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Sources of particulate air pollution in two high-altitude Bolivian cities: La Paz and El Alto

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La Paz and El Alto are two high-altitude (above 3000 m.a.s.l) Bolivian cities that form part of one of the largest metropolitan areas in the country with a population of around 1.8 million people. Air quality in this conurbation is strongly influenced by both regional and local anthropogenic and natural pollution sources that have not yet been studied in this region. Moreover, despite being contiguous cities, the drastic change in altitude and topography between them leads to different production, dynamics and transport of particulate matter (PM). The need for a characterization of the pollutant sources in these sites lies not only in the importance of regulating the emissions to protect public health, but also in the observed significant impact that these pollutant sources could have on the surrounding Bolivian glaciers. PM_{10} was collected onto 24-h filters at two background stations located in La Paz and El Alto between April 2016 and June 2017. The US-EPA Positive Matrix Factorization (PMF v.5.0) receptor model was applied for apportioning the sources that affect air quality in the two cities. This is the first source apportionment study in South America that incorporates a large set of organic markers (such as levoglucosan, PAH's, Hopanes and Alkanes) together with inorganic species. The multisite PMF allowed to resolve 11 main sources. The largest annual contribution to PM_{10} came from 2 major sources: The ensemble of vehicular emissions, responsible for 30.3% of the measured mass (gasoline-like-powered vehicles: 16.0%; diesel-like-powered vehicles: 7.8%; non-exhaust emissions: 3.8%; Lubricant oil: 2.7%) and Mineral Dust contributing 29.7% to the total PM_{10} mass. Other 21.9% was attributed to factors associated to secondary aerosols (NO_3-rich: 6.6%; SO_4-rich: 9.8%; MSA-rich: 5.5%). Agriculture-related smoke from biomass burning originated in the lowlands in the country and neighbouring countries contributed to 7.6% of the total PM_{10} mass annually, this contribution doubled at the end of the biomass burning season. Primary biogenic emissions, on their side, were responsible for 6.3% of the measured PM_{10} mass. Finally, it was possible to identify a profile related to open waste burning happening between the months of May and August. Despite the fact that this source contributed with only 4.6% to the total PM_{10} mass, it constitutes the second-largest source

of PAHs, compounds potentially hazardous for health. Running a multisite-PMF at these two high altitude sites, not only provided more robustness to the model, but also led to the dissociation of the found traffic profile into two separate vehicular sources, one for diesel and one for gasoline-powered vehicles. This study demonstrates that PM_{10} concentrations in this Bolivian region are mostly impacted by a limited number of local sources, which is different to what is observed in many European urban areas. We conclude that traffic emissions and biomass burning are the main sources to target in order to improve air quality in both cities. Our results highlight the need for dedicated studies of air pollution in high altitude regions of South America and can serve as the start of such investigations.