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To cite this version:

Nicolas Huneeus, Claire Granier, Laura Dawidowski, Hugo Denier van Der Gon, Marcello Alonso, et al.. Anthropogenic emissions in South America for air quality and climate modelling. 2017 International Emission Inventory Conference "Applying Science and Streamlining Processes to Improve Inventories", Aug 2017, Baltimore, United States. hal-02144915

HAL Id: hal-02144915

https://hal.science/hal-02144915v1

Submitted on 23 Jul 2019

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Anthropogenic emissions in South America for air quality and climate modelling

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Abstract

A workshop was held in Santiago, Chile, in March 2017, gathering experts in emissions from different countries in South America, Europe and the USA. Current status of emission inventories in five South American countries (Argentina, Brazil, Chile, Colombia and Peru) was presented and discussed. This information will be summarized in a document that will be used to seek international funding to generate a consistent emission inventory for each one of these South American countries.

National emission inventories in South America are prepared as part of the obligations of these countries to the United Nations Framework Convention on Climate Change within the framework of their national communications. These inventories include the emissions of greenhouse gases as well as non-GHG gases subject to complementary reporting under the Convention. Several pollutants with important impact on climate change and air quality are not included in these estimates. Emission inventories developed in different Latin America (LA) countries are typically developed at national level, providing an annual total, not necessarily for all criteria pollutants and without information on spatial and temporal emission patterns. There are also inventories for a number of LA cities, particularly large urban conglomerates, but these are not necessarily consistent with the corresponding national inventories. There is need to harmonize these estimates, and to fill the gap associated with the knowledge of spatially distributed and temporally disaggregated emissions. A network was established between members of the LA Emissions Inventory Group (LAEIG) from five countries (Argentina, Brazil, Chile, Colombia and Peru) and international researchers with the aim to build a consistent and shared emission inventory in the near future for these five countries.

1. Introduction

In order to be able to forecast and analyze air quality and climate at regional scales, accurate and detailed emissions are required. Up to now, there are no regional inventories providing anthropogenic emissions for the different countries of South America. A workshop was held in Santiago, Chile, in March 2017, gathering experts in emissions from different countries in South America, Europe and the USA. The status of the development of emission inventories in five South American countries (Argentina, Brazil, Chile, Colombia and Peru) was presented and discussed.

The presentation will provide information on existing datasets or available information on anthropogenic emissions for several countries in South America. Plans for developing a dataset covering the entire South American region will be discussed. Finally, we will also provide information on a new international project funded by the European Commission, where scientists from Europe and South America will work together to develop an air quality forecasting system for the region, which will include the development of surface emissions.

2. Emissions data in several South American countries

Chile

Chile has established a plan for reducing air pollution, which has motivated the development of emissions inventory for this country. Geographical areas with different problems related to atmospheric pollution have been defined, and a detailed plan for improving air quality in these regions for the 2014-2018 period has been published: some areas like North and Central Chile have very large sources of PM_{10} and SO_2, as a result of mining and power generation activities. In Central Chile, large and medium-size urban areas have a variety of sources. In the Central and Southern regions of Chile, large areas see an intensive use of firewood. A Pollutant Release and Transfer Registry (RETC) has been defined, which contains information on emissions and transfer to the environment of potentially harmful chemicals.

Detailed emissions are now available for the city of Santiago. For other regions or cities, official emission inventories have been developed only for a limited number of species. Emissions are available for the region of Santiago at a resolution of 1x1 km, for several chemical compounds.

The evaluation of the accuracy of the emissions is performed using observations and modeling, and includes inverse modeling at the city scale. An example of this work is given in Figure 1, which shows the CO to NOx ratio in the emissions from surface measurements in Santiago and emission inventories: large differences are seen between the observations and the ratios provided by the inventories, which seem to be due to an overestimate of emissions of NOx in Santiago. These differences could also be due to large uncertainties on emission factors for CO and on activity data for NOx.

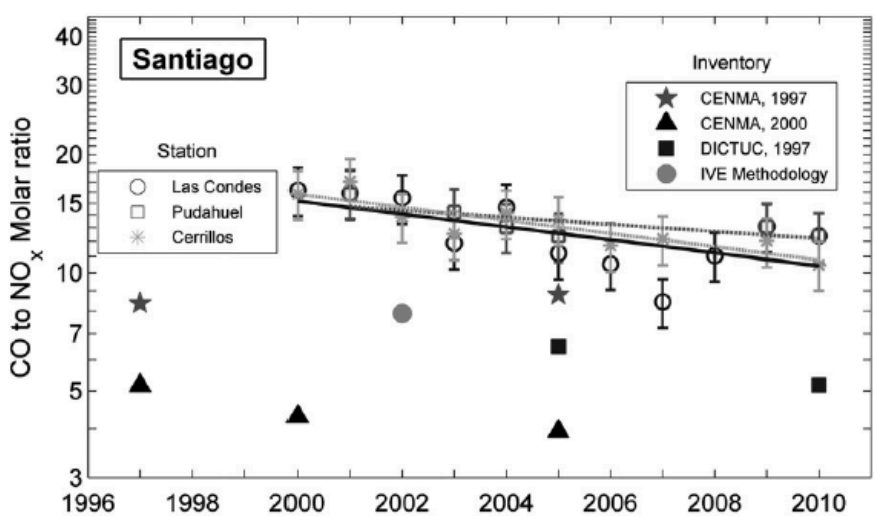

Figure 1: CO to NOx emission ratio on a logarithmic scale from observations and emission estimates for Santiago (Chile).

Satellite retrievals provide interesting data for emission validation, and work is being done in Chile coneerning the evaluation of emissions as well as the improvement of emissions using inverse modeling. However, retrievals involve assumptions that must be checked, such as surface reflectivity data, or vertical profiles that are difficult to quantify over complex terrain. It should also be mentioned that a large area of South America shows a persistent anomaly resulting in very noisy signals for SO2.

Future work for improving emissions in Chile includes an inventory of the emissions of black carbon, and a better quantification of the emissions from mining activity in the Andes, of emissions from biomass burning and from maritime transportation.

Argentina

Emissions data are collected and analyzed by different groups in Argentina, from universities, laboratories and private companies. These groups collect ancillary data as well as emissions information, check time series consistencies, verify and evaluate the data and work on the chemical characterization of the emissions. Spatial disaggregation of the emissions and analysis of the different drivers is also achieved.

Government agencies in Argentina focus mostly on greenhouse gases, i.e. CO_2, CH_4 and N_2O. Emissions for active compounds and particles are developed in universities, laboratories and consultants.

Emissions for the chemical compounds responsible for ozone pollution are available, as well as emissions of particulate matter, ammonia, SO_2 and BC, for a large number of emission sectors. Emissions from vegetation burning, i.e. forest fires, savanna burning and grassland fires, and from agricultural waste burning are also available.

Emissions have been developed for the different provinces in Argentina. Detailed information at a high spatial resolution is also available for the largest cities in Argentina; Buenos Aires and another large city, Mendoza. The spatial distribution of the emissions among the provinces and in the largest cities is based on indicators such as population and satellite imagery, such as night lights. Weekly and diurnal profiles are also available.

Information to analyze the temporal changes in emissions is available since the 1970s, and shows the impact of changes in the use of fuel, from liquid fuels in the 1970s, to the implementation of hydrology and nuclear for energy generation, followed by the use of natural gas, and more recently an increase in the use of liquid fuels.

Different measures are planned in the industry and transportation sector, including the use of biofuels (biodiesel and bioethanol), a better efficiency in heavy duty trucks, the replacement of old gasoline vehicles etc.

Over the past years, work has been done in the field for a better determination of emissions factors, for example for the emissions of N2O from soils, the emissions of NOx from power plants, or the emissions from on-road vehicles, etc.

Brazil

Government agencies have developed emissions inventories for greenhouse gases in Brazil. Different regions and cities of Brazil, as well as laboratories and universities have developed inventories for species contributing to atmospheric pollution.

A specificity of Brazil is the important usage of alcohol in the fuel used for vehicle transportation. For example, in Sao Paulo, alcohol represents about 55% of the fuel burned. Furthermore, the average age of the fleet is quite old, with about 50% of the cars older than 20 years in Sao Paulo. In the recent years, although the number of vehicles that can burn ethanol has increased (flex-fuel vehicles), the concentration of aldehydes has not increased (the use of ethanol has decreased).

An urban emissions inventory for South America has been developed by Alonso et al. (2010). It is based on available inventories for cities in Brazil as well as in other South American countries. As shown in this paper, there is a limited number of available local inventories: in order to develop the inventory for urban sources in the whole of South America, urban emissions were extrapolated using correlations between city vehicle density and mobile source emissions of CO and NOx. The resulting emissions for CO on a 20x20km grid are shown in Figure 2.

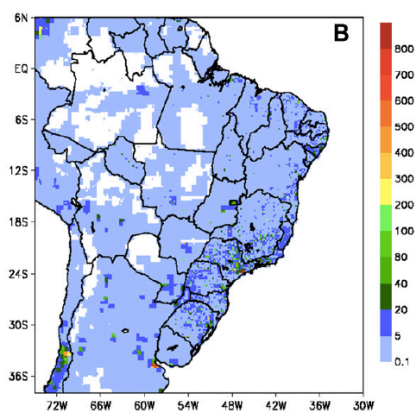

Figure 2: Emissions of CO (in 10^{-6} kg/m^2/day) at a 20 km grid

Emissions can be evaluated using surface observations, through the data provided by automatic stations installed in many cities. Concentrations of NO_x and CO have decreased significantly since the year 2000, as well as PM10 emissions. This reflects the actions by the Brazilian government and the state of São Paulo who have taken progressive actions since the 1980s to curb air pollution, starting with programs to control sulfur dioxide from industrial sources and followed by nationwide standards for cleaner vehicles and fuels. For example, a program to control vehicular emissions was established in 1983, followed by a program in 2003 to regulate motorcycle emissions.

Emissions are available at a high spatial resolution from some cities, using different proxies. For example, gridding of emissions in the region of Sao Paulo are obtained using geographic information from the Open Street Maps dataset. Figure 3 shows an example of the emissions of CO from traffic at 8:00 p.m. in the São Paulo region.

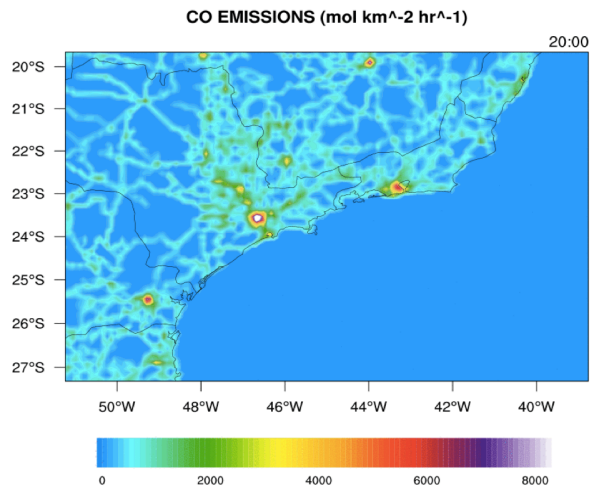

Figure 3: emissions from traffic in the evening in the Sao Paulo region

Several sources are not accounted properly in current inventories in Brazil, such as vehicle evaporative emissions, domestic emissions, wood and coal burning in restaurants/cooking, waste burning and biomass burning from agricultural practices. In order to improve the accuracy of emissions, emission factors have been characterized using tunnel measurements. These emission factors have been determined for CO, NO_x, PM_{10} and CO_2, as well as for different aldehydes and ketones.

The composition of particulate matter has been studied, with a focus on secondary organic aerosols, the ratio between black and organic carbon, bio-aerosols and secondary inorganic aerosols. A mass balance study of fine particles showed the importance of carbonaceous compounds, and showed that organic carbon and elemental carbon are mainly the result of vehicular emissions and that the particles originate also from biomass burning from local sources and remote transport from the Amazonian region.

Peru

Peru is a country of 31 million people, of which 77% live in cities. The main emissions of greenhouse gases and pollutants in Peru are from energy generation, agriculture and land-use.

Emissions for several compounds are available for Peru, with a detailed inventory of emissions for Lima and Arequipa. A network of monitoring sites has been established in different areas of Lima. The data show that, while pollution levels have improved in Lima over the past ten years, large emissions of pollutants, and more particularly particulate matter still remain in the city: Figure 4 shows the concentrations of PM10 in 10 monitoring sites in the area of Lima, demonstrating the large level of pollution at most sites and during a large part of the year. The changes in surface emissions are driven by the rapid population growth, especially in Lima, and by the economic growth in Peru. The corresponding increase in the number of vehicles in the country has led to an increase in the emissions. In order to limit the growth of the emissions, emission standards for vehicles have been implemented, for example limiting the diesel sulfur content to 50 ppm starting in 2016, and gasoline sulfur content to 50 ppm in 2017. Standards for the emissions from refineries have also been decided.

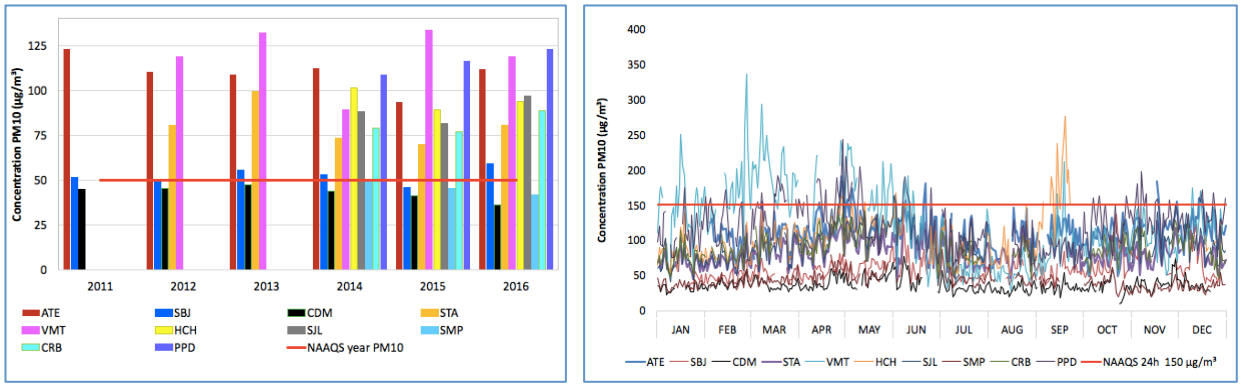

Figure 4: Annual concentrations of PM10 in Lima in 2016 (left) and daily variation (right) at different stations in the Lima area.

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Colombia

The work on the determination of emissions by national agencies in Colombia has so far focused on greenhouse compounds, i.e. CO_2, CH_4, N_2O, HFCs and SF_6. Emissions of compounds related to atmospheric pollution have been developed by regional and urban agencies, with collaborations from universities, laboratories and private companies or associations: these groups have developed emissions for CO, NO_x, SO_2 and PMs. There are currently large differences among the datasets developed for the different regions, due to a lack of standard protocols and formats to report emissions. Furthermore, the domains considered are not necessarily consistent between consecutive inventories.

Emissions are available for several cities in Colombia: Bogota, Medellin and Cundinamarca, at a resolution of 1x1 or 2x2 kms, for PM, NO_x, CO, SO_2 and VOCs.

Diurnal patterns of the emissions have been developed for the emissions from transportation, as shown in Figure 5, for different species.

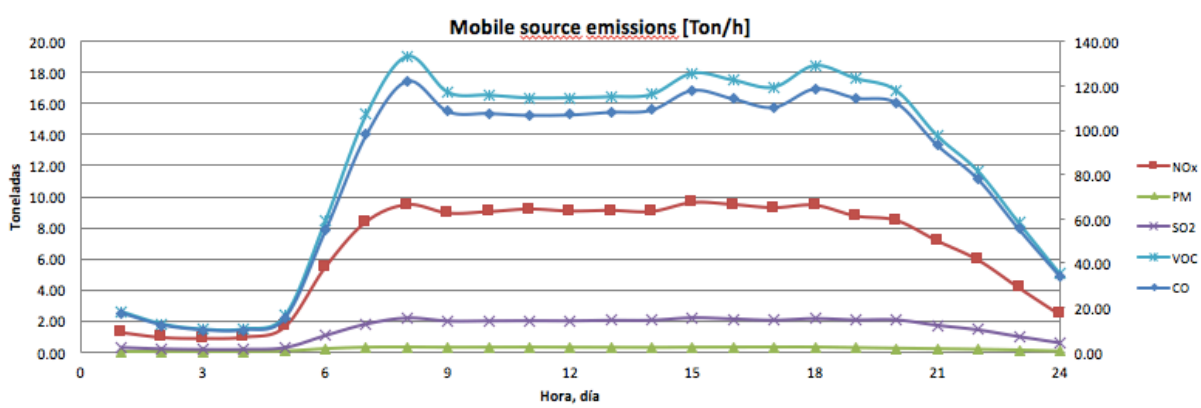

Figure 5: diurnal variations of the emissions of NOx, PM, SO2, VOCs and CO from mobile sources.

Detailed emissions are available for the city of Bogota. They include a large diversity of sources, as well as point sources emissions. Mobile sources contribute to more than 90% to the emissions of NO_x, CO, CO_2. Concerning PMs, direct mobile sources have a small contribution, but indirect sources, i.e. resuspended dust are the main contributor to the emissions for PM2.5 and PM10. Studies conducted in Colombia have emphasized the importance of re-suspended particulate matter. These sources include paved and unpaved roads, agricultural tilling, construction activities and mining, and they depend on traffic activity and soil moisture.

3. Emissions from global inventories: temporal evolution and evaluation

As indicated in the previous section, no inventory currently exists, which provides gridded emissions for the whole of South America for different sectors for all atmospheric compounds. Emissions for South America have been evaluated using global inventories. Several results will be discussed in the presentation.

The evolution of emission factors from the CEDS inventory (see Hoesly et al., 2017) for road emissions in the different countries in South America is shown in Figure 6. Differences between countries in the emissions factors are large, reflecting the implementation of emission reduction policies. Evaluation of such data will have to be performed with ground observations, for a better determination of the emissions.

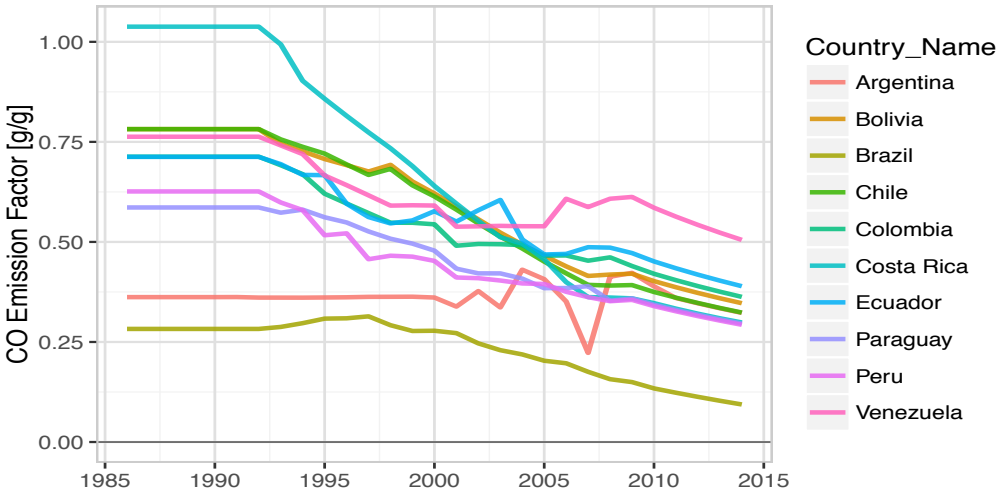

Figure 6: evolution of the emission factors for CO for road emissions for different countries, as used in the CEDS inventory.

Changes in the emissions during the past decades have been evaluated, using datasets provided by different inventories. Figure 7 compares the emissions of NH_3 (Chile) and NMVOCs for Brazil, from 1960 to 2014. Large differences among the datasets can be seen.

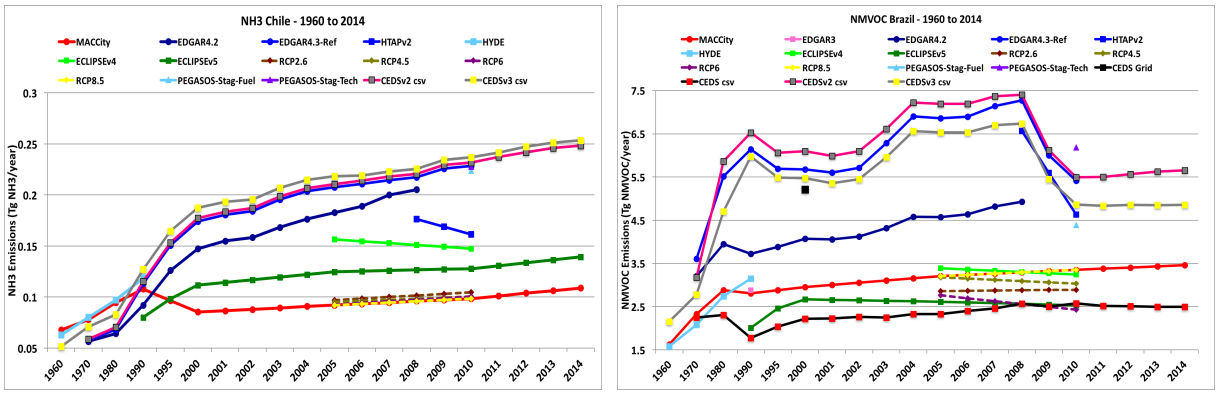

Figure 7: NH_3 emissions in Chile (left) and NMVOCs emissions in Brazil (right) from 1960 to 2014.

These differences can be explained by the use of different emission factors and activity data and of their evolution. In order to better understand the differences in the emissions, comparisons between different sectors were analyzed, which will be discussed during the presentation. The definition of the sectors is however not the same in all inventories, which makes this comparison rather difficult to interpret.

4. The PAPILA project

The emissions described in the previous sections will be further developed as part of a new project between Europe and South America called PAPILA: Prediction of Air Pollution in Latin America and the Carribean. This project, funded by the European Commission will establish a sustained network of partners with complementary expertise to develop and implement an analysis and forecast system for air quality with downscaling capability for Latin America and the Caribbean region (LAC region). Nine European institutions are involved, as well as nine institutions from Latin America, i.e. Chile, Brazil, Colombia, Argentina, Bolivia, Venezuela, Mexico and Puerto Rico. As part of PAPILA, an inventory covering all the countries of Latin America at a 0.1x0.1 degree resolution will be developed.

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