Adaptation of Black Carbon Footprint concept would accelerate mitigation of global warming

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The world urgently needs fast-tracked solutions to combat global warming, and to this end we propose the rapid adoption of the concept of Black Carbon Footprint (BC Footprint), analogous to CO_2 Footprint. Carbon footprint is already a well-established concept aiming to describe the climatic effects of atmospheric carbon dioxide (CO_2) and Greenhouse gas emissions. However, no such concepts exist for particulate BC emissions despite their climate and health impacts. The BC Footprint concept would be an efficient tool for BC emission mitigation and impact assessment and would support the development of new BC emission mitigation technologies and emission reduction policies.

In the Paris Agreement (Article 3, Paris Agreement (2015)), 174 States and the European Union have committed to undertake ambitious efforts to mitigate global warming. The most important atmospheric climate forcers, carbon dioxide (CO_2), methane and black carbon (BC), differ from each other in several respects. CO_2 and methane are gaseous compounds with relatively long atmospheric lifetimes (years to decades), while BC is a primary particulate emission with a relatively short atmospheric lifetime (days to weeks). It originates mainly from anthropogenic combustion sources, such as transportation, industry and residential combustion (Fig 1). Atmospheric BC consists mostly of agglomerated ultrafine particles, effectively absorbing solar radiation over a large wavelength range, and capable of being transported with air masses over large distances (1). However, due to the limited atmospheric lifetime and unevenly distributed sources, atmospheric BC is characterized by large spatial and temporal variation. In the atmosphere, BC particles can change during ageing process via particle growth and surface reactions (Figure 1). In addition to direct warming impacts, BC can deposit on snow and ice leading to reduction of the earth's surface albedo. This emphasizes the importance of BC emission and induced warming in the Arctic and generally over northern latitudes (1,2). In urban areas, BC significantly affects public health and air quality. Recent studies have highlighted BC as stronger and in some cases more robust marker of PM health effects than PM2.5 (3).

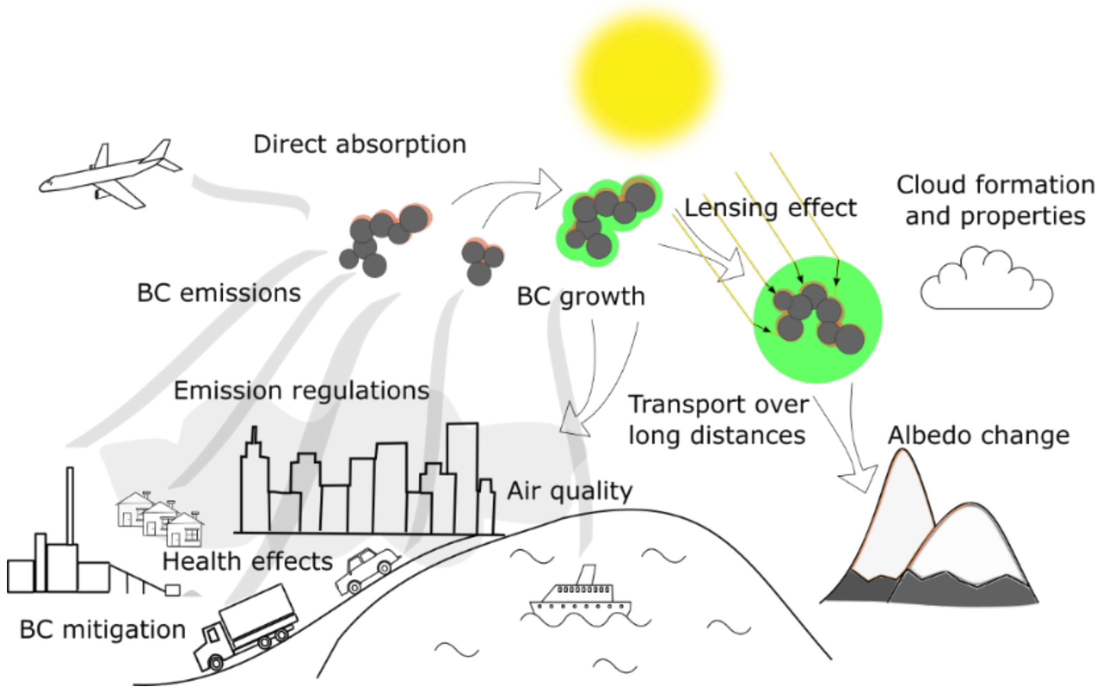

Figure 1. Schematic showing the complexity of sources, atmospheric transformation, and climatic and air quality impacts of particulate Black Carbon (BC).

BC measurements have been conducted already since the 1950's. Yet, no uniform metrics exist for emissions, concentrations or impacts characterization and even the strict definition of BC is missing. BC in atmospheric research and emission studies is characterized by techniques varying in their operation principle (4), producing results of different dimension and metrics. This, together with the lack of universal calibration methods for BC instruments, significantly hinders compilation of consistent BC emission inventories. Furthermore, this complicates the legislative actions for emission mitigation, and the estimation of the effects of BC on global climate and human health.

Several BC control solutions for combustion sources already exist, mainly based on process optimization, fuel choices, flue-gas cleaning and exhaust filtration. A wider implementation of these technologies in developing countries and in the residential sector could further significantly curb the warming (1). Due to the short atmospheric lifetime of BC, the climate benefit from these actions would be immediate. BC mitigation would also produce additional cost savings due to better air quality and consequent health benefits (5).

Despite above-mentioned uncertainties and ambiguities in BC measurement, various initiatives to reduce BC emissions have been established by international bodies, such as the Climate and Clean Air Coalition, the Arctic Council's Arctic Contaminants Action Program (ACAP), International Cryosphere Climate Initiative (ICCI), the UN Convention on Long-range Transboundary Air Pollution and the International Maritime Organization (IMO). Although these examples are mostly voluntary-based non-binding instruments, it is evident that regulations with binding emission reduction targets will come into effect in the future.

To improve the communication and start developing a common understanding on BC, there is a clear need to develop simple metrics for BC, i.e., establish a "BC Footprint" concept. BC Footprint would allow to compare different BC emissions sources and levels of atmospheric BC concentrations, and would enable more efficient communication regarding the climate, health and air quality impacts of BC. Practical examples on the use of the BC Footprint concept are numerous. It would for instance, allow comparing the full impacts of the new vehicle technologies. So far, particulate filters installed on diesel and, recently, gasoline vehicles are considered to increase carbon footprint, due to their impact on fuel consumption. However, the simultaneous reduction of BC emissions they offer, and thus the BC Footprint of relevant vehicles, can counter-balance the negative climate impact in the short-term. Another example is residential heating with biomass, that has zero carbon footprint, but still has BC emissions and climate impacts that are not taken into account when only considering CO_2 emissions.

In-line with the carbon footprint, the BC Footprint concept can be built on detailed, application-specific BC emission factors from different combustion processes to providing bases for the uniform metrics. It has to overcome the discrepancies due to the measurement methodology, instruments' features and the sampling techniques utilized. The proposed concept needs to allow calculation of the BC Footprint of certain actions (e.g. producing a megawatt of energy or utilization of solid, liquid and gaseous biofuels), services (e.g. public transportation) or manufacturing of products, thus providing the common grounds for scientific, policy and public communication. Importantly, the BC Footprint should use easily adoptable units to allow the quantification of climatic influences of BC and to compare the emissions.

Finally, the BC Footprint would enable simple calculation, visualization and communication of BC emissions and their climate impacts by proving simple metrics for BC. These could be used to demonstrate climate-friendly practices and products to companies' decision-making procedures, to consumers and, overall, to facilitate the dialogue between the scientific community, companies, political actors, and citizens. We encourage researchers across the world to participate the development of BC Footprint and to adopt the idea into the scientific research and development.

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