferred from different data and methodologies. Regional scale modeling studies will provide further insights in the matter, but that of course, is beyond the scope of this paper.



Duncan, B. N., Lamsal, L. N., Thompson, A. M., Yoshida, Y., Lu, Z. and co-authors. 2016. A space-based, high-resolution view of notable changes in urban NOx pollution around the world (2005–2014. J. Geophys. Res. Atmos. 121, 976–996. doi: 10.1002/2015JD024121

Gallardo, L., Escribano, J., Dawidowski, L., Rojas, N., de Fátima Andrade, M., Osses, M., 2012. Evaluation of vehicle emission inventories for carbon monoxide and nitrogen oxides for Bogotá, Buenos Aires, Santiago, and São Paulo. Atmos. Environ. 47, 12–19. https://doi.org/10.1016/j.atmosenv.2011.11.051

Goldberg, D.L., Anenberg, S.C., Lu, Z., Streets, D.G., Lamsal, L.N., E McDuffie, E., Smith, S.J., 2021. Urban NO x emissions around the world declined faster than anticipated between 2005 and 2019. Environ. Res. Lett. 16, 115004. https://doi.org/10.1088/1748-9326/ac2c34

Menares, C., Gallardo, L., Kanakidou, M., Seguel, R., Huneeus, N., 2020. Increasing trends (2001–2018) in photochemical activity and secondary aerosols in Santiago, Chile. Tellus, Ser. B Chem. Phys. Meteorol. 72, 1–18. https://doi.org/10.1080/16000889.2020.1821512

** https://airquality.gsfc.nasa.gov/no2/world/south-and-central-america/santiago*

R2: Comparisons with EDGAR (4): The EDGARv5.0 emission inventory includes estimates of PM emissions from road surface wear and road vehicle tyre and break wear based on the EMEP/EEA guidebook 2019 Tier 1 approach. If I understood correctly, these sources of non-exhaust emissions are not considered in INEMA and could explain some of the discrepancies shown between the two datasets for PM. Please comment on that.

A: INEMA does not consider non-exhaust PM emissions. The results from external datasets (EDGARv5.0, CAMS, CEDS, LEAP) have been selected only for exhaust emissions from on-road transportation in Chile, assuring the comparison is based on the same source. Attending this comment, we have double-checked this analysis and there is no mixing of exhaust and non-exhaust PM emissions in the comparison.

R2: Comparisons with EDGAR (5): Figures 7, 8, 9 and 10: Please include the whole time series of the INEMA emissions (up to 2020)

A: The updated figures, with additional datasets for comparison, include the whole time series for INEMA (1990-2020).

R2: Effect of COVID-19 restrictions: the time series presented by the authors include the year 2020, which was heavily affected by COVID-19 restrictions. I think it would be very relevant to include a section discussing the results for 2020 and quantifying how they compare to the previous year (2019) (i.e., how total emissions decreased as a consequence of COVID-19). This comment is also linked to the previous one about representing the whole 1990-2020 trend in figures 7 to 10.

A: We absolutely agree. This emission model was designed and run before COVID-19 effects on mobility and does not consider 2020 reductions in emissions. However, the methodology should incorporate this disruption if the updated official figures of fuel sales are used in the calculation, but the validated 2020 National Energy Balance is not available yet. Nevertheless, there are other recent publications addressing COVID-19 effects on urban vehicle emissions and air quality in Santiago. We have included this issue as a limitation of the dataset (see next answer), offering the reader another reference were COVID-19 impacts have been studied.

R2: Conclusions: I would recommend to the authors to re-structure the conclusions section and add a new subsection entitled "Limitations of the dataset", in which they clearly state what are the limitations of the current inventory (e.g., non-inclusion of cold-start emissions, use of EU emission factors instead of local EF, ...).

A: A paragraph on limitations of the dataset has been added to the conclusions.

R2: Others (1): Replace MP2.5 for PM2.5 in the text

A: The acronym was replaced by the English version.

R2: Others (2): The reference (Gomez, 2020) is missing

A: The reference was added and the spelling corrected because it should be "Gómez"

R2: Figure 5: For clarification, I would suggest to change the units to e.g., kg/year. Also, it would be interesting to see the spatial distribution not only of the emissions in specific urban regions but across the whole country.

A: Since we are building this emission inventory for other users such as ECCAD (https://eccad.aeris-data.fr/) and the information has been uploaded as a doi dataset (http://dx.doi.org/10.17632/z69m8xm843.2), we are using Gg as a common unit for all compounds. For this reason, we consider it is better to present the data in the same format.

Regarding regional distribution, it is rather interesting, however the Metropolitan Region dominates with approximately 50% of the national emissions. We considered some approaches for including this analysis, but finally decided not to do it and we would like to maintain this decision.

R2: Figure 6: Please add a legend

A: Thanks for the observation, "same as Figure 5" was added to the caption.