Comments on “Climate Models Underestimate Pre-Industrial Fire Emissions”

This study compiles a geographically extensive set of ice-core combustion records and compares observed pre-industrial-to-present-day changes in black carbon with CMIP6, LENS, and CESM2 simulations. The manuscript addresses an important and timely question, particularly because uncertainties in pre-industrial fire emissions directly affect estimates of historical aerosol radiative forcing. The expanded ice-core compilation and the attempt to examine emissions, transport, and deposition processes are valuable aspects of the work.

However, the current analysis does not yet fully support the strong attribution that underestimated pre-industrial fire emissions are the dominant cause of the model–observation discrepancy. Several comparisons involve physically different quantities, and uncertainties associated with snow accumulation, post-depositional processes, source-region representativeness, and structural transport errors are not sufficiently constrained. Major revisions are therefore required before the manuscript can provide a solid and convincing contribution to the literature. I ask the authors to consider the following points.

Major comments

1. The manuscript clearly identifies a systematic mismatch between ice-core and modeled PD/PI BC ratios, but the attribution to underestimated PI fire emissions remains too strong. Ice-core BC concentrations reflect not only emissions, but also changes in transport, wet and dry deposition, snow accumulation, BC aging, source locations, and post-depositional processes. The conclusion should therefore be presented as the explanation most consistent with the current evidence rather than as a definitive attribution. Ideally, this interpretation should be supported by direct sensitivity simulations in which PI fire emissions are increased by different factors and the resulting BC deposition or snow concentrations are evaluated against the ice-core records.
2. The compared quantities are not fully consistent across datasets. Ice-core BC concentrations are compared with CMIP6 deposition fluxes, LENS atmospheric BC, and CESM2 column burden, surface concentration, deposition, and BC in snow. Ratios do not necessarily eliminate these physical differences because precipitation, scavenging efficiency, vertical transport, and snow accumulation may change between the PI and PD periods. The exact variable used from each model should be clearly documented, and the physical comparability among these quantities should be better justified. The manuscript should also resolve the apparent inconsistency in the description of the LENS variable as either surface BC concentration or column burden.

3. The LENS ensemble only samples internal meteorological variability within one model framework. It does not represent structural uncertainty in atmospheric transport, convection, boundary-layer mixing, wet scavenging, aerosol aging, or deposition parameterizations. Therefore, the conclusion that transport is of secondary importance should be narrowed considerably. The current analysis supports the more limited conclusion that internal meteorological variability within CESM/LENS is insufficient to reconcile the model–observation discrepancy. Structural transport uncertainty should either be assessed using multiple models or more clearly acknowledged as unresolved.
4. The treatment of the ice-core observations requires further scrutiny. Snow accumulation rates and post-depositional processes can strongly affect BC concentrations, yet these effects are discussed but not explicitly accounted for in the model–observation comparison. At minimum, the authors should evaluate whether PI-to-PD changes in accumulation rates could materially alter the reported ratios. In addition, the single levoglucosan record should not be treated quantitatively as equivalent to a BC record because the two tracers differ in source specificity, atmospheric lifetime, degradation, and deposition. Sensitivity results excluding the levoglucosan record should be provided.
5. The definition of the "local regions" in Figure 2 is insufficiently described. The manuscript states that local upwind emission regions are used to compare emission ratios with nearby alpine ice cores, but the exact geographical boundaries, selection criteria, and physical basis of these regions are unclear. The authors should provide the coordinates of each region, explain whether they were defined objectively or subjectively, and justify why these boxes represent the dominant source regions for each ice core. Given that high-altitude and polar sites may receive BC from distant and seasonally varying source regions, sensitivity tests using alternative regional boundaries or transport-informed source regions would substantially strengthen the analysis.

Specific comments

6. Line 64: Use "Earth System models (ESMs)" at first mention.
7. Line 102: Please quantify the contribution of fire to total BC emissions in the PI and PD.
8. Lines 117–118: Note that burned-area trends differ across regions and biomes; the global decline is not spatially uniform.
9. Figure 2: Correct the mismatch between map and legend colors, and enlarge the maps for readability.
10. Line 263: Define LENS in full at its first occurrence.

11. Line 289: Consider adding a figure showing the CMIP6 anthropogenic and biomass-burning BC emission trends from PI to PD.
12. Line 314: Please correct and consistently define the PD averaging period; “1965–1980” is inconsistent with the stated 25-year window.