REPLY TO YU ET AL.:

Global temperature change as the ultimate driver of the shift in the summer monsoon rain belt in East Asia

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In reference to our recent paper (1), Yu et al. (2) maintain that (*i*) increased anthropogenic aerosols caused a weakening of the East Asian summer monsoon (EASM) over the past few decades, together with a concomitant "southern-flood-northern-drought" (SFND) pattern in China, and (*ii*) our finding of a warming-induced northward shift of the EASM from the Last Glacial Maximum (LGM) to the Holocene is not applicable to the present case. Atmospheric aerosols, formed from both natural and anthropogenic sources, may affect the climate in multiple and complex ways through their interactions with radiation and clouds (3). However, the impact of aerosols on regional climate is fraught with uncertainties (3). Yu et al. (ref. 2 and references therein) emphasize several studies favorable for their conclusions but ignore those studies that are unfavorable.

First, despite an acknowledged overall cooling effect of aerosols on climate, the contribution of anthropogenic aerosols is controversial. For example, a recent study (4) showed that the massive increase in anthropogenic aerosols since 1980 had caused hardly any cooling, suggesting that the present atmosphere, which is far from the pristine preindustrial background state, is quite well buffered against further changes in aerosols.

Second, the contribution of anthropogenic aerosols to the decreased summer monsoon and the SFND precipitation pattern is also debated. Li et al. (5) suggested that the greenhouse gas plus direct aerosol forcing enhances the land-sea thermal contrast and thus intensifies, rather than weakens, the EASM circulation. A recent aerosol forcing study (6) partly reproduced a decreased EASM intensity for the past few decades but failed to capture the SFND pattern. Moreover, the simulated decreasing trend of the EASM is much weaker than observed (6), suggesting key roles of both the Tibetan Plateau snow cover and Pacific sea surface temperatures in the EASM variability (5, 7), with aerosols having a secondary or complementary role (6). Zhu et al. (8) even found that the high aerosol concentrations over eastern China in recent decades are at least partly a result of the weakened EASM.

To conclude, anthropogenic aerosols may affect the EASM to some extent; however, the direction (positive or negative), strength, and mechanism of such an effect remain poorly understood and require further investigation. In fact, the global temperature field plays an ultimate role in the intensity and position of the EASM (1), which has been confirmed by numerous climate records through the past 2.6 million years (9). From the LGM to Holocene, global temperature increased by 3–8 °C (3), which is comparable to the projected temperature increase of ∼1–4 °C by 2100 relative to the present (3). Moreover, a significant positive temperature–precipitation relationship has been found in monsoonal Asia on time scales longer than 30–50 y (10). We therefore believe that the weakening trend of the EASM, which has already lasted nearly half a century, will reverse soon as global warming continues, and a symptom of such a reverse may have emerged since the early 2000s (7).

Acknowledgments

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