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Response to Comments by Yuan WANG on "Trends of Extreme Precipitation in Eastern China and Their Possible Causes"

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ABSTRACT

In his comments, Wang cites a number of works to dispute the conclusion in our previous work, which attributes the observed decreases/increases in light/heavy precipitation in eastern China primarily to global warming rather than the regional aerosol effect. However, most of the cited works (admittedly, including our previous work), employ correlation analysis, which has little bearing on the cause–effect relationship. Theoretical analyses and/or modeling studies are needed to ascertain the cause–effect relationship. We argue that theoretical analyses and modeling results show that global warming is the primary cause of the widely observed phenomena of suppression of light precipitation and enhancement of heavy precipitation across the globe, including in eastern China.

Key words: extreme precipitation, global warming, aerosols

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Wang (2015) (referred to as WANG hereafter) disputes the conclusion in Liu et al. (2015) (referred to as LIU hereafter), which attributes the observed decreases/increases in light/heavy precipitation in eastern China primarily to global warming rather than the regional aerosol effect. Our responses to the comments of WANG are presented as follows.

We believe that the dispute can be more efficiently addressed by first summing up the key areas in which WANG and LIU agree. First, both WANG and LIU agree that there are widely observed phenomena of the suppression of light precipitation and the enhancement of heavy precipitation. Second, both parties agree that, in theory and qualitatively, both global warming and the anthropogenic aerosol effect can lead to an increase in precipitation intensity. Third, we notice that WANG did not challenge the primary role of global warming in altering the observed precipitation intensity trends over the equatorial tropics (10°S–10°N), subtropics (10°–20°N), and midlatitudes (20°–45°N) during 1979–2007, as well as the trends in western and eastern Taiwan in the summer seasons of 1966–2009.

Most of the supporting works cited by WANG employed some sort of correlation analysis. LIU also depended heavily on correlation analysis. It is well-known that a good correlation does not imply a causal relationship. Thus, the validity of the conclusion on the cause–effect relationship in each of the works mentioned above depends critically on theoretical analyses and/or modeling results.

We argue that the theoretical analyses and modeling results from reanalysis data (ERA-Interim) presented in LIU show that the interannual trends in precipitation intensities over the equatorial tropics (10°S–10°N), subtropics (10°–20°N), and midlatitudes (20°–45°N), derived from Global Precipitation Climatology Project data, as well as over Taiwan and eastern China, derived from gauge data, can be attributed semi-quantitatively to global warming. WANG does not challenge this contention, except for eastern China. In contrast, the aerosol theory cannot provide any reasonable explanation for all the above trends, except those over east-

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ern China. Furthermore, given the geographical closeness of Taiwan region and eastern China and the higher emissions of aerosols in the latter, one would expect a greater trend over eastern China (particularly in urban areas) than Taiwan if the aerosol effect is the primary cause of the increasing trend in precipitation intensity. This is contradicted by the observed trends of precipitation intensity in Taiwan region (Liu et al., 2009) and eastern China (Liu et al., 2015).

In regard to modeling works, LIU stated that "The aerosol effect on precipitation processes, considered part of the Albrecht effect—the second indirect effect on cloud extent and life time (Ackerman et al., 1978; Albrecht, 1989; Hansen et al., 1997)—is complex and uncertain, especially for mixed-phase convective clouds (Tao et al., 2012)." Hence, we believe that considerable advances in understanding the fundamental processes of the aerosol–cloud–precipitation system are needed in order to realistically address the complex aerosol effect on precipitation in a self-consistent model. In this context, results from an ensemble of coupled climate models show that these models are capable of simulating a significant increasing trend in precipitation intensity with global temperature (Sun et al., 2007); albeit, quantitatively, these models underestimate the observed trend substantially (Liu et al., 2009). Finally, LIU acknowledges a possible secondary role of aerosols in the observed increases in precipitation intensity in eastern China.

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