**Response to comments #1**

Response: Thanks for your helpful and constructive comments. We have made several modifications and implemented the suggestions as needed. We describe a few major changes, followed by our response to individual comments.

i) We added ground heat term in the bar plot (Figure 4 and Figure S5);

ii) We added a table, summarizing global mean values of each energy budget term;

iii) We added the variable "humidity gradient" in Figure 6, as it may also influence latent heat flux, along with some discussions;

iv) We made some changes to global mean values in the previous version due to a coding mistake. These changes are tiny, and do not impact any conclusions reached.

General comment:
This study analyzed the PDRMIP multi-model ensemble to show that changes to the surface energy budget are distinctively different in the case of the BC-induced climate change from those enforced by other forcing agents such as CO2, scattering aerosol, and solar insolation. Specifically, the authors show that the climate response of the surface air temperature is governed by changes to multiple components of the surface energy budget in the BC case, contrary to other scenarios where surface radiative flux changes is the major factor that mostly determines the temperature response. I think this study is a nice follow up for recent studies that similarly assessed the surface energy budget change for some of the forcing agents to identify their different characteristics of climate responses. I would recommend the paper be considered for publication in ACP contingent upon if the authors appropriately address my specific concerns described below.

Response: thanks for your positive consideration and recommendation.

Specific comment:
Line 34-39: The numbers listed here should be shown with appropriate units (dimensions) since these numbers are for a unit BC forcing. For example, the energy flux changes (radiative, sensible and latent) should be dimensionless (rather than having the unit of $Wm^{-2}$) given that they are normalized by the TOA radiative flux change.

Response: corrected. We added 'per W $m^{-2}$' to all the units of changed variables in the abstract for clarity.

New abstract:

… … Globally, when a unit BC forcing was imposed at TOA, the net shortwave radiation at the surface decreased by -5.87±0.67 W $m^{-2}$ per W $m^{-2}$ (averaged over global land without Antarctica), which is partially offset by increased downward longwave radiation (2.32±0.38 W $m^{-2}$ per W $m^{-2}$) from the warmer atmosphere, causing a net decrease in the incoming downward surface radiation of -3.56±0.60 W $m^{-2}$ per W $m^{-2}$. Despite a reduction in the downward radiation energy, the surface air temperature still increased by 0.25±0.08 K because of less efficient energy dissipation, manifested by reduced surface sensible (-2.88±0.43 W $m^{-2}$ per W $m^{-2}$) and latent heat flux (-1.54±0.27 W $m^{-2}$ per W $m^{-2}$), as well as a decrease of Bowen ratio (-0.20±0.07 per W $m^{-2}$). Such reductions of turbulent fluxes can be largely explained by enhanced air stability (0.07±0.02 K per W $m^{-2}$), measured as the difference of the potential temperature between 925 hPa and surface, and reduced surface wind speed (-0.05±0.01 m $s^{-1}$ per W $m^{-2}$). … …

Line 38-39: I'm a bit surprised that the sensible heat flux change (2.53W$m^{-2}$) is larger than the latent heat flux change (1.30W$m^{-2}$) simply because of my naïve understanding that the latent heat typically dominates the turbulent heat transfer from the surface to atmosphere. Can the authors explain why the opposite (i.e. sensible heat is larger than latent heat) occurs in the BC-forced scenario? The enhanced stability just explains the sum of latent and sensible heat changes but no explanation for their partitioning.

Response: yes, typically the latent heat flux is roughly four times as that of sensible heat. However, that is global mean values, combining both land and ocean. The large latent heat flux is mainly contributed by evaporation from ocean (~85%, e.g., *Schmitt, R. W., 2008: Salinity and the global water cycle. Oceanography, 21, 12–19.*). As we only focus on land grids in this study, the latent heat flux is greatly reduced. This is an interesting point, we added two sentences in the revised manuscript to note this.

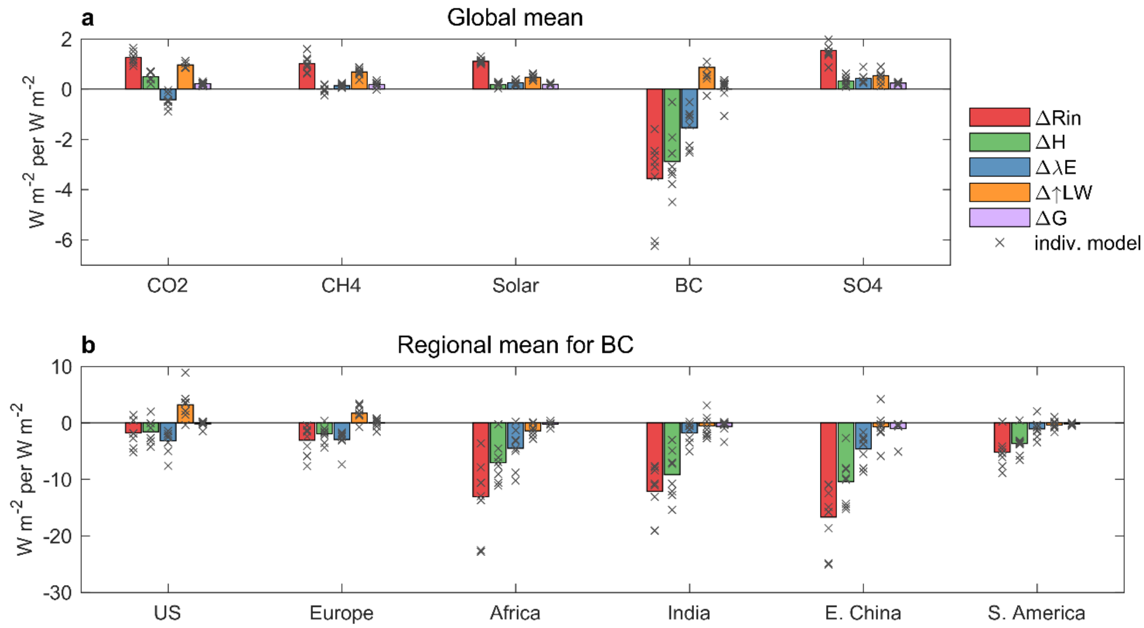
We added the following text after Line 177:

"The larger change of H is somewhat contradicting to the common sense that λE dominates the turbulent flux on global mean scale. This is because on global scale, 85% of λE is from the ocean (Schmitt, 2008). In this study, we only focus on land grids, in which the λE is largely suppressed."

Section 2.2: I'm wondering if the energy balance described by equations (2) and (3) indeed applies when analysis is restricted to land grids only. Don't these equations need additional terms for energy exchange between land and ocean? Did the authors confirm that the balance relationship of (3) is indeed true in the model data analyzed? This can possibly be addressed by adding a bar for the residual in Fig. 4.

Response: accepted. Equations (2) and (3) have been widely used in the Earth science community, and to our best knowledge, no lateral heat exchange term between land and ocean could be found in any literature. We added the term ground heat (G, estimated as the residual) in the revised Figure 4, which shows that the term G is negligible in most cases. Thus, this term, if any, is presumably small and unlikely to be a large source of uncertainty in our analyses.

New Figure 4:

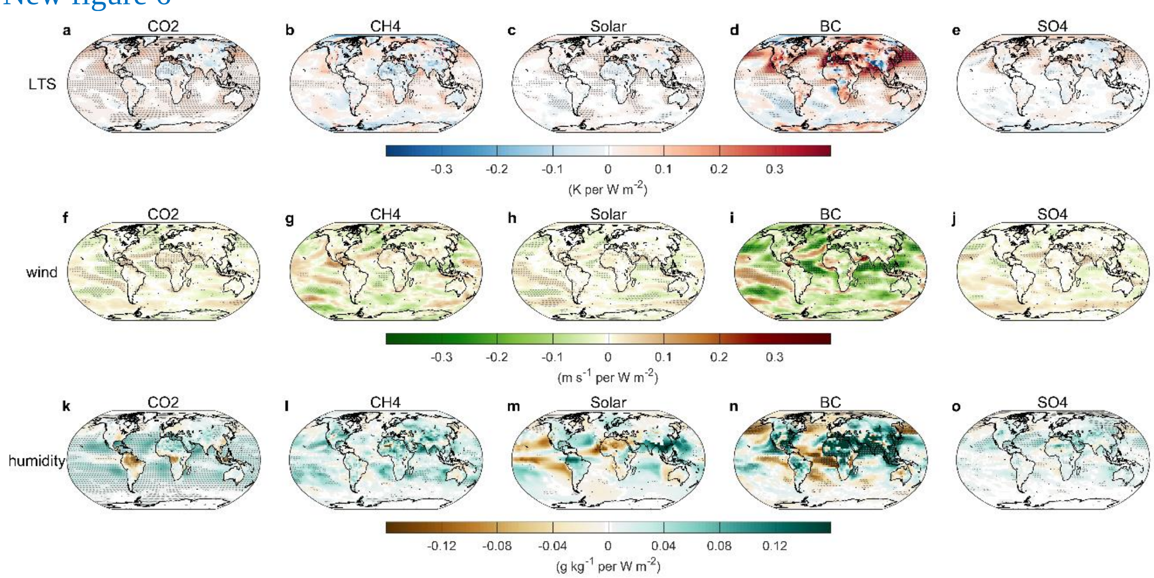



Minor point:
Line 101: relative -> relatively
Response: corrected.

Line 205: "wind speed (U) is likely the only main factor driving the change of latent heat flux": How about the specific humidity (qa)? The enhanced stability in the BC case can also change qa.

Response: added humidity gradient in the revised Fig. 6, along with some discussions. Please see the revised manuscript.

New figure 6



We added the following text after Line 228:

"Figure 6k-o show the changes of humidity gradient ($q_s$-$q_a$), defined as the specific humidity difference between the surface and 850 hPa. For $CH_4$, solar and $SO_4$, the gradient increases globally with values of 0.02 g $kg^{-1}$ per W $m^2$, 0.01 g $kg^{-1}$ per W $m^2$ and 0.01 g $kg^{-1}$ per W $m^2$ respectively, causing an increase of λE (Figure 3 and 4). For $CO_2$, the gradient shows slightly negative values (-0.002 g $kg^{-1}$ per W $m^2$), corresponding to reduced λE (Figure 3 and 4). In terms of BC, the humidity gradient increases by 0.06±0.02 g $kg^{-1}$ per W $m^2$, but with reduced λE flux, indicating that humidity gradient is not the primary driver of latent heat change. These analyses illustrate that humidity gradient may also influence latent heat flux for $CO_2$, $CH_4$, solar and scattering aerosols. For BC, on the other hand, change of wind speed should be the primary driver of the reduction of λE and humidity gradient is of less importance."

Line 256: I don't understand what 'bottom-up' means here. To my understanding, the energy balance constraint discussed throughout this paper is all 'top-down' regardless whether it is for top-of-atmosphere or surface. Why is it called 'bottom-up' when the surface energy response to solar insolation change is discussed? Please clarify.

Response: 'bottom-up' is a term widely used in the solar forcing study, in which the solar radiation directly heats the surface. The temperature responds firstly and then the impacts propagate upward. Our initial intention was to highlight that the influence of BC is somewhat similar to the solar forcing, as both of them have 'top-down' impact, in which BC and solar could modify the conditions of atmosphere first and then the impacts propagate downward to influence the surface.

We deleted these two terms to avoid confusion. In the revised version, we just say that the impact starts from the atmosphere and propagate downward to the surface (please see revised manuscript).

Revised abstract:

…… "These rapid adjustments under BC forcing occur in the lower atmosphere and propagate downward to influence the surface energy redistribution and thus, surface temperature response, which is not observed under greenhouse gases or scattering aerosols." ……