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Quantification of CO emissions from the city of Madrid using MOPITT satellite retrievals and WRF simulations

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1. Emission datasets

The Edgar and TNO-MACC inventories have a slightly different categorization of emissions. In our paper, we use for both inventories the total emissions from all categories together.

Sectors in Edgar:
Agricultural waste burning, residential, road transportation, non-road transportation, fossil fuel fires, large scale biomass burning (Emissions from savannah burning (4E) and land use change and forestry (5) are not gridded), combustion in manufacturing industry, metal processes, energy industry and waste incinerator, non-metallic paper chemical industry; transformation, oil production and refinery.

Sectors in TNO-MACC:
Combustion in energy and transformation industries, non-industrial combustion plants, combustion in manufacturing industry, production processes, extraction and distribution of fossil fuels and geothermal energy, solvents and other product use, road transport, other mobile sources and machinery, waste treatment and disposal, agriculture.

2. Simulation periods

For the quantification of CO emissions from Madrid, we tested four different simulation periods in WRF. In this test, we optimized the trade-off between minimizing model calculation time and maximizing retrieval information content. The following averaging periods were selected: 10 days (from 1-10 July 2006), a full month (July 2006), a four months summer season (June-September 2006, JJAS) and a full year (2006). The shorter periods are all chosen in summer, as most data are available in this season. WRF was sampled for each individual MOPITT retrieval applying the AK, as described earlier, and a spatial comparison was made between the WRF and MOPITT-derived images of 200x200km^2 over Madrid. For each period the oversampling method was applied to grid both WRF and MOPITT data on the 2x2km^2 grid; no wind rotation was done. The scatterplots of these gridded data are shown in Fig. S2. Each subplot consists of the 10,000 points of this grid (note that for the shorter periods, there are overlapping points, originating from neighboring grid cells that rely on the same data). Generally, the spatial variation in the WRF column averaged CO mixing ratios is much smaller compared to the MOPITT data, because of the limited precision of the individual data and the smaller variability in the CO signal in WRF. After averaging 10 days and 1 month of data the variability in MOPITT is still much higher than the variability in WRF, R2 values are respectively 0.43 and 0.33. This is probably partly due to the high measurement noise in MOPITT and partly caused by the lack of spatial variability in the model. Using four summer months (JJAS) or one year leads to better results, with R2 values of 0.55 and 0.75 respectively. The period of a year gave clearly the best, and useful, results and was therefore selected for emission estimation. A CO mixing ratio enhancement over the city was also best visible for the yearly period (not shown).

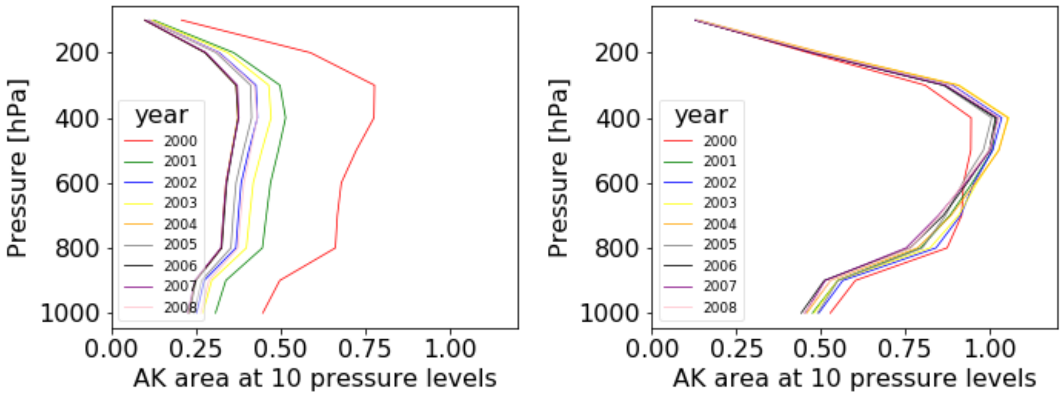

Figure S1 Yearly averaged **AK** area (Rodgers, 2000) values for the 200x200 km^2 domain around Madrid from the surface (values plotted at 1000hPa, note that the average surface pressure around Madrid is actually closer to 900hPa) to the 50 hPa level for the years 2000-2008, March to December (except June, July to minimize biases from uneven sampling, for NIR (left) and TIR (right)).

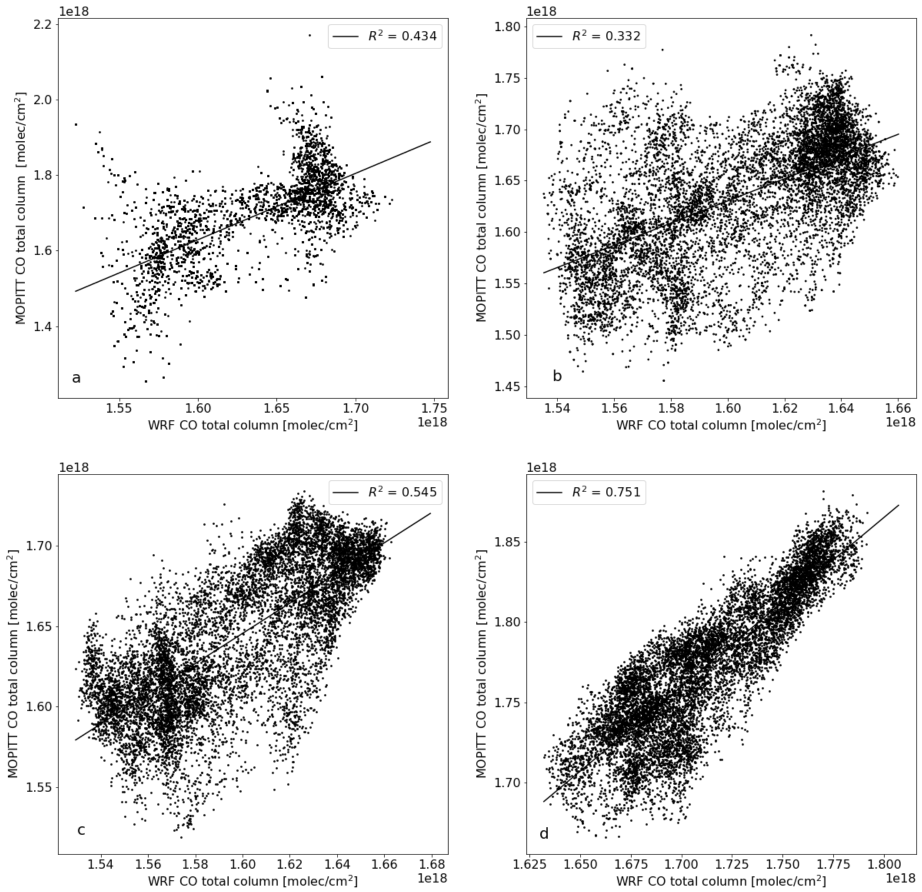

Figure S2 Comparison between MOPITT V6 and WRF for different temporal sampling times. WRF results are sampled according to the coordinates of single MOPITT retrievals and both are averaged on a 2x2km^2 grid, (a) for a 10 day period (1-10 July 2006), (b) for a 1 month period (July 2006), (c) for a 4 month period: June-September 2006 and (d) for the whole year 2006.

Table S1 MOPITT V5 multispectral Downwind-upwind differences (V_d-V_u) in total column CO over large cities and the relative difference (RD) between 2000-2003 and 2004-2008, comparing results from this study and Pommier et al. (2013). The values from Pommier et al. (2013) are provided in parentheses.

Megacity (Coordinates)	V_d-V_u: Our study, (Pommier et al.) 2000-2003 [10^{17} molec/cm^2]	V_d-V_u: Our study, (Pommier et al.) 2004-2008 [10^{17} molec/cm^2]	RD: Our study, (Pommier et al.) [%]
Moscow (55.75ºN,37.62ºE)	2.41±0.04 (2.8±0.03)	1.74±0.05 (2.3±0.06)	-27.9±4.5 (-18.5±3.7)
Paris (48.86ºN,2.36ºE)	1.48±0.06 (1.3±0.05)	0.58±0.03 (1.0±0.03)	-60.7±8.5 (-22.2±6.9)
Mexico (19.43ºN,99.13ºW)	7.27±0.06 (7.0±0.09)	5.08±0.04 (4.2±0.06)	-30.1±1.6 (-39.9±2.6)
Tehran (35.70ºN,51.42ºE)	5.06±0.05 (4.4±0.02)	3.20±0.03 (2.5±0.06)	-21.5±2.6 (-42.9±2.8)
Baghdad (33.33ºN,44.38ºE)	2.31±0.03 (2.2±0.01)	1.23±0.04 (1.2±0.03)	-46.7±4.4 (-46.5±2.9)
Los Angeles (34.05ºN,118.2ºW)	4.82±0.07 (6.1±0.11)	3.38±0.07 (4.9±0.07)	-29.8±3.7 (-19.6±3.4)
Sao Paulo (23.54ºS,46.64ºW)	1.96±0.03 (1.5±0.04)	1.79±0.05 (1.1±0.03)	+5.7±4.9 (-26.9±5.4)
Delhi (28.61ºN,77.21ºE)	1.16±0.02 (0.9±0.02)	1.42±0.04 (1.1±0.04)	+22.0±4.3 (+22.4±5.8)
Madrid* (40.41ºN,3.71ºW)	0.79±0.02 (--)	0.95±0.02 (--)	+20.5±4.6 (--)

*Madrid was not included in the study of Pommier et al. (2013)

Table S2 MOPITT V6 multispectral Downwind−upwind differences (Vd−Vu) in total column CO over large cities and the relative difference (RD) between 2000-2003 and 2004-2008, comparing results from this study and Pommier et al. (2013). The values from Pommier et al. (2013) are provided in parentheses.

Megacity (Coordinates)	V_d-V_u: Our study, (Pommier et al.) 2000-2003 [10^{17} molec/cm^2]	V_d-V_u: Our study, (Pommier et al.) 2004-2008 [10^{17} molec/cm^2]	RD: Our study, (Pommier et al.) [%]
Moscow (55.75ºN,37.62ºE)	3.19±0.04 (2.8±0.03)	2.08±0.04(2.3±0.06)	-34.93±3.1 (-18.5±3.7)
Paris (48.86ºN,2.36ºE)	1.29±0.02 (1.3±0.05)	0.94±0.03 (1.0±0.03)	-27.3±4.4 (-22.2±6.9)
Mexico (19.43ºN,99.13ºW)	6.98±0.05 (7.0±0.09)	5.34±0.05 (4.2±0.06)	-23.4±1.6 (-39.9±2.6)
Tehran (35.70ºN,51.42ºE)	4.05±0.06 (4.4±0.02)	3.04±0.02 (2.5±0.06)	-24.8±2.0 (-42.9±2.8)
Baghdad (33.33ºN,44.38ºE)	2.24±0.03 (2.2±0.01)	1.37±0.02 (1.2±0.03)	-39.0±2.8 (-46.5±2.9)
Los Angeles (34.05ºN,118.2ºW)	5.75±0.06 (6.1±0.11)	3.32±0.117 (4.9±0.07)	-36.6±3.6 (-19.6±3.4)
Sao Paulo (23.54ºS,46.64ºW)	1.70±0.02 (1.5±0.04)	2.38±0.08 (1.1±0.03)	+40.0±4.4 (-26.9±5.4)
Delhi (28.61ºN,77.21ºE)	1.09±0.02 (0.9±0.02)	1.11±0.02 (1.1±0.04)	+2.24±5.6 (+22.4±5.8)
Madrid* (40.41ºN,3.71ºW)	0.97±0.03 (--)	0.64±0.02 (--)	-33.0±5.7 (--)

*Madrid was not included in the study of Pommier et al. (2013)

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