Impacts of atmospheric transport and biomass burning on the inter-annual variation in black carbon aerosols over the Tibetan Plateau

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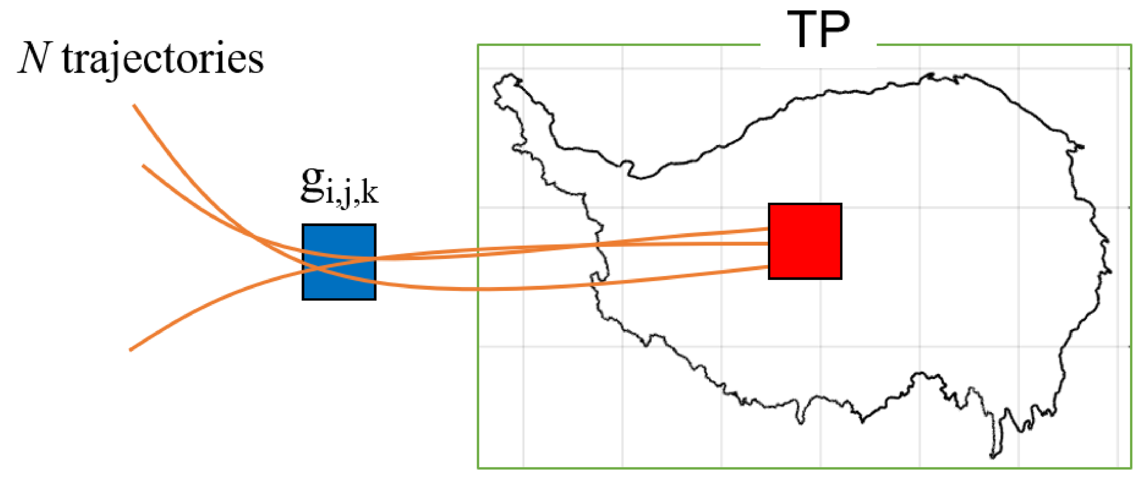
1. Introduction

Atmospheric black carbon (BC) in the Tibetan Plateau (TP) can largely impact regional and global climate. BC in the TP can drive surface warming (He et al., 2014), reduce surface albedo and the duration of snow cover (Ménégoz et al., 2014; Zhang et al., 2018), and is further responsible for retreats of the snow cover and glaciers in the past decades (Menon et al., 2010; Xu et al., 2016). Due to weak anthropogenic activities, concentrations of atmospheric BC in the TP are greatly influenced by the long-range transport of BC from non-local regions (Kopacz et al., 2011; Lu et al., 2012; Zhang et al., 2015; Kang et al., 2019). However, large uncertainties remain in the quantified fractional contributions of BC transport from different source regions to the TP (Yang et al., 2018). Furthermore, how BC transport to the TP varies inter-annually and what the underlying mechanisms for the variation are remain unclear.

2. Data and methods

- Combining BC simulations from a global chemical transport model, GEOS-Chem, and trajectories from an atmospheric transport and dispersion model, HYSPLIT, we estimated the contributions of different source regions in the world to surface BC in the TP during 1995–2014.



$$C_{i,j,k} = \frac{\sum_{n=1}^{N} c \times v}{D \times M}$$

- ➢We assume that BC aerosols have a lifetime of D days, and the back trajectories using HYSPLIT are simulated for D days (D=7 in this study).
- ➢For a grid $g_{i,j,k}$ outside the TP, the amount of BC transported from $g_{i,j,k}$ to the TP during a period of interest can be estimated by $C_{i,j,k}$.
- ➢c is the daily BC concentrations at $g_{i,j,k}$ when trajectory n passes $g_{i,j,k}$, and v is the volume of $g_{i,j,k}$. M is the number of trajectories in a day (M=4 in this study).

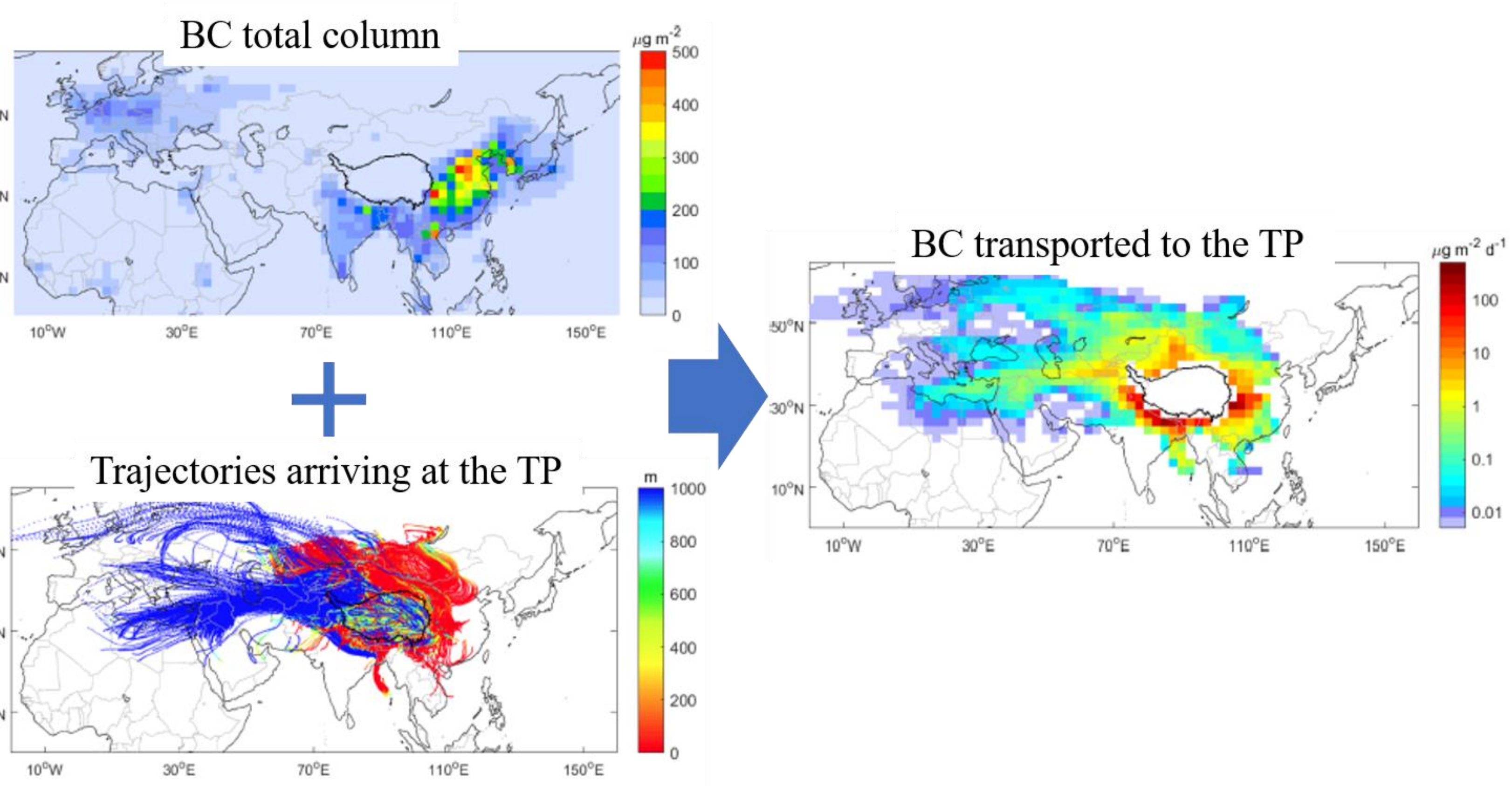


Figure 1. An example of estimated BC transport to the TP surface from non-local regions in April 2005.

- The transport pathway of BC can be visibly expressed.
- The spatial variation in the contribution of source regions can be shown explicitly.

3. Source regions of BC in the TP

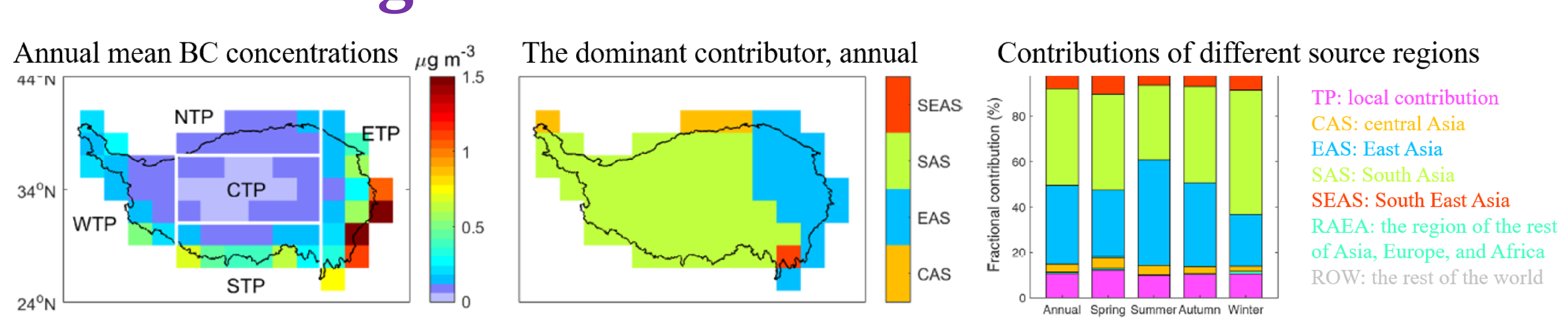


Figure 2. Contributions of different source regions to surface BC in the TP.

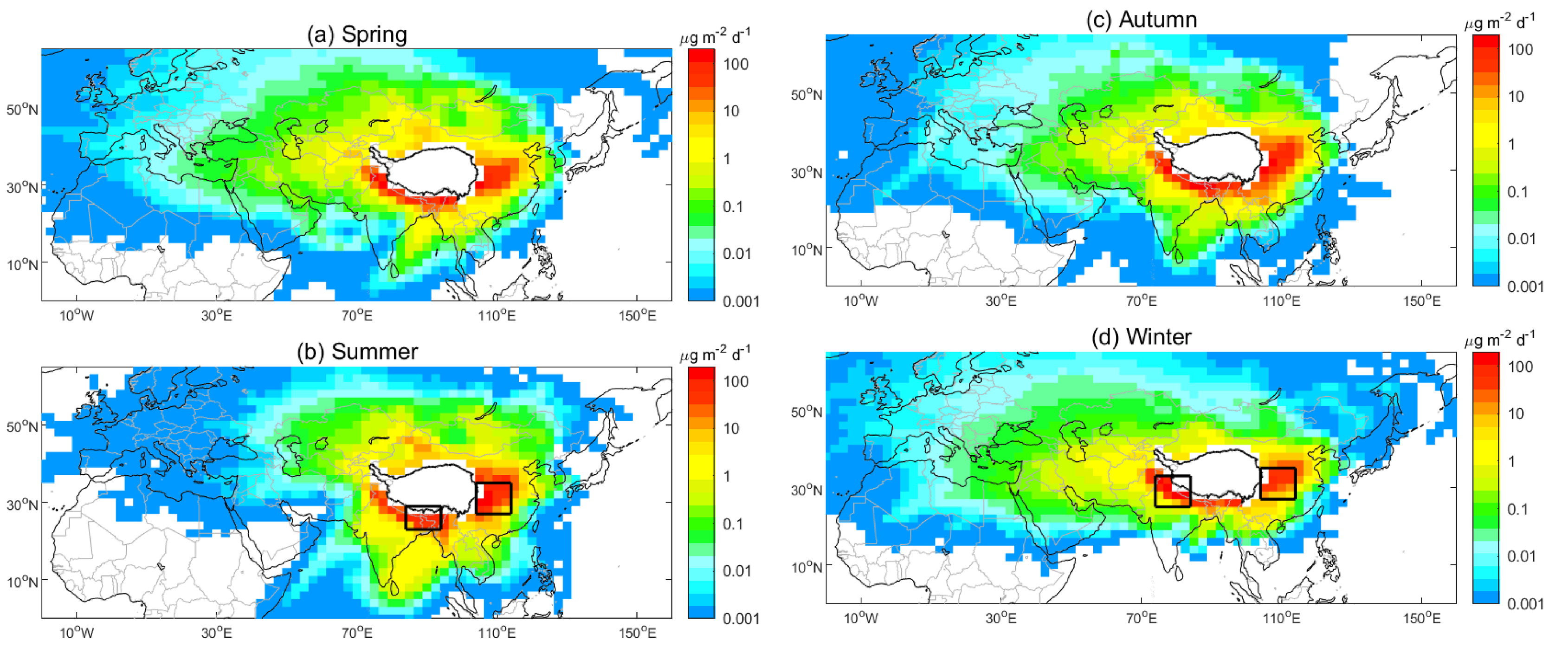


Figure 3. The amount of BC transported to the TP surface (μg m^{-2} d^{-1}) from non-local regions in the four seasons.

- ➢On the 20-year average from 1995–2014, 77% of surface BC in the TP comes from South Asia (43 %) and East Asia (35 %).
- ➢In terms of the amount of BC imported, South Asia and East Asia are dominant source regions, respectively, in winter and summer.

4. Inter-annual variations of BC in the TP

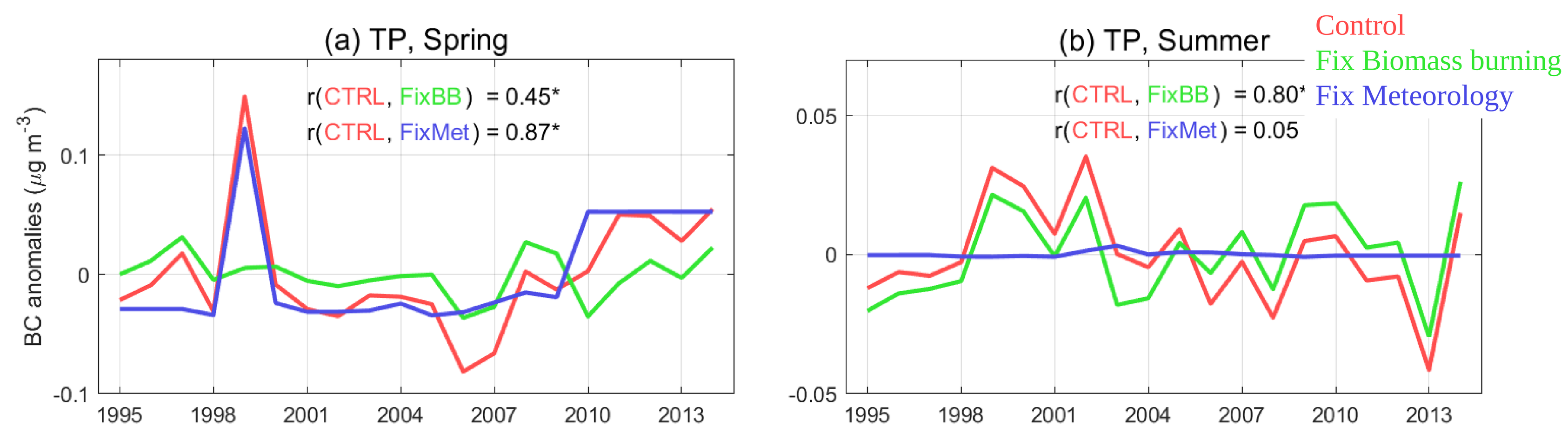


Figure 4. Inter-annual variations in the anomalies of surface BC concentrations averaged over the TP from different simulations during 1995–2014 in the four seasons. A correlation coefficient (r) with "*" indicates that the r is statistically significant (p <0.05).

- ➢Biomass burning is an important driver of the inter-annual variation in surface BC over the TP in spring, while meteorology is more important than biomass burning in the other seasons.

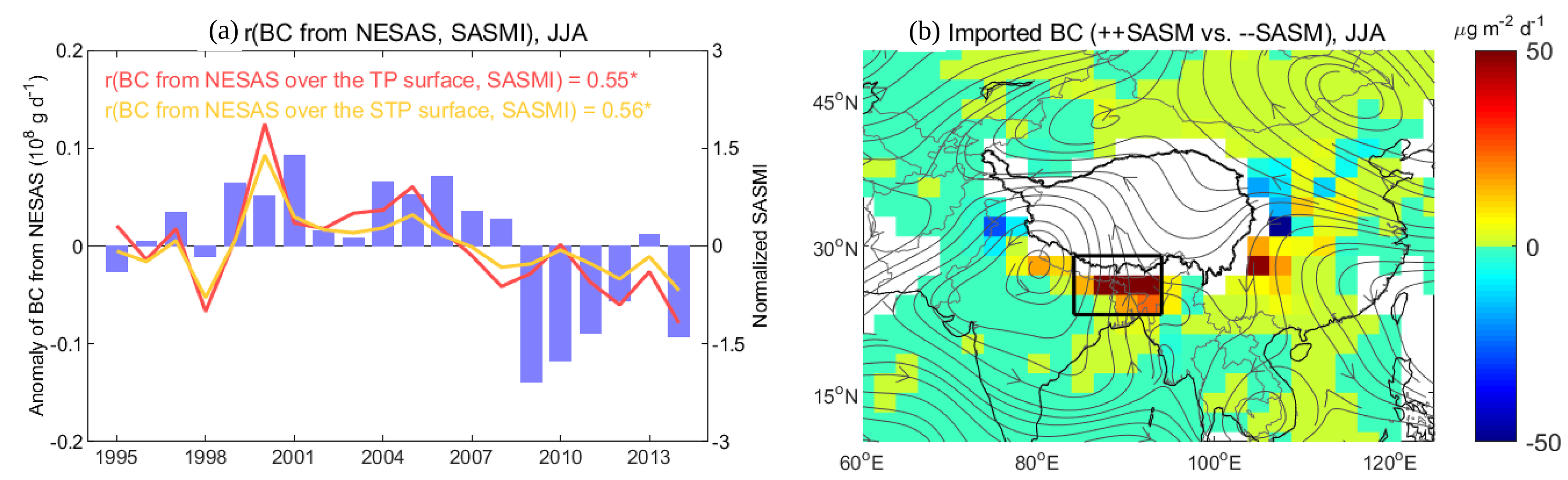


Figure 5. (a) Inter-annual variations in the intensity of the South Asian summer monsoon (SASM) and imported BC from Northeast South Asia to the surface of the TP and southern TP (STP); (b) differences in BC transport to the TP surface between the years with strong and weak SASM.

- ➢When the SASM is stronger, the increased meridional wind over north-eastern South Asia in the middle troposphere can enhance BC transport from north-eastern South Asia to the TP.

5. Conclusions

- ➢Surface BC in the TP is mainly influenced by two source regions: East Asia and South Asia. The two regions totally contribute 77% of the surface BC in the TP. The influence of East Asia is dominant in summer, while the influence of South Asia is dominant in winter.
- ➢In the spring of 1999, the extremely strong biomass burning in South Asia largely elevated surface BC concentrations (0.08 μg m^{-3}, or 31% relative to the climatology) over the TP.
- ➢The inter-annual variation in surface BC over the TP is greatly influenced by the Asian monsoon system, which alters the long-range transport of BC to the TP by modulating the atmospheric circulation.

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