Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2017-40-AC1, 2017

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Dominance of climate warming effects on recent drying trends over wet monsoon regions" *by* Chang-Eui Park et al.

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Received and published: 10 March 2017

We are deeply appreciate to your critical review and technical comments. Detailed responses to individual specific comments are presented below.

1. It is unclear how the computation is conducted. In particular, how did the author derive the numbers used in Fig. 1? Did they computed the station values first and then average over the region for PET and P separately or did they compute PET/P at individual station and then average over the region? The order of calculation would have an impact on the time series used to plot Fig 1a.

[Reply] Except for directly measured variables (surface air temperature, precipitation, 10m wind speed, sunshine duration, and relative humidity), all variable is computed at each individual station first based on daily observation. After that, we compute annual-

mean values of variables at individual station, and then compute the mean value for each region to make time series. Thus, the PET/P time series are made by the average of PET/P at each weather site.

2. It is unclear how the statistical significance of the change point in Fig. 1 was determined. What kind of test for statistical significance was employed for equation (6)? Would the error term epsilon in (5) follow a Gaussian distribution? More importantly, as the authors moving i in (4), the authors are conducting multiple tests. This means that the statistical significance would be incorrect if multiple testing (which the author did not mention) is not explicitly considered. Additionally, Fig. 1 does show long-term trend but the model (5) only considered a step function which is not correct. If a linear trend is considered in (5), would the authors still find a change point around 1980? Note that if there is a long-term trend in the series and if that trend is not considered in the change-point detection, one would always detect a change point in the middle of the time series. This is not useful and it seems that this is what the authors were doing. There is a body of climate literature discussing proper models and tests for the detection of change point but authors do not seem to be aware such studies.

5. Fig. 1 does not support the use of step regression of (5). It looks more like a long term trend with the last few years reversed that trend rather than an abrupt change in the 1980s. This would also invalidate the subsequent analyses regarding different impacts of precipitation and temperature change before and after 1980 as discussed in the paper.

[Reply] We think that it is better to response to the second and fifth comment together because of both two comments mention the long-term trend in temporal variation of PET/P. As you commented, there is a significant trend in temporal variations in PET/P ($p > 0.95$) for 1961-2010 shown in figure 1a. This significant trend is because of trends in PET/P are negative at 86.7% of total weather sites (Fig. S1a). However, at most of the individual stations, PET/P trends for 1961-2010 are not significant at a 95% confidence level except the northwestern China (Fig. S1a). A few stations show significant trends over monsoon regions (> 100°E), which we focused on. This spatial distribution of PET/P trends is similar to that of P trends rather than that of PET trends (Fig. S1). The spatial patterns of P trends are well-known results of previous studies: significant increase in P over northwestern China (Zhai et al., 2005; Shi et al., 2007; Piao et al., 2010) and insignificant trends over the monsoon regions (Wang and Ding, 2006; Piao et al., 2010). We will add figure S1 to revised manuscript to show trends in PET/P and P over the monsoon regions are not significant. In addition, we separate the monsoon regions into three regions based on the 50-year climatology of PET/P in the present study: arid (PET/P>2), transient (1<PET/P<2), and humid (PET/P<1) regions. However, the times series of PET/P, P, and PET in figure 1 is based on averages of each variable over whole analysis domain. Figure S2 shows the temporal variations of annual-mean PET/P for 1961-2010 over arid, transient, and humid regions over the monsoon regions, respectively. Magnitudes of PET/P variations are much larger in the arid region than those in other regions. The original time series of PET/P variations may hide variations of PET/P in arid and humid regions. In addition, the linear trend in PET/P variations is not significant in arid and humid regions ($p < 0.9$ for the both regions). The only transient region shows a significant trend in the PET/P variation ($p > 0.95$). Thus, we conclude that the time series shown in figure 1 gives wrong information to readers. We will remove the figure 1 in the revised manuscript.

There are numerous studies about decadal variations in atmospheric circulation and rainfall over the monsoon regions around 1980 (Gong and Ho, 2002; Zhou et al., 2008; Ding et al., 2008; Ha et al. 2012). Based on both insignificant trends over monsoon regions for 1961-2010 shown in figure S1 and background assessments, we can guess easily that there is an abrupt change in temporal changes in PET/P over monsoon regions around 1980. In the present study, we want to verify whether this timing is determined or not based on change-point methods, which can determine undocumented abrupt change. In the original manuscript, we applied two kinds of change-point methods to find a year of abrupt change in PET/P variations shown in figure 1: 1) detection of change-point based on cumulative sum (Pettitt, 1980), 2) detection of change-point

based on simple linear regression model (Elsner et al., 2000). If there is an abrupt change around 1970 or 2000 based on these methods, the change-point is just statistical value and physically meaningless. Fortunately, two methods commonly identify the change-point as 1983, which is generally consistent with decadal variations described in many previous assessments. We concluded that this year, 1983, is a suitable year for separating the period of 1961-2010 into two periods, however, we verify the different time series of PET/P variations over three climate regimes. Now, we apply 3 kinds of change-point methods to temporal variations in PET/P in each region.Details of change-point methods are presented in supplementary.

3. The PET calculation (1) involves non-linear interactions among different drivers in particular wind, vapor pressure, and temperature. However, in order to derive the relative importance of different drivers, the authors simplified such interaction by using a linear regression (8). Is such simplification justified? Are the interactions among different drivers too small to be ignored? A proof or references supporting this approach is required. Also, are the regression estimated for individual stations separately or on the regional mean series? These details need to be clearly described for the work to be reproducible. Even if the interaction term among different variables to be small, the variables in (8) may not be independent (e.g., there must be some correlation between radiation and temperature, between temperature and humidity because a day of clear sky would correspond to high radiation, high temperature, and low relative humidity). So how did the authors test the significance of regression?

[Reply] As you pointed out, equation (8) looks simple considering the non-linear relationship between PET and climate parameters derived in equation (1). However, there are several studies using this linear regression method to determine the most important climate variable for the response of PET to climate changes (Chattopadhyay and Hulme, 1997; Yin et al., 2010; Dinpashoh et al., 2011; Han et al., 2012). We will add this documents to the list of references in the revised manuscript.

To test the significant of regression equation (8), we compute partial correlation coefficients at 189 stations for the period 1961-1983 and 1984-2010 between PET and four parameters, Rn, WS, Ta, and RH (Fig. S4). Regardless of the analysis periods, Rn, WS, and Ta are positively correlated with PET, whereas the partial correlation coefficient of RH is negative. For all four variables, partial correlation coefficients are significant at the 95% confidence level except at few stations, indicating that these fields are closely correlated with PET. Also, significant values of partial correlation coefficients prove that the regression equation does not suffer from multicollinearity of climate parameters. Thus, we can prove the significance of equation (8) and ignore the interaction between climate parameters.

Likewise, the other computed variables, the regression (8) also estimated for individual stations first, and then we compute regional means. We will clarify the order of computation in the revised manuscript.

4. How did the authors estimate the confidence interval in Fig. 3?

[Reply] We calculate the confidence interval at 95% confidence level as the following equation:

$(m-1.96 \times s/\sqrt{n}, m+1.96 \times s/\sqrt{n})$

where, m and s is the mean and standard deviation of relative contributions of each climate variable, respectively. n is the number of stations located in arid (56), transient (50), and humid regions (51), respectively. We will clarify this in the revised manuscript.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2017-40/acp-2017-40-AC1-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2017-40, 2017.

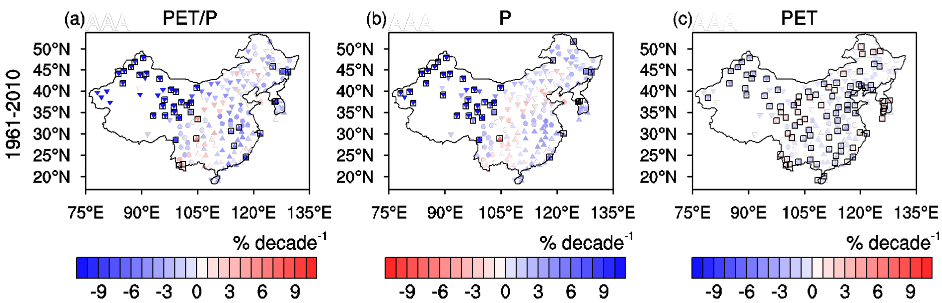

Fig. 1. Spatial distributions of trends in PET/P, P, and PET over continental East Asia. a–c: The spatial distribution of trends in annual-mean PET/P (a), P (b), and PET (c) for the period of 1961–2010.

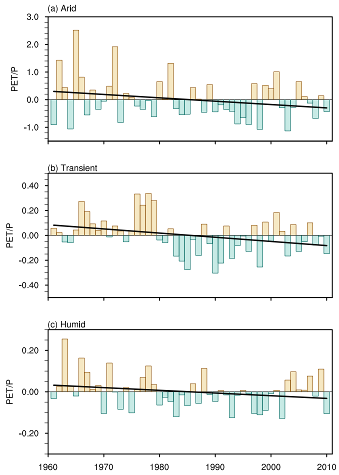

Fig. 2. Temporal variations of annual-mean PET/P over (a) arid, (b) transient, and (c) humid regions where located east of 100°E, respectively. Yellow and blue bars indicate the positive and negative values.

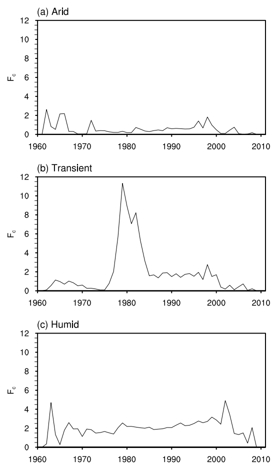

Fig. 3. The Fc statistics for temporal variations of annual-mean PET/P over (a) arid, (b) transient, and (c) humid regions, respectively.

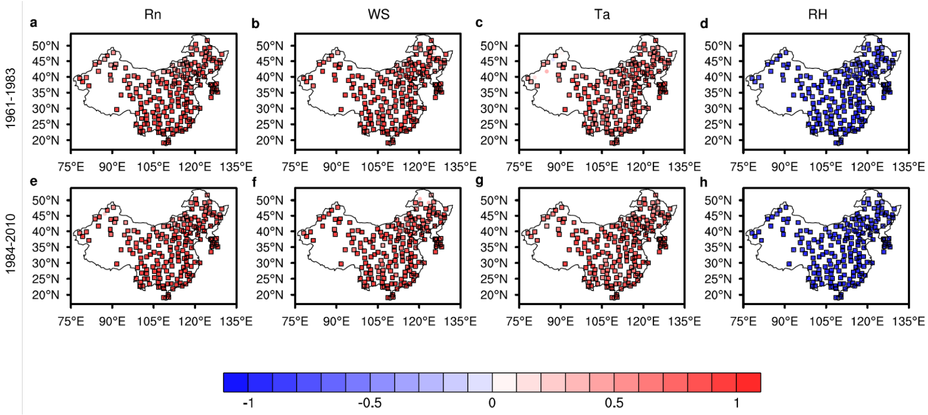

Fig. 4. Spatial distribution of partial correlation coefficient over continental East Asia for 1961-1983 and 1984-2010 between PET and four parameters such as Rn, WS, Ta, and RH.