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Atmospheric Boundary Layer and Air Pollution Relationships over the Atacama Desert, Chile

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The Atacama Desert in northern Chile is the driest desert in the world and plays a significant role in the economic development of the country, which is the largest producer of copper worldwide. The Desert, located along the western coast of Southern South America, spans large areas of complex topography under the effect of both a persistent temperature inversion layer and the South Pacific Anticyclone. The Air Stagnation Index (ASI) was computed for the Atacama Desert (16ºS-32ºS) from outcomes of three Regional Climate Models forced by the IRA-Interim reanalysis throughout the evaluation experiment (1980-2015); UCAN-WRF3411 (res 0,4 deg), RegCM-SAM44 (res 0,4 deg) and RegCM-CL09 (res 0,09 deg). Additionally, the daily-basis Ventilation Coefficient (VC) based on surface wind speeds and the Planetary Boundary Layer Height (PBLH), inferred from the observed Temperature Inversion Layer Height (TILH), was computed for five desert locations in the Antofagasta Region. This area was selected as it presents both high levels of PM10-PM2.5 and high frequencies of stagnant episodes. TILH was calculated from radio sounding observational data, and PM-wind time series were obtained from Chile's National Air Quality Information System (SINCA network). Connections between ASI, VC, and PM10-PM2.5 were explored for the period 2000-2018. Also, ASI index and the modelled boundary layer thickness were explored throughout the RCP4.5 Climate Change scenario to provide an insight into the potential effects of climate change on the atmospheric processes governing PM levels.

Modelled ASI index suggests higher frequencies of stagnant days at lower latitudes where the desert is drier and stronger mechanisms for inhibition of precipitation take place. In these areas, stagnation is present at least during the half of the year leading to a quasi-permanent stagnant condition given mainly by the extreme stable atmosphere along the coast and almost null precipitations. Although the three climate models consistently reproduced vast stagnant areas, the finest model (RegCM-CL09) suggests higher frequencies than the coarser ones, reaching until 270 stagnant days/year in some locations in the northern Atacama. In the Antofagasta Region, characterized by high ASI values, a response of extreme PM events to ASI index is observed. Also, atmospheric ventilation (VC) seems to play a significant role modulating the PM time series. The observed VC was found from low-moderate to highly correlated with the PM10-PM2.5 observational records. Higher correlations were observed during summer in coastal locations where both TILH and surface wind speed were found significantly associated to the observed PM variability. In contrast, in in-land locations, stronger relationships were found in autumn-winter being wind speed the more significant component of VC modulating the PM time series. Under the RCP4.5 Climate Change scenario, modelling outcomes suggest an increasing frequency of stagnant events in some areas of Northern Atacama. Also, a decreasing trend of the boundary layer thickness is projected at lower latitudes. Further research based on a coupled climate-chemical modelling approach is proposed to improve the understanding of the effects of climate change on the boundary layer dynamic and the atmospheric processes setting the PM concentrations along a highly polluted and vulnerable area.