We greatly appreciate the constructive suggestions and have carefully revised the manuscript accordingly. Please check the following responses for our detailed modification.

Point-to-point responses:

Anonymous Referee #1

General comments:

1. *Usually, the Budyko framework is used in long-term scale so that the water storage change can be ignored. It is a big challenge to apply this framework in interannual catchment water balance. The hydrological year is better than the calendar year, but it is not enough. In present researches, the parameter, such as oumiga, was determined for each catchments then the relation between this parameter and other factors, such vegetation, landscape and climate characteristics were discussed. For example, Li et al. published in WRR in 2013. Therefore, my advice is to set up the relation between oumiga and M and S based on the long-term water balance for the 13 catchments then to discuss the contribution of different part to the runoff change.*

Response: Thanks for your good comments. We agree your opinion that the Budyko framework is mostly used in long-term scale. The reason why we use a period of hydrologic year to develop the semi-empirical formula is to exclude the cross correlation between *M* and *S*. We checked the relationship of *M* and *S* on the 5-year, 10-year and 30-year scales, and found that they are cross correlated. Particularly, the correlation coefficients increase with the lengths of time scale, and the determining coefficient (R^2) is 0.8 for the 30-year scale. If *M* and *S* is not independent of each other, they cannot be used together to express different functions. After substantial tests, we found that the relationship between *M* and *S* is not significant in a period of hydrologic year. Thus, they can be used to express the controlling parameter. Furthermore，there are several researches have figured out that although the parameter in the Budyko relationship has been used to represent the catchment characteristics, this parameter is also affected by climate seasonality (Milly, 1994;Donohue et al., 2011;Williams et al., 2012;Berghuijs and Woods, 2016;Zhou et al., 2016). In our study, we also found that parameter ω has a negative correction with climate seasonality. Thus, the climate seasonality should be incorporating into the parameter.

Your concern about the changes in water storage is really very important in water balance equation. To exclude the potential impacts, we checked the interannual variation of catchment-scale water storage in some studies, and presented some discussion about this part. Specifically, we found that the water storage change in the Loess Plateau is relative small compared with the other regions of China. In such cases, assessing catchment-scale water balance by ignoring water storage change should be reasonable on a time scale of hydrologic year.

Despite that catchment-scale water storage changes are usually assumed to be zero on long-term scale, the interannual variability of storage change can be an important component in annual water budget during dry or wet years (Wang and Alimohammadi, 2012), and cannot be ignored. However, the Loess Plateau has a subhumid to semiarid climate, the water storage and its annual variation are relatively small compared with humid regions (see Figure 5 from Mo et al., 2016). For example, using GRACE (Gravity Recovery and Climate Experiment), the water storage variations in the Yangtze, Yellow and Zhujiang from 2003 to 2008 were analyzed by Zhao et al. (2011), and the values for the Yangtze and Zhujiang basins were 37.8 mm and 65.2 mm, while no clear annual variations are observed in the Yellow River basin (3.0 mm). Furthermore, Mo et al. (2016) found that the water storage in Yellow River kept decreasing from 2004 to 2011, whereas it was changing slowly with a rate of 1.3 mm yr^{-1}. Therefore, considering the small water storage change in study area, ignoring water storage change in a period of hydrologic year is reasonable.

2. *For the contribution analysis, it is better to divide the whole period into two periods, for example, before 1980 and after 1980. A, B and C in Equation 5 can be estimated by the P, ET0 and oumiga of the whole period. Then deltaP=P2-P1, deltaET0=ET02-ET01, delta oumiga = oumiga 2- oumiga 1. After that, the contribution of P, ET0 and oumiga can be estimated.*

Response: Thanks for reviewer's good suggestion. We recalculated the contribution according to your suggestion by dividing the whole study period into two subperiods. Further, we replaced the previous method with a new method developed by Zhou et al. (2016). The previous method ignored the higher orders of the Taylor expansion and resulted in errors; however, the new method proposed by Zhou et al. (2016) decompose the runoff/ET changes into two components precisely without any residuals. And the detailed revisions are showed in the section 2.3 and 4.3.

2.3. Evaluating the contributions of climate change and surface condition alterations

Based on the climate elasticity method, which was introduced by (Schaake and Waggoner, 1990) and improved by (Sankarasubramanian et al., 2001), the contribution of change for each climate factor to runoff was defined as the product of the sensitivity coefficient and the variation of the climate factor (Roderick and Farquhar, 2011):

$$dR = \frac{\partial R}{\partial P} dP + \frac{\partial R}{\partial ET_0} + \frac{\partial R}{\partial \omega} d\omega \qquad (5)$$

However, due to ignoring the higher orders of the Taylor expansion in equation (5), this method will result in high errors (Yang et al., 2014). Recently, Zhou et al. (2016) proposed a new method to partition climate and catchment effect on the mean annual runoff based on the Budyko complementary relationship, called “the complementary method”. The algebraic identities in their work can ensure that the change in runoff can be decomposed into two components precisely without any residuals. Here, we extend “the complementary method” to conduct attribution analysis of *ET* changes for each basin by further incorporating the effects of vegetation coverage and climate seasonality:

$$\Delta ET = \alpha\left[\left(\frac{\partial ET}{\partial P}\right)_1 \Delta P + \left(\frac{\partial ET}{\partial ET_0}\right)_1 \Delta ET_0 + P_2\Delta\left(\frac{\partial ET}{\partial P}\right) + ET_{0,2}\Delta\left(\frac{\partial ET}{\partial ET_0}\right)\right]$$
$$+(1-\alpha)\left[\left(\frac{\partial ET}{\partial P}\right)_2 \Delta P + \left(\frac{\partial ET}{\partial ET_0}\right)_2 \Delta ET_0 + P_1\Delta\left(\frac{\partial ET}{\partial P}\right) + ET_{0,1}\Delta\left(\frac{\partial ET}{\partial ET_0}\right)\right] \quad (6)$$

where α is a weighting factor that varies from 0 to 1, which can determine the upper and lower bounds of the climate and the controlling parameter effect. In this study, we defined α=0.5 according to the recommendation of Zhou et al. (2016).The difference operator (Δ) refers to the difference of a variable from period 1 (1981 to the changing point detected by Pettitt’s test (Pettitt, 1979)) to period 2 (period-1 end to 2012) ,e.g., $\Delta ET_0 = ET_{0,2} - ET_{0,1}$. Then the contributions of *P*, ET_0, and ω changes to the *ET* changes can be expressed as follows:

$$C\_(P) = \alpha\left[\left(\frac{\partial ET}{\partial P}\right)_1 \Delta P\right] + (1-\alpha)\left[\left(\frac{\partial ET}{\partial P}\right)_2 \Delta P\right] \quad (7a)$$

$$C\_(ET_0) = \alpha\left[\left(\frac{\partial ET}{\partial ET_0}\right)_1 \Delta ET_0\right] + (1-\alpha)\left[\left(\frac{\partial ET}{\partial ET_0}\right)_2 \Delta ET_0\right] \quad (7b)$$

$$C\_(\omega) = \alpha\left[P_2\Delta\left(\frac{\partial ET}{\partial P}\right) + ET_{0,2}\Delta\left(\frac{\partial ET}{\partial ET_0}\right)\right] + (1-\alpha)\left[P_1\Delta\left(\frac{\partial ET}{\partial P}\right) + ET_{0,1}\Delta\left(\frac{\partial ET}{\partial ET_0}\right)\right] \quad (7c)$$

After obtaining the contribution of parameter *ω* to the *ET* change, the contributions of vegetation coverage (*M*) and climate seasonality (*S*) to *ET* change can be further decomposed as follows.

First, the contributions of *M* and *S* to parameter *ω* are calculated by using the sensitivity method similar to Eq. (5) based the relationship between *ω* and *M* as well as *S* we built:

$$\Delta\omega = \frac{\partial\omega}{\partial M}\Delta M + \frac{\partial\omega}{\partial S}\Delta S \quad (8)$$

Furthermore, the individual relative contributions (RC) of *M* and *S* to *ω* can be calculated. Then, the contributions of *M* (C_(*M*)) and *S* (C_(*S*)) to *ET* changes can be obtained as follows:

$$C\_(M) = C\_(\omega) \times RC\_(M) \quad (9a)$$

$$C\_(S) = C\_(\omega) \times RC\_(S) \quad (9b)$$

4.3. Quantitative attribution of the variation in *ET*

The impacts of vegetation changes on *ET* have been widely studied with the

Budyko framework by assuming surface conditions can be represented by the controlling parameter. However, according to the developed relationships in our study, the controlling parameter is not only related to surface condition change, but also to climate seasonality. The contributions of changes in climate (*P*, ET_0, and *S*) and vegetation (*M*) to the *ET* change were thus estimated by using the semi-empirical formula for parameter ω in the context of Fu's framework.

Trend in hydrometeorological variables and vegetation coverage were first analyzed for each basin (Table 4). ET_0 and *S* in all basins exhibited an upward trend, though with different significances. Similarly, *M* in most basins increased during past several decades. Based on the sensitivity coefficients of *ET* (Table S1) and the changes in mean annual *P*, ET_0, ω, *M* and *S* from period I to period II (Table 5), the changes in *ET* due to those in *P*, ET_0, *M* and *S* were estimated using the method described in Section 2.3. The contributions of four variables to *ET* change for each basin were presented in Table 5. In basin #1, 3-4 and #6, the *ET* changes were controlled by vegetation improvement; however, in the other basins, the dominant factor was precipitation. Except for basin #6, #9 and #12, elevated vegetation in most basins positively contributed to *ET* changes, which is consistent with Feng et al. (2016). *ET* in several basins showed a downward trend even though *M* positively contributed to *ET* changes; which is due to the offsetting effect of the other factors.

Table 4. Trend analysis for the hydrometeorological variables and vegetation coverage[b].

ID	Basin	*ET*,mm yr^{-2}	ET_0,mm yr^{-2}	*P*,mm yr^{-2}	*M*	*S*
1	Huangfu	1.89	1.16	0.61	0.002*	0.001
2	Gushan	0.76	3.85**	-0.01	0.004**	0.012
3	Kuye	2.34*	2.04*	0.53	0.004**	0.006
4	Tuwei	1.87	2.33**	0.53	0.005**	0.006
5	Wuding	0.88	1.17	0.31	0.006**	0.004
6	Qingjian	-0.45	1.78*	-0.94	0.007**	0.006
7	Yan	-1.62	2.03*	-1.99	0.005**	0.006
8	Beiluo	-5.4*	4.6*	-6.2*	0.0001	0.017
9	Jing	-0.97	1.47*	-1.79	0.002**	0.001
10	Fen	-0.72	1.93*	-1.16	0.002*	0.003
11	Xinshui	0.33	1.80	-0.12	0.003**	0.005
12	Sanchuan	1.49	1.84	0.09	-0.0004	0.004
13	Qiushui	-0.50	1.79	-0.83	0.002	0.008

[b] * and ** indicate the trend is significant at the level of p = 0.05 and p = 0.01 by the Mann–Kendall test, respectively.

It should be noted that the climate seasonality (represented by *S*) played an important role in the catchment *ET* variation. The contributions of *S* to *ET* changes ranged from 0.1% to 65.5% (absolute values). Besides basin #6, #9 and #12, the climate seasonality had a negative effect on *ET* variation in most of the basins, which means that larger seasonality differences between seasonal water and heat will lead to smaller amounts of evapotranspiration. Accordingly, if ω is supposed to only represent the landscape condition, the effects of landscape condition change on *ET* variation will be underestimated in basin #1, #3, #6-7, #9 and #11. Except for basin #9, the area of these basins is relative smaller; while its effects will be overestimated in the other basins, and the error would be equal to the contributions of *S* to *ET* changes.

Table 5. Attribution analysis for *ET* changes for each basin [c]

ID	Basin	Break point of ET	Change from Period 1 to Period 2					ET_0/ *P/M/S* induced ET change (mm)					Contribution to ET change (%)			
			ΔET	ΔET_0	ΔP	ΔM	ΔS	C_ (ET_0)	C_ (*P*)	C_ (ω)	C_ (*M*)	C_ (*S*)	φ_ (ET_0)	φ_ (*P*)	φ_ (*M*)	φ_ (*S*)
1	Huangfu	2001(ns)	41.7	7.0	22.2	0.03	0.01	0.28	18.67	22.70	22.73	-0.04	0.7	44.8	54.6	-0.1
2	Gushan	2000(ns)	33.6	64.9	20.6	0.07	-0.10	2.81	17.01	13.77	8.87	4.90	8.4	50.6	26.4	14.6
3	Kuye	2000(**)	51.4	32.0	17.3	0.06	0.05	1.54	13.34	36.48	55.95	-19.47	3.0	26.0	108.9	-37.9
4	Tuwei	2000(**)	43.2	39.6	24.0	0.07	-0.03	2.57	15.28	25.35	21.85	3.49	5.9	35.4	50.6	8.1
5	Wuding	2000(*)	35.2	17.6	26.9	0.09	-0.12	0.77	21.82	12.64	8.24	4.40	2.2	61.9	23.4	12.5
6	Qingjian	1988(**)	-50.1	32.0	-48.0	0.08	0.19	2.06	-37.80	-14.31	-47.09	32.78	-4.1	75.5	94.08	-65.5
7	Yan	1985(**)	-82.3	44.6	-86.9	0.05	0.30	3.19	-69.52	-15.96	22.19	-38.14	-3.9	84.5	-27.0	46.4
8	Beiluo	1985(**)	-65.1	49.4	-79.8	0.01	0.19	4.33	-62.9	-6.75	3.69	-10.43	-6.6	96.3	-5.7	16.0
9	Jing	1990(**)	-33.7	43.0	-47.8	0.03	0.11	4.1	-37.2	-0.61	-8.23	7.61	-12.2	110.3	24.4	-22.6
10	Fen	2005(ns)	23.1	8.5	21.2	0.07	-0.20	0.33	19.00	3.81	2.13	1.68	1.4	82.1	9.2	7.3
11	Xinshui	1990(**)	-19.1	39.7	-24.7	0.02	0.09	2.06	-21.08	-0.14	0.41	-0.55	-10.8	110.1	-2.1	2.9
12	Sanchuan	1996(ns)	-27.0	45.4	-43.4	-0.01	0.22	3.01	-32.52	2.56	0.20	2.36	-11.2	120.6	-0.7	-8.8
13	Qiushui	1996(ns)	-80.3	77.5	-103.5	-0.01	0.68	3.76	-83.68	-0.40	-0.02	-0.37	-4.7	104.2	0.1	0.5

[c] The relative contribution of a certain variable to the *ET* change ($\varphi(x)$) was calculated as follows: $\varphi(x) = (\mathrm{C}\_(x)/\Delta ET) \times 100\%$, where C_(*x*) represents the contribution of each variable.

3. It is better to analyze the trend of runoff and climate factors with MK test.

Response: The trend analysis of each variable has been shown in table 4.

Special comments:

1. *Please give more detail about the climate seasonality index (S).*

Response: Thanks for reviewer's good suggestion, and the more detailed description has been added in the section 2.2.

Solar radiation was considered as the dominant factor that controls the climate seasonality and thus the seasonality of P and ET_0 can be can be expressed by sine functions (Milly, 1994;Woods, 2003):

$$P(t) = \bar{P}(1 + \delta_P sin\omega t) \quad (3a)$$

$$ET_0(t) = \overline{ET_0}(1 + \delta_{ET_0} sin\omega t) \quad (3b)$$

where $\bar{P}$ and $\overline{ET_0}$ are the mean monthly P and ET_0; δ_P and δ_{ET_0} are the seasonal amplitude of precipitation and potential evapotranspiration, respectively. The values of δ_P and δ_{ET_0} might both range from -1 to 1 because P and ET_0 always have positive value on physical grounds. Larger absolute values of δ_P and δ_{ET_0} mean larger variability of climate seasonality. φ is the duration of the seasonal cycle, $2\pi\varphi$ equal to 1 year. Woods (2003) summarized the modelled climate of Eqs.(3a) and (3b) in dimensionless form and defined the climate seasonality index (S) and here it was used to reflect the non-uniformity in the annual distribution of water and heat in our study:

$$S = \left|\delta_P - \delta_{ET_0}\emptyset\right| \quad (4)$$

where $\emptyset$ is the dryness index, $\emptyset = \overline{ET_0}/\bar{P}$. If S=0, there is no seasonal fluctuation of the difference between P and ET_0. Larger values of S indicate that the larger changes in the balance between P and ET_0 during the seasonal cycle.

2. *L225, "out of phase", "out phase", which one is right?*

Response: "out of phase" should be more suitable. The same expression was also used by Potter et al. in WRR in 2005.

3. *L237, just from 0.45 to 0.51, it is not a significant improvement.*

Response: Thanks for reviewer's comment. The more important meaning of incorporating the climate seasonality into the controlling parameter oumiga is to further explore the factors that controlling the interannual catchment water balance, rather than only considering its function of improving the estimation of parameter oumiga. And the results of attribution analysis showed that the contribution of vegetation coverage changes to ET variation will be estimated with a large error if the effects of climate seasonality were ignored. Thus, we will no longer address the improvement of the estimation of parameter oumiga after considering climate seasonality, and remove Table 2 as well as related comparison.

4. *L242, crossing-validation is not a good choice here because each catchments has its own characteristics, so it can not be validated by other catchments.*

Response: We agree. Each catchment has its own characteristics, mainly including the underlying physical conditions (such as soil properties and topography), vegetation and climate characteristics. Ignoring the spatial heterogeneity of underlying physical conditions for studied basins may influence the performance of the empirical equation we built. However, we think that the crossing-validation approach can be used to calibrate and test the semi-empirical formula for parameter oumiga, because the rotated calibrations using 12 basins instead of all 13 basins only produce slight variations in the slopes and intercepts from regressions (Table 3), which suggests that the formula we built are robust and it can be used to assess catchment actual evapotranspiration in the Loess Plateau. And the subsequent validations further prove the good performance of our formula. This method was also widely used by previous studies (e.g. Li et al., 2013;Chen et al., 2014;Schnier and Cai, 2014;Kim et al., 2015;Nerini et al., 2015;Lv and Zhou, 2016;Rakovec et al., 2016;Toth, 2016). Among them, the study of Li et al. (2013) is similar with ours, who also used the crossing-validation approach to test their formula for each catchment.

5. *Keep all the panels (including the label, range and scale of x/yaxis) within a figure be consistent. Have a close look at the Fig 2-4.*

Response: Thanks for reviewer's suggestion, and we have unified the format of Fig 2-4 & S1.

6. *It may be better to replace Fig 3 and 4 by a table show R^2 with a certain category. The original figures could be provided as supplementary documents.*

Response: We have moved the Fig3 &4 into the supplementary documents. Since these two figures have contained "R^2" and "p", we think it is not necessary to make new tables.

7. *Table 4, "Relative contributions of vegetation change and climate seasonality to ET trends for each basin", which miss out the contributors from "ET0 and P".*

Response: We have corrected this title as "Attribution analysis for *ET* changes for each basin"

8. *For reading convenience, better to insert the ordering number according to the ordering system given in Fig1 and Table1 in the text when mentioning a particular basin in Results.*

Response: We have inserted the ordering number of each basin in the revised text, for example, “Huangfu” was revised as “basin #1”.

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