Editor Comments – A comprehensive assessment of emissions from prescribed fires in two Mediterranean shrublands: chemical and morphological analysis

In response to Reviewer #2's point about the scope of this manuscript in its current form being more suitable for Measurement Reports, the authors have addressed this comment with a more detailed comparison of emission factors with other vegetative types. At this point I believe that this is sufficient. However, the abstract and the conclusions sections currently do not meet the ACP guidelines. The authors should refer to: https://www.atmospheric-chemistry-and-physics.net/policies/guidelines_for_authors.html The conclusions section, in particular, falls far short of what is expected for ACP.

Thank you for your valuable comment. We have revised the abstract to ensure that it provides a comprehensive overview of the study, including the relevance of the research topic, the current state of scientific knowledge, and the knowledge gap addressed. The revised version also clearly states the objectives of the study, describes the methodological approach used, summarizes the main results with relevant quantitative information where applicable, and highlights the significance and broader implications of our findings. We believe that these changes have improved the clarity and completeness of the abstract and better emphasize the contribution of our work.

The revised Abstract now reads:

"Prescribed burning is widely used to reduce fuel loads and mitigate wildfire risk in Mediterranean shrublands, yet field-based emission factors (EFs) for these ecosystems remain scarce, limiting the accuracy of emission inventories and atmospheric models. This study investigates gaseous and particulate emissions from prescribed fires in *Calluna vulgaris* and *Genista hispanica* shrublands in northwestern Spain to characterize emission profiles and evaluate how vegetation-specific fire behaviour influences atmospheric emissions. A field-based approach combined gravimetric analysis, thermal–optical transmittance, ion chromatography, Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). *Calluna* burns were more intense and flaming (modified combustion efficiency, MCE = 90.6 %), whereas *Genista* burns were dominated by smouldering combustion (MCE = 70.8 %). Gas-phase concentrations of CO_2, CO, CH_4, C_2H_6, and total organic carbon were higher in *Calluna* fires, although EFs for incomplete-combustion products (CO, CH_4, TOC, and elemental carbon) were generally higher for *Genista*. $PM_{2.5}$ EFs reached 53.5 g kg^{-1} for *Calluna* and 44.7 g kg^{-1} for *Genista*. Organic and elemental carbon accounted for 28.1 % and 32.9 % of $PM_{2.5}$ mass, respectively, while water-soluble inorganic ions contributed 6.9 % and 4.5 %. Morphological analysis revealed abundant tar-ball-like submicrometric organic particles and aggregates with thick organic coatings, suggesting effects on aerosol optical properties, hygroscopicity, and cloud condensation nuclei activity. These field-derived EFs improve the representation of Mediterranean shrubland fires in emission inventories and atmospheric chemistry–transport models, contributing to a better understanding of their impacts on air quality and the carbon cycle."

The Conclusions section has been substantially rewritten and is no longer presented as a simple list of findings. It now follows the structure recommended by ACP by including: i) a concise summary of the main quantitative results; ii) a synthesis and interpretation of how shrubland type, fuel-bed structure, and combustion regime influence the emission profiles; iii) a comparison with literature-average values for savannas/grasslands, temperate forests, and previous Mediterranean shrubland wildfire experiments; iv) a specific discussion of the main limitations; and v) a clearer statement of the implications for atmospheric chemistry, air quality, aerosol–radiation interactions, aerosol–cloud processes, emission inventories, receptor modelling, atmospheric chemistry–transport models, and fire-management decision-making.

The revised Conclusions section now reads:

"This study provides a field-based characterisation of gaseous and particulate emissions from prescribed fires in two Mediterranean shrubland communities dominated by *Calluna vulgaris* and *Genista hispanica* subsp. *occidentalis*. The results show that, under broadly comparable meteorological

conditions, the two fuels produced markedly different combustion regimes. *Calluna* fires were more intense and predominantly flaming, with an MCE of 90.6 %, whereas *Genista* fires were dominated by smouldering combustion, with an MCE of 70.8 %. These differences indicate that shrubland type, fuel-bed structure, and combustion regime strongly influence the chemical signature of prescribed-fire emissions.

The findings indicate that biomass structure and litter presence—substantial in *Genista* and virtually absent in *Calluna*—are the fundamental reasons for the observed differences in fire behaviour. The intense flaming combustion in *Calluna* not only produces more CO_2 but also enhances the volatilization of organic compounds, leading to higher concentrations of methane and total organic carbon (TOC) despite the higher efficiency. Conversely, the smouldering nature of *Genista* fires favours the production of hydrogen fluoride and nitrogen oxides.

Compared with literature-average values for savannas/grasslands and temperate forests, the $PM_{2.5}$ emission factors measured here were substantially higher, suggesting that Mediterranean shrubland fires may be poorly represented by generic biomass-burning emission factors. Relative to previous Mediterranean shrubland wildfire experiments, the present prescribed fires showed lower CO and CH_4 emission factors but higher $PM_{2.5}$, OC, and EC emission factors. These differences highlight the need for fuel-specific and combustion-specific emission factors in regional fire-emission inventories and atmospheric models.

Scanning Electron Microscopy (SEM) observations showed that the emitted particles were dominated by spherical and compact particles in the submicrometre size range, including tar-ball-like particles and internally mixed aggregates with thick organic coatings and inorganic inclusions. These characteristics suggest that aerosols from Mediterranean shrubland prescribed fires may influence aerosol optical properties, hygroscopicity, and cloud condensation nuclei activity during atmospheric ageing. However, these implications should be interpreted cautiously because optical properties, hygroscopic growth, and cloud condensation nuclei (CCN) activity were not directly measured.

Several limitations should be considered when extrapolating the results. The study is based on a limited number of field burns, gas samples collected in Tedlar bags may underestimate reactive or polar compounds, fuel moisture may have been affected by partial drying before analysis, and litter and mulch loads were not quantified separately. In addition, the SEM analysis was qualitative, and the measurements represent near-source fresh smoke rather than aged regional plumes.

Overall, this work shows that prescribed burning in Mediterranean shrublands can generate substantial short-term emissions of fine particulate matter and carbonaceous aerosol, even when used as a fuel-management strategy. These results have profound implications for our understanding of climate forcing. The dominance of submicrometer "tar balls" with thick organic coatings suggests an enhanced "lensing effect" that increases light absorption and radiative forcing. Simultaneously, the internal mixing of inorganic salts (such as KCl) with organic matter increases particle hygroscopicity, promoting their ability to act as CCN. The field-based emission factors and particle-composition data reported here can improve the representation of prescribed and unplanned fires in Mediterranean emission inventories, numerical models, receptor modelling studies, and SPECIEUROPE source profiles, thereby supporting more robust assessments of fire impacts on air quality, aerosol–radiation interactions, and aerosol–cloud processes, as well as decision-making in fire management.”

We believe that these revisions address the editor’s concern and bring the Abstract and Conclusions sections into closer alignment with the expectations of ACP.