

Interactive comment on “Dominant climatic factor driving annual runoff change at catchments scale over China” by Z. Huang and H. Yang

Response to M. Renner

The authors apply the runoff elasticity method of Yang and Yang (2011) to mainland China and thereby extend work by Yang et al., (2014). The method is based on a Budyko framework and a first order derivative of the Penman equation to analyze the effect of observed trends in meteorological variables such as precipitation, net radiation, temperature, wind speed and relative humidity. This manuscript analyzed the same dataset as Yang et al., (2014) who also presented a runoff elasticity method but not with respect to forcing variables of the Penman equation.

1. Scientific interest

The reported trends between 1960-2010 in these variables are remarkable and deserve attention because they may have direct impacts on potential evaporation and the water balance. The proposed method by Yang and Yang (2011) is a quantitative and theory based way to estimate how runoff might have changed due to these trends. As the authors show in this manuscript these trends vary spatially in China and the sensitivity of the different catchments to change varies as well.

Unfortunately the authors do not discuss their results in depth. For example one potentially interesting point which is somewhat hidden in the results is that decreases both in net radiation and wind speed partly compensate the runoff decline caused by precipitation decreases. Also no discussion or further references on the origin, magnitude of the trends in the meteorological variables such as net radiation or wind speed is presented. Is the reduction in net radiation a result of decreasing solar radiation induced by atmospheric dimming or due to other variables? Such a discussion would help to understand the climatic impacts and their implications on water resources.

Response:

Thanks for your positive evaluation and detailed comments. We are revising the manuscript following your comments and suggestions.

2. Novelty

The manuscript largely builds on previous work. The method, its comparison to hydrological modeling studies and an application to a large set of 89 catchments was presented by Yang and Yang (2011). The same dataset and the elasticity of precipitation and potential evaporation was recently presented by Yang et al., (2014). Some maps shown in this manuscript are very similar to those presented in Yang et al., (2014). For example compare Fig. 7 with Fig. 9 of Yang et al., (2014). Because this overlap is substantial (see also similarity report) I strongly recommend to discuss and explain the novelty and implications of this research.

Response:

Thanks for your comments. We think that the contribution of this manuscript are: (1) separating the contribution to runoff from precipitation, temperature, wind speed, net radiation and relative humidity, while Yang et al. (2014) only separated that from precipitation and potential evaporation; and (2) detecting the dominant climatic factor driving annual runoff change, which shows a regional variation, i.e. precipitation in most of the 207 catchments, net radiation in the lower reach of Yangtze River Basin and the southeast, and wind speed in part of the northeast.

3. Comparison vs. validation

The authors only compare their method with hydrological modeling results. This comparison is useful but is not a validation with independent data. Validation of runoff elasticity is generally difficult when other changes on catchment properties, water extraction, have been happening at the same time. Within the presented test catchments the actual runoff change was always quite different to the estimated change by climate in on case even the sign was different (Table 3). In addition, while the data is presented on catchment level, apparently no runoff data was presented. I am wondering why is there no comparison with of the estimated runoff change with the actual runoff changes? This would give an indication on the importance of the climatic factors on actual runoff changes.

Response:

Thanks for your comments. As you said, climate change, catchment properties, and water extraction have great impacts on runoff when they happen at the same time, which makes it difficult for the validation. However, in this study, we only try to analyze the impacts of climate change on runoff and to detect the dominant climatic factor driving annual runoff change. In the further research, we will study on the effect from human activities. In this study, the reason why we compared their method with hydrological modeling results is that the observed runoff includes the effects not only from climate change but also from human activities, while the hydrological modeling runoff doesn't include human activities.

4. Definition of the aridity index/energy limit

Budyko defined the energy limit through the water equivalent of net radiation R_n . Because R_n is not measured densely enough R_n was replaced by some formulation of potential evaporation (UNEP 1992, World Atlas of desertification), which might be estimated by meteorological variables such as was done in this work. Interestingly, by using the approach of Yang and Yang (2011), net radiation reappears as control on evapotranspiration but in a different setting as originally proposed by Budyko's energy limits. Please discuss this aspect.

Response:

Thanks for your comments. Evapotranspiration depends on the energy supply and water supply. Budyko defined the energy limit through the water equivalent of net

radiation R_n , at large spatial scale. However, at a small spatial scale, except net radiation, the energy imported by horizontal advection will affect water and energy balances. And the effect of the horizontal advection can be exposed by climatic variables, such humid, air temperature and etc. Therefore, we chose potential evaporation to represent energy supply. And we are adding more discussion on this aspect.

5. Format / presentation

The paper is written in rather focused way and is mostly easy to follow for the interested reader. However, the English needs to be improved throughout the manuscript. In particular the results section uses past tense when describing results. Some figures are too small to be able to read annotations and legends. The legends must also be harmonized among similar maps to allow a visual comparison.

Response:

Thanks for your comments. In the revised version, we will improve the English and the figures to make the manuscript better.

6. Further Comments:

6.1-Section 5.1 Discussion of climate sensitivity estimates:

- a) I wonder why other estimates using the same method / data should be different, please clarify!*
- b) If the cited estimates from the literature are independently derived, I advise to make a table which is easier than having all these numbers in the text.*

Response:

- a) Thanks for your comments. Yang and Yang (2011) evaluated climate elasticity to runoff in 89 catchments of the Yellow River basin and the Hai River basin. Tang et al.(2013) evaluated climate elasticity to runoff in the whole Yellow River basin. The main cause is the scale of study region. For the Yellow River basin, Yang and Yang(2011) selected about 50 small catchments, and Tang et al.(2013) treated it as one basin. In our study, we divided it into 29 catchments.
- b) Thanks for your comments. Following your suggestion, we will make a table to compare the results of our study with the cited estimates in the revised manuscript.

6.2 -Section 5.1 Discussion of temperature sensitivity:

The whole paragraph starting on page 12925L12 is not very clear and needs a better presentation. For example results on $\partial E_0 / \partial \Delta$ and $\partial E_0 / \partial e_s$ are discussed but I could not find them in the results section.

Response:

Thanks for your comments. We will make a better presentation of this part in the

revised manuscript.

6.3 -The last paragraph of section 5.1 seems to be copied from Yang and Yang (2011)

Response:

Thanks for your comments. We will revise this part.

6.4 -Please, provide the reference for Eq.12?

Response:

Thanks for your comments. The reference for Eq.12 will be added in the revised version.

6.5 State that Eq.12 is an empirical formulation for net radiation

Response:

Thanks for your comments. “Eq. is an empirical formulation for net radiation” will be added in the revised vision.

6.6 P12917L3: missing word

Response:

Thanks for your comments. We are sorry for carelessness. It should be “80 second-level”.

6.7 P12919L21: Maidment

Response:

Thanks for your comments. We are sorry for the spell mistake. We amended it as “Maidment” in the revision.

6.8 P12920L5: change to “Comparison of the climate elasticity method with hydrological models”

Response:

Thanks for your comments. We have changed it following your suggestion.

6.9 P12920L11 remove and rephrase “provided strong evidence” see earlier comments

Response:

Thanks for your comments. We will make a appropriate presentation of this part in the revised manuscript.

6.10 P12920 / Figure 2b: What data has been used for figure 2B?

Response:

Figure 2B showed the relative error (%) caused by the first-order approximation, where dE01 and dE02 are the potential evaporation change (mm) calculated by Eq. (9)

and that by Eq. (17), respectively. Figure 2B used the data of annual climatic factors in 207 catchments which were interpolated from the meteorological station observation. To a better understanding, we will add more description in the revision.

6.11 P12921L11: Does it mean that runoff on map in Figure 3f was estimated by a Budyko function, rather than actual data?

Response:

In P12917L1, the mean runoff was calculated according to mean annual precipitation and runoff ratio, and runoff ratio was estimated by Hydrological Bureau according to observed precipitation and runoff. Unfortunately, we can't collect the first-hand runoff data for all the 207 catchments.

6.12 P12921L21: rephrase sentence, avoid "caused" because this is just an estimate.

Response:

Thanks for your comments. We replaced it with "result in" in the revised version.

6.13 P12921L25: why is temperature sensitivity reported in / °C and not as percentage %? In the moment one cannot compare the sensitivities and related attributed changes in runoff. This is related to Eq. 9. Please clarify and adapt.

Response:

Thanks for your comments. In Eq.(10), the temperature change was reported in °C, which is different from other climate factors. This is because people are generally used to concern on the runoff change caused by 1 °C. In addition, some catchments possibly have a mean annual air temperature below zero, which will lead to a change in sign. Hence, in this study, temperature sensitivity reported in °C may easy to understand.

6.14 P12927L13: What is meant by "small hydrology changes"?

Response:

Thanks for your comments. We wanted to express a little change in runoff and precipitation. We will give a better representation in revised version.

6.15 P12928L8: unclear, please rephrase

Response:

Thanks for your comments. Changing original text "the error of ε_p caused by first-order approximation can be discounted, but the error will increase with changes increasing with a 0.5–5% relative error in ε_p When $\Delta P = 10$ mm and a 5–50% relative error in ε_p When $\Delta P = 100$ mm." into "the error of ε_p caused by first-order approximation can be neglected, but the error will increase with precipitation changes increasing, with a 0.5–5% relative error in ε_p when $\Delta P = 10$

mm and a 5–50% relative error in ε_p when $\Delta P = 100$ mm.”

6.16 Table 1: Variable z from logarithmic wind profile is not reported.

Response:

We will add more description. The wind speed at a height of 2 m was estimated from a logarithmic wind profile based on the observed wind speed at the height of 10 m.

6.17 Table 3: a) column headers mistake b) report units c) Which period is considered form the changes d) Consistent with P and PET report absolute values of R

Response:

Thanks for your comments. We have revised them in the revision as follow:

- a) Changing the first “Upper Hanjiang River Basin” into “Upper Luan River Basin”;
- b) Adding the units in the revision;
- c) Adding explanation on the period (the change was regressed according the annual value from 1961-2010);
- d) Adding R into the Table.

6.18 Figure 1b) only two test catchments are shown. Consider to highlight these test catchments in Fig 1a).

Response:

Thanks for your comments. We will redraw this figure following your suggestion.

6.19 Figure 3: caption delete first wind speed

Response:

Thanks for your careful review. I am sorry for our carelessness. We deleted the first wind speed in the revision.

6.20 Figure 4: Do elasticities add up to 1?

Response:

In theory, it should be 1.

6.21 Figure 5: Much too small to read! Increase size of plots. Maybe combine 1 and 2 panels by only showing significant catchments or using bold borders. The unit for the temperature trend seems wrong.

Response:

Thanks for your suggestion. We redraw it and corrected the unit of the temperature trend in the revision

6.22 Figure 6: Use the same color legend for all panels!

Response:

Thanks for your comments. We will use the same color legend for all panels in the revision.

6.23 *Figure 7: Almost the same as in Yang et al., (2014)!*

Response:

Thanks for your comments. Figure 7 will be deleted and a reference will be added.